UN environment programme

FORESIGHT Brief

022

January 2021

Early Warning, Emerging Issues and Futures

Desert locusts' upsurges: A harbinger of emerging climate change induced crises?

Background

The Foresight Briefs are published by the United Nations Environment Programme to highlight a hotspot of environmental change, feature an emerging science topic, or discuss a contemporary environmental issue. The public is provided with the opportunity to find out what is happening to their changing environment and the consequences of everyday choices, and to think about future directions for policy. The 22nd edition of UNEP's Foresight Brief highlights the possible role of climate change in locust infestations, and calls for well organised early warning systems that operate within an integrated pest management context and employ innovative strategies such as ecosystem-based approaches.

Introduction: What is the issue?

In the past several months, there have been movements of adult groups and swarms of desert locusts in South-West Asia, West Asia, and East Africa (Food and Agriculture Organization of the United Nations [FAO] 2020a). In early 2020, the worst swarms of desert locusts in decades decimated crops and pasture across Eastern Africa and beyond, threatening the food security of the entire sub-region. Desert Locusts pose an unprecedented risk to agriculture-based livelihoods and food security in already fragile regions. Approximately 20.2 million people faced severe acute food insecurity in East Africa economies such as Ethiopia, Kenya, Somalia, South Sudan, Uganda and Tanzania (FAO 2020b). With the ongoing concerns about immature swarms continuing to form within the regions of eastern Ethiopia and central Somalia, the locust invasion threatens to drive this number even higher.

Schistocerca gregaria, the desert locust

Photo credit: © Kuttelvaserova Stuchelova / Shutterstock.com

What are desert locusts?

Locusts are the oldest migratory pest in the world (FAO 2020c). They belong to the grasshopper family *Acrididae*, which includes most short-horned grasshoppers. Locusts differ from grasshoppers because they have the ability to change their behaviour, physiology and in particular their morphology (colour and shape), in response to changes in density, when meteorological conditions are favourable (Steedman 1990).

Often considered to be the "most important and dangerous of all migratory pests" in the world, the desert locust (*Schistocerca gregaria*) has the ability to consume the equivalent of its own weight per day (Cressman 2016). As a swarm, it can devour a farmer's field and his entire livelihood in a single morning (Cressman 2016). A swarm measuring just a single square kilometre can contain up to 80 million adults, with the capacity to consume the same amount of food in one day as 35,000 people (FAO 2020c).

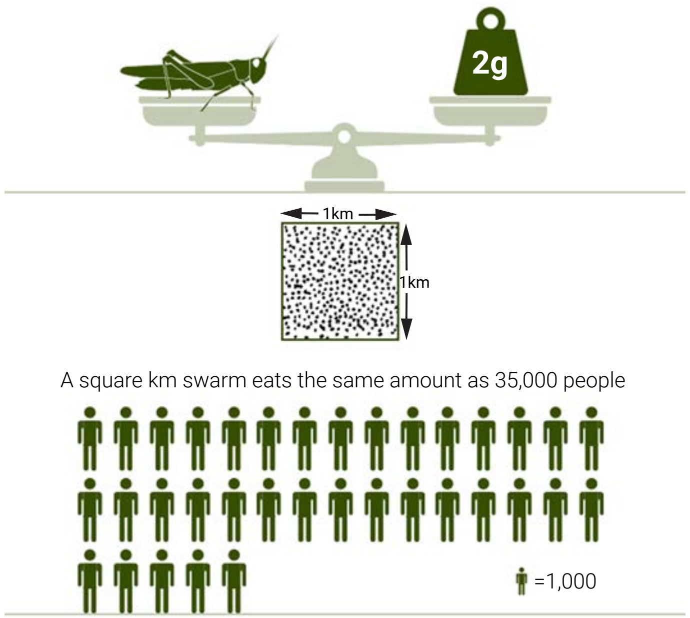


Figure 1: Locusts consume equivalent of their own weight in a day and 1 sq. km of locusts can consume the same amount of food consumed by 35,000 people. *Source: BBC 2020; FAO 2020c*

During normal conditions (quiet periods known as recessions) 'solitarious' (lonesome) desert locusts are found in low numbers scattered throughout the semi-arid and arid deserts of Africa, the Near East and Southwest Asia that receive less than 200 mm of rain annually (Cressman 2016; FAO 2020c). This is an area of about 16 million square kilometres, consisting of about 30 countries (FAO 2020c).

Dense and highly mobile swarms of desert locusts can form in response to environmental stimuli. The danger of their invasions are growing in the context of exceptional weather events associated with climate change, due to their very high capacity to take advantage of new situations. This is illustrated by the fact that the locust situation has deteriorated with recurrent droughts since the beginning of the twenty-first century (FAO 2020c).

The Desert Locusts have their usual habitat somewhere in the deserts between Mauritania and India (FAO 2020c). If good rains fall and green vegetation develops, Desert Locusts can rapidly increase in number and within a month or two, start to concentrate, gregarize which, unless checked, can lead to the formation of small groups or bands of wingless hoppers and small groups or swarms of winged adults (FAO 2020c). If uncontrolled and supported by favourable conditions, these can undergo successive breeding seasons to affect entire regions and even several large regions simultaneously. Therefore, the three stages of a locust plague development are as follows (Cressman 2013):

- Outbreak: These are small and localized swarm formations and can affect the size of a small town and consist of dispersed populations. Outbreaks usually occur within an area of about 5,000 sq. km (100 km by 50 km) in one part of a country.
- Upsurge: In an upsurge, there is a large increase in locust numbers, usually following 2-3 successive transient breeding seasons resulting in hopper band and adult swarm formation. These can affect the size of a country.
- Plague: Plagues are widespread and heavy infestation of locust bands and swarms after a year of good rains and uncontrolled upsurges. These can be intraregional and can affect regions- the size of a continent. Major plagues affect two or more regions simultaneously.

Desert Locust plagues have been reported since Pharaonic times in ancient Egypt. There is no evidence that they occur after a specific number of years (Figure 2). During the last century, plagues occurred in 1926-1934, 1940-1948, 1949-1963, 1967-1969, 1986-1989 and 2003-2005. Recent major upsurges were reported in 1992-1994, 1996-1998 and 2003 (Commission for Controlling the Desert Locust in the Central Region [CRC] n.d).

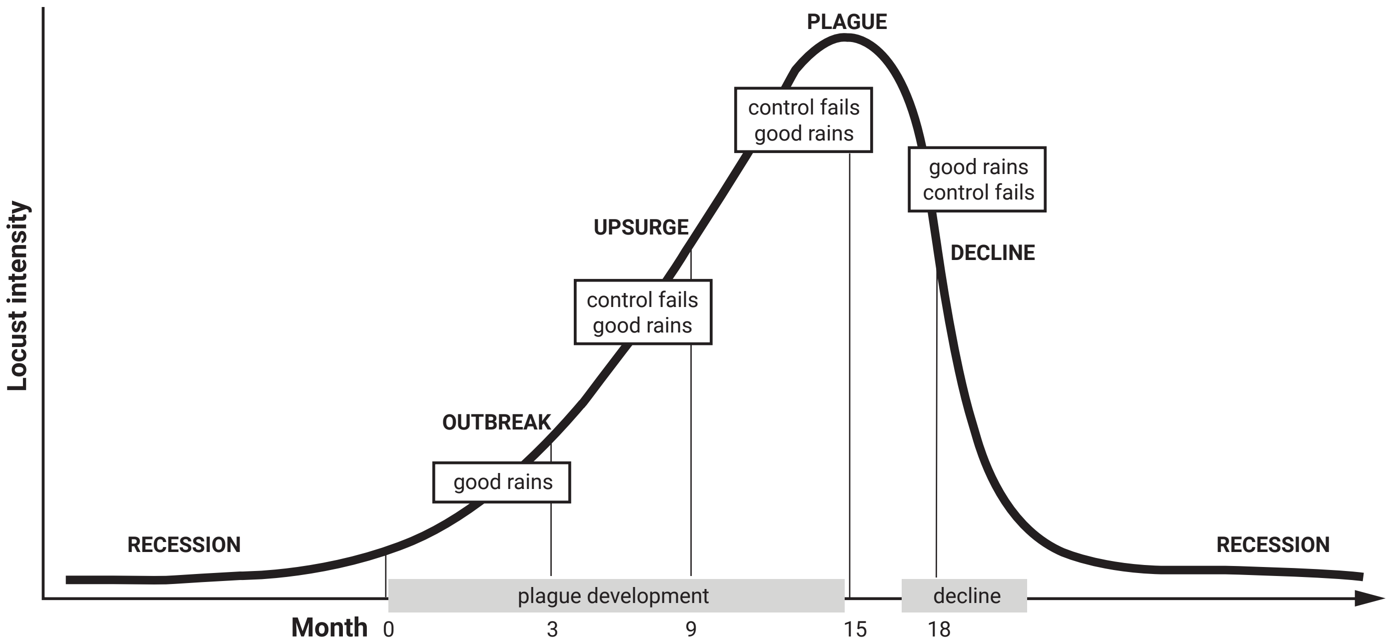


Figure 2: The evolution of desert locust plague. *Source: Cressman 2016*

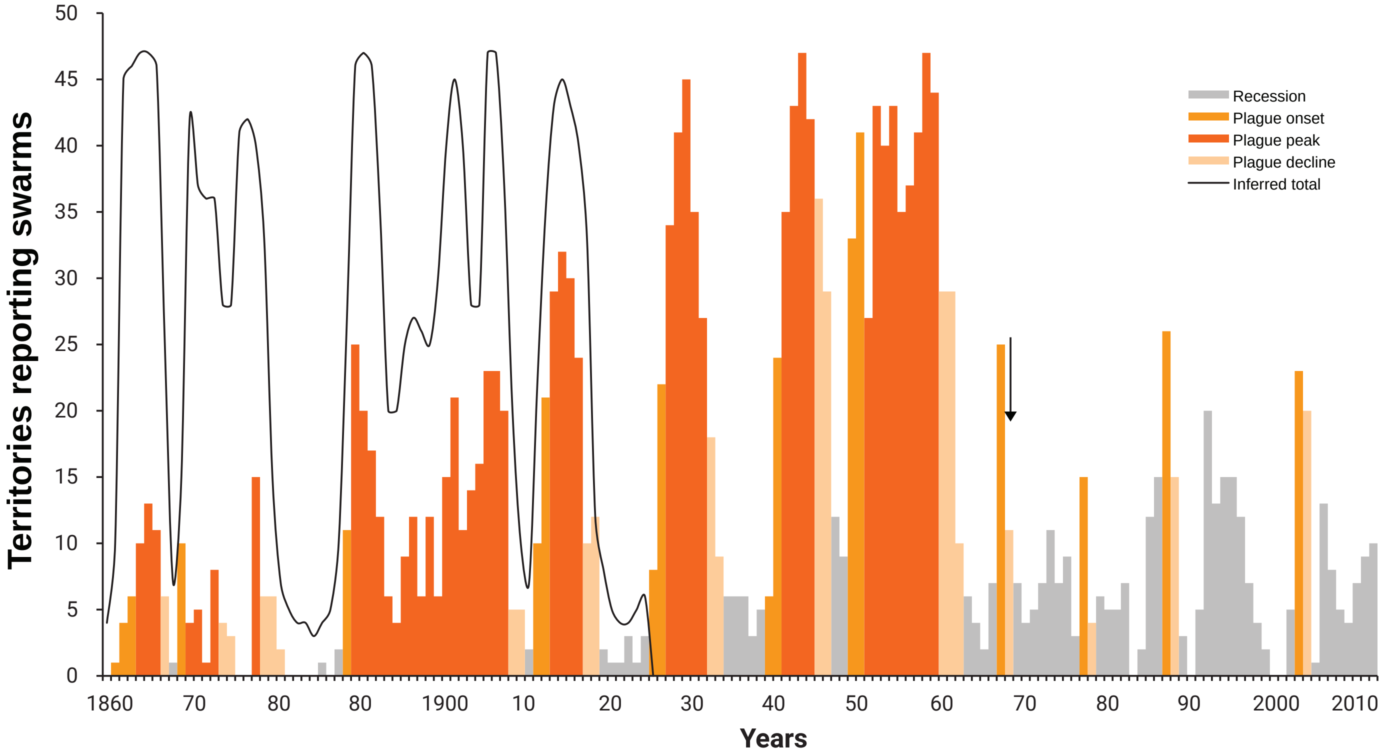


Figure 3: Locust upsurges and plagues between 1860s and 2019. *Source: Cressman 2016*

The current upsurge started to develop slowly over the period of two years starting between May and October 2018 when two cyclones brought heavy rains to the Empty Quarter in the Arabian Peninsula (FAO 2020c). Under these conditions, an unprecedented three generations of breeding occurred causing locust numbers to increase 8 000-fold across 9 months (FAO 2020c). The remote nature of the site made survey and control operations very difficult.

As the vegetation started to dry out, waves of swarms migrated from this area northwards in the Arabian interior to invade the southwest of the Islamic Republic of Iran, and southwards to invade eastern Yemen. Despite massive control operations, numerous spring-bred swarms migrated east and invaded the desert along both sides of the Indo-Pakistan border (FAO 2020c). Again, substantial control operations were required to reduce locust numbers. Nevertheless, some summer-bred swarms migrated back to the Islamic Republic of Iran in late 2019, while other swarms remained in Pakistan in early 2020. The swarms that left the Empty Quarter in early 2019 and moved southwards found exceptional breeding conditions in the interior of Yemen as a result of widespread heavy rains. This allowed at least one generation of breeding to occur that went mostly undetected and was also not controlled. This gave rise to swarms that invaded eastern Ethiopia and northern Somalia at the beginning of the summer in 2019. Heavy rains in both countries allowed breeding and swarm formation despite control operations in Ethiopia (FAO 2020c).

Consequences: Why is this issue important?

As highlighted in the 2020 Global Report on Food Crises, in 2019, almost 135 million people in 55 countries or territories, or 16 percent of the total population analysed, were classified in crisis conditions[1] or worse (Food Security Information Network [FSIN] 2020). Four countries, among the ten most affected, are currently also experiencing the ongoing desert locust upsurge (FAO 2020c). These are Ethiopia, South Sudan, the Sudan and Yemen.

The FAO has estimated that the current outbreak is the largest seen in 70 years in Kenya, in 50 years in the Islamic Republic of Iran and in 25 years in Somalia and Ethiopia. Pakistan officials say the outbreak there is the worst in 30 years (French Press Agency [AFP] 2020; FAO 2020d; FAO 2020e). In Iran, locust infestations have the potential to negatively impact the food security of over 30% of the population, as the affected provinces are the primary breadbasket of the country (FAO 2020e).

Desert locust Schistocerca gregaria is a species of locust, a periodically swarming, short-horned grasshopper in the family Acrididae
Photo credit: © Powerofflowers / Shutterstock.com

1 Integrated Food Security Phase Classification [IPC]/Cadre Harmonisé [CH] Phase 3 and above

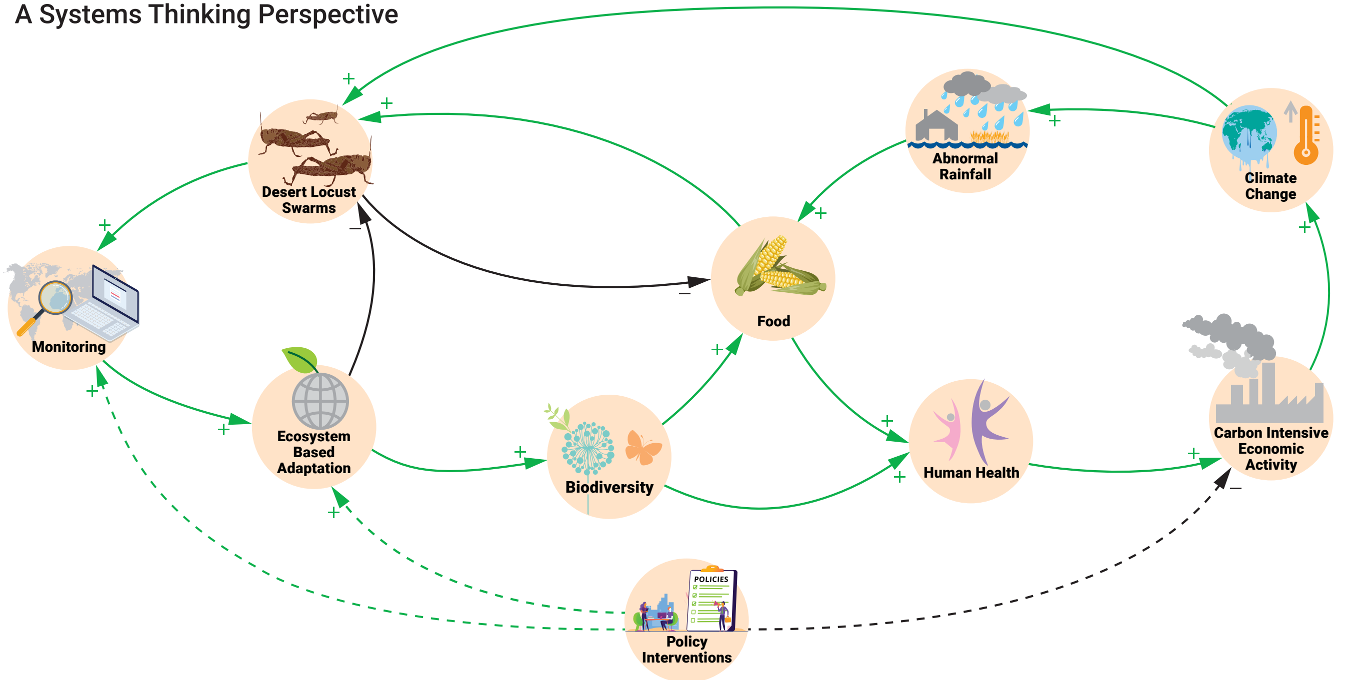
Locust on wheat grain. Crop damage to whole grain harvest.
Photo credit: © WildlifeWorld / Shutterstock.com

An assessment jointly conducted by the Ethiopian government, FAO, other UN organisations and NGOs suggests that in Ethiopia the desert locusts damaged several hundreds of thousands of hectares causing crop and pasture damage and resulting in limited cereal stocks in the households in the affected area. Their overall impact can be summarised into three main negative outcomes (UN-SPIDER 2020):

- **Livelihoods/Food security and nutrition:** By destroying crops and affecting availability of food for human populations, desert locusts threaten the food security of affected regions. They also affect livestock and wild animals as they feed on grasses and other wild vegetation (Escorihuela *et al*. 2018).
- **Economic development:** Globally, the agricultural commodities trade suffers greatly due to the destruction of crops. Additionally, there is an added cost of the locust outbreak response and control operations as it takes millions of litres of pesticides, along with the necessary equipment and labour. Farmers and governments have to bear a huge economic burden recovering from the destructive impact of locust attacks (Cressman, Van der Elstraeten and Pedrick 2016; Escorihuela *et al*. 2018; Lazar *et al*. 2016) . For example, the annual cost of locust emergency in West Africa is USD 3.3 million; but in 2003-2005, it costed a hefty USD 570 million to combat the West and North Africa plague, an equivalent of 170 years of emergency response costs for the region (Cressman, Van der Elstraeten and Pedrick 2016; Escorihuela *et al*. 2018).
- **Environment:** Locust control operations may have environmental side effects due to the high use of chemicals and pesticides (Lazar *et al*. 2016). Inevitably, there is also collateral damage to the ecosystems as it is not easy to discriminate between the locust swarms and other non-harmful organisms and vegetation. In addition to the direct impacts on the local ecosystem, there is also the possibility of human intoxication by the chemical pesticides used (Brader *et al*. 2006).

Migratory locust swarm. *Locusta migratoria. Acrididae. Oedipodinae*
Photo credit: © Poweroffloweres / Shutterstock.com

A Systems Thinking Perspective



Swarms of desert locusts can form in response to environmental stimuli in the semi-arid and arid deserts of Africa, the Near East and Southwest Asia. A hotter climate combined with abnormal rainfall arising from climate change provides optimal conditions and more food available for swarms of desert locusts to form. These in turn swarm to other regions to seek out more food. Food crops are destroyed and this adversely affects human well-being. Policy interventions focused on improved monitoring and ecosystem based adaptation approaches, can help manage desert locusts effectively, as well as enhance biodiversity which is in turn beneficial for human health. (+) Influence is in the Same direction, (-) influence is in the Opposite direction.

What are the findings?

The conditions for locust swarm formation

Studies have linked a hotter climate to more damaging locust swarms (Qiu 2009). Wet weather also favours multiplication of locusts. The desert locusts, despite their name, thrive following periods of heavy rainfall that trigger blooms of vegetation across their normally arid habitats in Africa and the Middle East (Stone 2020). Widespread, above average rain that pounded the Horn of Africa from October to December 2019, due, in part, to the many rare cyclones that struck the region around that time were up to 400% above normal rainfall amount. These abnormal rains can be attributed to the Indian Ocean Dipole (IOD). The IOD is an ocean temperature gradient that was recently extremely pronounced, and a phenomenon accentuated by climate change (Stone 2020). To understand how the IOD, the warmer weather, high rainfall, cyclones and the outbreak are linked, it is useful to understand the biology of the desert locust.

“Biphasic” in nature, the desert locusts can take on two entirely different forms. In their “solitary” form (drab brown in colour), they are relatively harmless to crops (Dunne 2020). In contrast, under favourable conditions, the insects can take a “gregarious” form – turning electric yellow and displaying swarming behaviour (Dunne 2020). Desert locusts only switch to a gregarious form when they reach high enough numbers in a certain area (Dunne 2020).

When in May 2018, Cyclone Mekunu, the first storm of the season, hit the Arab peninsula, the moisture allowed the growth of rich vegetation to grow in the otherwise barren environment, making it conducive for many desert locusts hunting for food, to move into the area. Once they reach a certain density, they start to touch each other a lot and this triggers them to change their behaviour (Lehmann 2020). By the time the second storm – Cyclone Luban – arrived in the same region in October, the locusts had just hit a critical point where they had started to multiply rapidly (Dunne 2020).

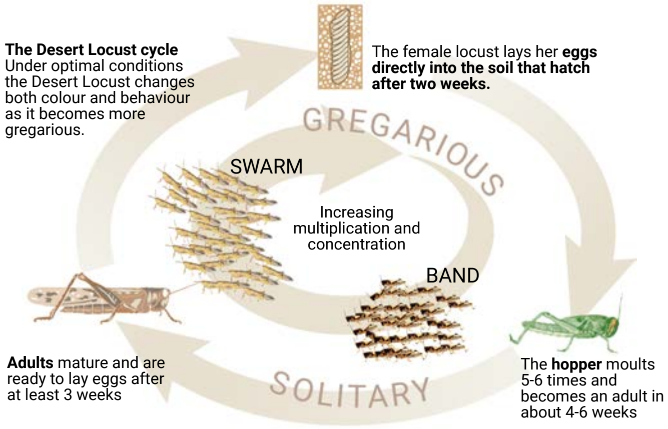


Figure 4: Desert locusts lifecycle. *Source: WMO and FAO 2016*

This period was then followed by a particularly mild winter, which allowed the locusts to survive in large numbers. Then, in the summer of 2019, the insects began to migrate from the Arab peninsula into the horn of Africa. As the insects moved through East Africa, the region was hit by unusually wet conditions and more cyclones – allowing the swarms to grow even larger (Lehmann 2020). Across the Horn of Africa, rainfall between October and mid-November was 300% above average. In Kenya, rainfall was up to 400% higher than average. Overall, the Horn of Africa was hit by eight cyclones in 2019, the largest number in any year since 1976 (Dunne 2020).

Links to changing climate

The unusual wet weather in East Africa is linked to a wider climate system -the Indian Ocean Dipole (IOD) (Saji *et al*. 1999a; WMO 2020). The dipole affects weather on both sides of the ocean, from East Africa and the Arab Peninsula to Indonesia, Papua New Guinea and Australia.

The dipole, has three phases – positive, negative and neutral (Saji *et al*. 1999a). In the positive phase, temperatures are higher in the western Indian Ocean than in the eastern Indian Ocean resulting in a positive index, overall. As a result, westerly winds weaken and, sometimes, easterly winds form – dragging warm water towards the Arab Peninsula and the Horn of Africa. This, in turn, plays a role in driving cyclones and heavy rainfall in the region because the additional warmth and moisture brought by the climate system acts as fuel for budding storms (Dunne 2020). Figure 6 illustrates the impacts of a positive IOD phase.

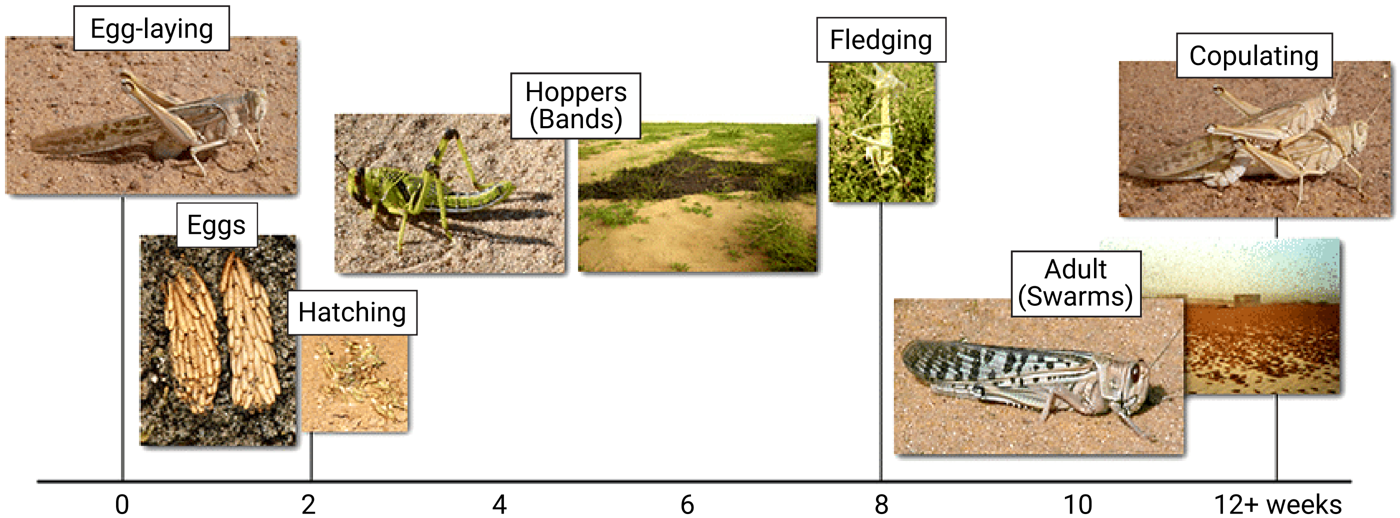


Figure 5: Desert locusts lifecycle. *Source: Cressman 2016*

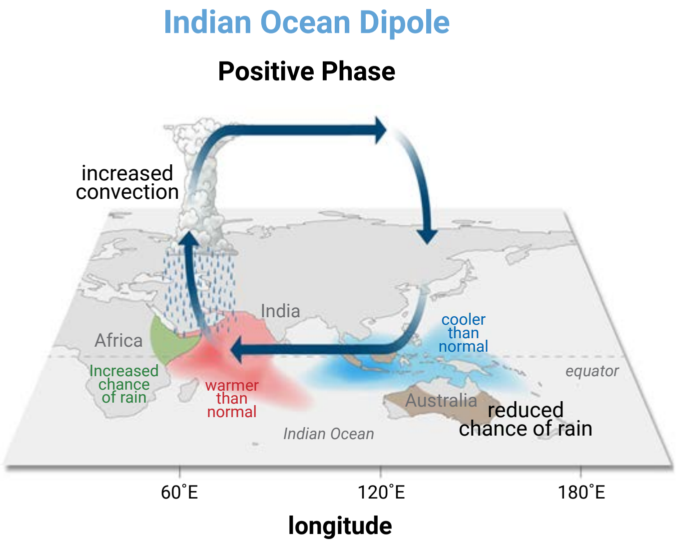


Figure 6: Positive phase of Indian Ocean Dipole. *Source: Johnson 2020*

The IOD was in its positive phase in the June to December period of both 2018 and 2019. In 2019, the dipole reached its most extreme positive level in 40 years (Figure below). Figure 7 shows the changes in monthly dipole mode index from January 1979 to December 2019.

In recent years, there has been an apparent increase in the occurrence of positive IOD events. (Cai, Cowan and Sullivan 2009). The frequency of occurrence of a positive dipole phase measured in a 30 year time-period increased from roughly four times in the first half of the 20th century to ten times in the latter half, between 1979s and 2009. (Cai, Cowan and Sullivan 2009).

Uncontrolled future climate change could cause positive dipole events to increase by a factor of three by 2099, when compared to the period 1900-1999 (Cai *et al.* 2014). Even if global temperature rise is limited to 1.5˚C, the number of positive dipole events could still be double the numbers in the pre-industrial era (Cai *et al.* 2018).

More generally, climate change experts predict more extreme weather, including droughts, floods and cyclones. Whereas locust numbers decrease during droughts, locust outbreaks often follow floods and cyclones. Local increases in rainfall can favour breeding conditions for locusts and determine the size of feeding areas, leading to changes in plague development (WMO and FAO 2016).

Climate change experts also predict that temperatures will continue to rise. Temperature governs the speed of locust development and swarm movement. Thus, increased temperatures associated with climate change can potentially shorten both the long maturation and incubation periods during the spring and allow an extra generation of breeding to occur in North-West Africa, the Arabian Peninsula and South-West Asia. This could increase the number of locust generations in a year in these regions and amplify overall plague risk. Changes in El Niño and La Niña events due to climate change could affect breeding during the winter in the Greater Horn of Africa and during the summer in the West African Sahel. The effects of climate change on winds are less certain. Any changes in wind speed, direction and circulation flows are expected to affect Desert Locust migration and could allow adults and swarms to reach new areas at different times of the year. Whether they will be able to become established, survive and breed in these new areas will depend on ecological, habitat and weather conditions (WMO and FAO 2016).

This is how unexpected weather conditions and cyclones fuelled by climate change play a role in driving locust outbreaks.

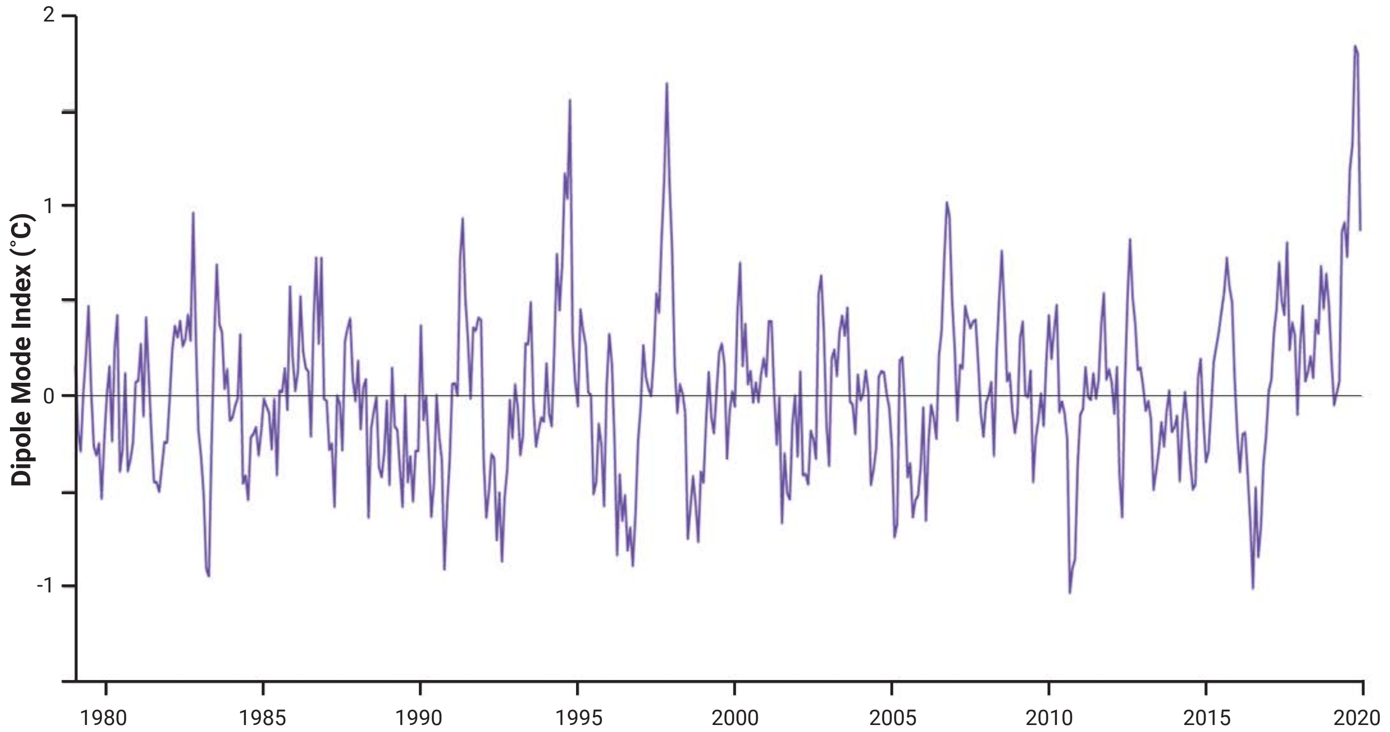


Figure 7: Monthly dipole Mode Index (DMI) from January 1979 to December 2019. *Source: Johnson 2020*

What has been done so far?

Early warning and monitoring

Early detection in the solitarious phase is critical in locust management. This is because they possess very high mobility in the gregarious phase, and it is difficult to control mass migrating insects. New advances in technologies such as satellite techniques have led to a paradigm shift in locust early warning from that of collecting information for interpreting and forecasting breeding and migration to predicting habitat development and the development of outbreaks, upsurges, and plagues (Cressman 2016) in the following ways (UN-SPIDER 2020):

1. Monitoring rainfall for monitoring the areas of breeding and swarming
2. Forecasting for prevention of upsurge/invasion. Short- and medium-term forecasts can be created for locust-favourable areas with the help of national locust survey reports, satellite imagery and meteorological data .
3. Monitoring environmental conditions conducive for locust reproduction/invasion: Rains that are very sporadic and localised, green vegetation, etc.
4. Mapping of spatial distribution of locusts to inform control operations in affected regions

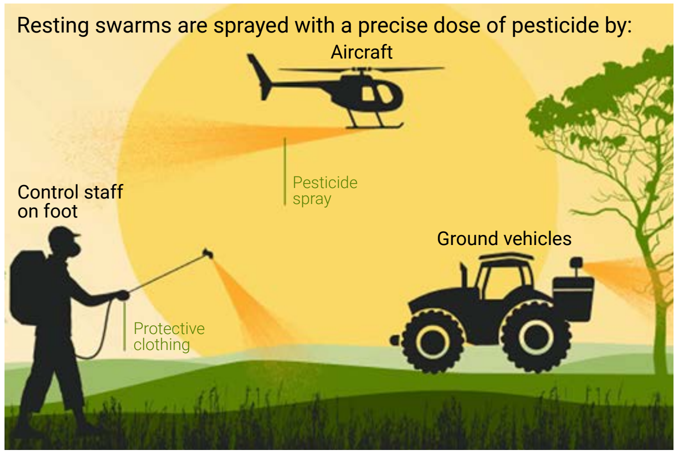


Figure 8: Schematic diagram of Desert Locust control operations. Sources: BBC 2020

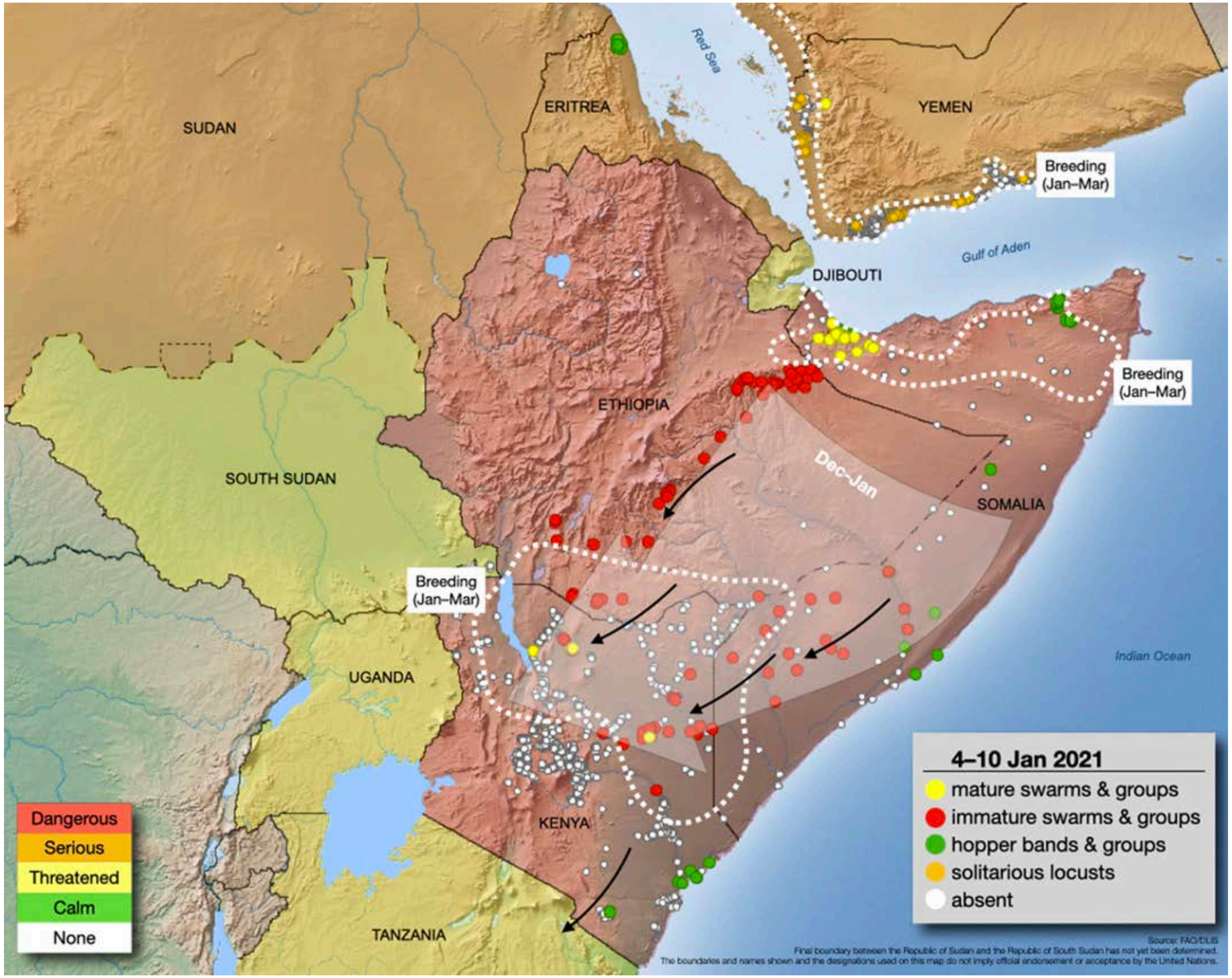


Figure 9: Desert locust movement prediction as on December 2020. Source: FAO 2020a

Controlling and managing locusts swarms

The primary control methods for locust swarms and hopper bands, at present, is using organophosphate chemicals applied in “ultra-low volumes (ULV) formulations” i.e. small concentrated doses by vehicle-mounted and aerial sprayers and to a lesser extent by knapsack and hand-held sprayers (CRC n.d.).

The Ministry of Agriculture and national locust units therein in locust affected countries are primarily responsible for undertaking locust survey and control operations. Additionally, many regional locust organizations also assist with these operations. External assistance from the donor community and international organizations are of value during times of outbreaks and plagues. (CRC n.d.)

There is ongoing external research on biological and other means of non-chemical control with focus on pathogens and insect growth regulators. Control by natural predators and parasites is limited so far because locusts can move away very quickly from most natural enemies. While people and birds often eat locusts, this is often insufficient to significantly reduce population levels over large areas (CRC n.d.).

Future projections

In the Horn of Africa, immature swarms continue to arrive and disperse throughout northern and central Kenya, Ethopia and Somalia (FAO 2020a). Despite control operations, a substantial number of hoppers bands are present and fledging to form new immature swarms (FAO 2020a). There remains a risk that another generation of breeding may occur during the next seasonal rains. (FAO 2020a). The situation remains calm in the other regions (FAO 2020a).

What are the challenges?

Predicting: The interactions between locust populations, their dynamics and the predictability of seasonal rainfall etc. are complex to predict (Adriaansen *et al*. 2016). As a result, populations may go undetected for months especially in the 16 million km^2 recession areas (Brader *et al*. 2006; Dinku *et al*. 2010).

Targeting and controlling outbreaks: There are several approaches to the control operations. Some argue that waiting until later stages of gregarization is efficient as the swarms occupy less land area in this stage than the hoppers in solitarious or early gregarization phases (UN-SPIDER 2020). On the other hand, such delay in action may be costly especially if the affected region does not have the capacity to respond fast over extensive areas of invasion (Brader *et al*. 2006).

Sociopolitical factors: i) Locust upsurges spread across several countries calls for cross border management. Political unrest and instability, national border disputes and sensitivities, kidnappings, mines, and conflict have led to insecurity in many parts of the recession area. This makes it increasingly difficult for survey and control teams to access many important areas, where desert locusts may be present and breeding. ii) Locusts are also considered beneficial to some communities as a source of food, fertilizer and nutrients (Lockwood 2016).

What are the implications for policy?

Addressing the underlying causes

While climate change is a global phenomenon, Africa and the affected parts of the Middle East and Asia stands out for their vulnerability which is driven primarily by the prevailing low levels of socioeconomic development. People living in poverty face compounding vulnerabilities to climate change impacts because they lack the resources to quickly recover from its effects. In these cases, desert locusts are ravaging crops in the field before harvesting, wiping out livestock and wildlife feed, and with them savings, assets and livelihoods.

Deployment of climate action solutions such as decentralizing solar dryers to agro-value chain actors, can ensure that they earn up to 30 times more by being able to preserve their harvest and sell during the offseason, or gives them flexibility to compensate for unpredictable events such as these locust swarms (Munang 2020). It can also create enterprise opportunities for auxiliary value chains fabricating these solar dryers (Munang 2020). Interventions like this are critical to increase climate resilience for some of the most vulnerable communities across the continent.

Multi-agency cooperation between UN organisations for better management of the locusts' issue

The United Nations' response to locust attack control should continue to be multi-agency in nature. While the immediate sector at risk is food security, climate can play an exacerbating role. The UN Environment Programme plays an important role in disseminating the latest science on emerging climate trends to inform cross-sectorial policies and ensure resilience is built in the relevant sectors. The World Meteorological Organization plays the crucial role of forecasting the more immediate weather changes that may exacerbate the locusts' attacks.

While the traditional form of control considered is use of pesticides, the impact of these chemicals on the environment and other critical ecosystems key to food security—such as bees and other insects, which not only pollinate up to 70 per cent of our food but also may have an impact on human health—cannot be overlooked. The World Health Organization's role is to classify potential risks of different chemical agents to enable governments to invest in the safest one.

It is in the mandate of the Food and Agricultural Organizations to provide up to date information along with timely warnings and forecasts on the general locust situation to those countries in danger of a locust invasion. The organization operates a centralized desert locust

Desert locust *Schistocerca gregaria* is a species of locust, a periodically swarming, short-horned grasshopper in the family *Acrididae*
Photo credit: © Powerofflowers / Shutterstock.com

information service. In addition, empowering communities with technologies for value addition—which are also climate action solutions—enables them to preserve their harvest. This makes it possible for an early harvest at the onset of attacks to ensure they save most of their yields.

Employing an Ecosystems Based Adaptation approach

Along with greater synergy and action between implementing UN and other development agencies (as indicated above), employing the Ecosystems Based Adaptation (EBA) approach will offer an additional dimension to address the climate change challenge. One strategic tool is the use of integrated pest management (IPM) that deploys physical, biological, chemical, mechanical and cultural methods in various combinations to keep locust pest populations at levels where they do not cause any economic damage. Chemical control has already been shown to have negative impacts on water bodies, biodiversity (including agriculturally important pollinators), domestic animals and human wellbeing. There is urgent need to explore opportunities provided by IPM to address the locust problem. For instance, combining biological control (use of the locust's natural enemies) and bio-pesticides (the use of living microbes) could prove successful in controlling the locust.

The implication for policy, therefore, is to promote the uptake and expansion of EBA tools such as the Integrated Pest Management. To ensure prioritization, these techniques should be part and parcel of research, training and extension policies. Regional and National Research Institutes should verify the efficacy of biopesticides under the differing national conditions to facilitate their use and better propose key actions required to integrate these into operational campaigns.

Inter-ministerial and intersectoral policies at the level of nation states

The success of the early warning system for desert locusts depends on a well-organized and funded National Locust Control Centres (NLCC) in every locust-affected country that can monitor field conditions and respond to locust infestations by: (1) conducting ground surveys and control operations; (2) collecting and transmitting accurate geospatial data rapidly; (3) using a GIS to analyse the data; (4) keeping all stakeholders informed on a regular and timely basis through simple well targeted outputs; (5) sharing reports within a robust and reliable information network; and (6) maintaining a cadre of well-trained and dedicated individuals (Cressman 2016).

At the same time, inter-sectoral efforts to build resilience of farmers and others involved in livelihoods directly impacted by locust outbreaks may be strengthened under the larger umbrella of the goals for 2030. Climate action at the national and subnational levels will also go a long way in addressing the root cause of such phenomena, which could be harbingers of larger events symptomatic of a deteriorating global climate system.

The need for a joined-up approach to policy implementation

More and more, policy development, is being done using a collaborative approach involving different sectors and stakeholders. However, the challenge comes with implementation. There is urgent need to adopt a multi-sectoral approach as accountability for the fight against locusts must be shared across governments as a whole. Coordinated, intersectoral action (joined-up approach) for locust control, including between ministries at national level, between the different lower levels of government and with stakeholders outside government, is necessary in order to address the locust challenge.

Policy is the biggest driver of change. And to be particularly effective there will be need for clear joined up policy implementation to deliver incentives that encourage and complement a sustainable locust control and management approach. Financial, energy, agricultural, education and environmental policies will need to be leveraged to adequately complement and encourage each other. There will also be need for political support to ensure the team of policy experts that convene to draw up these integrated solutions have a supportive environment in which to work and subsequently ensure implementation.

Conclusion

The adverse economic significance of locusts is evident from their impacts on livelihoods, food security and nutrition, economic development and on the environment. This Foresight Brief discusses some of these issues and highlights the possible role of climate change in locust infestations. It was noted that:

- Africa and the affected parts of the Middle East and Asia stands out for their vulnerability both due to the increasing impact of climate variability and the prevailing level of socio-economic development.
- Even if global temperature rise is limited to 1.5˚C, the number of positive dipole events could still be double the numbers in the pre-industrial era, potentially increasing the frequency for similar locust upsurges in the future.
- Predicting and controlling locust outbreaks are some of the major challenges that countries face.
- There is an urgent need to adopt a multi- sectoral approach as accountability for the fight against locusts must be shared across governments as a whole.
- More importantly, there is an urgent need to build the resilience of economies facing a growing threat of such outbreaks while at the same time working on mitigating the underlying causes including climate change.

Moving forward, intergovernmental partnerships and international collaboration to mobilise adequate resources, along with an interdisciplinary leadership will be crucial to minimise the socio-economic and environmental damage while also ensuring that the underlying causes are addressed.

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