From the Co-ordinator’s Desk...

The Environmental Information System (ENVIS) has been providing information on issues related to State of Environment of Odisha. Publication of newsletter is one of the ways for dissemination of information among the wider public. The other ways include dissemination through a web-enabled system and query services. The Centre has been trying to respond to various queries on environmental issues.

Our Centre is always trying to bring out environmental issues of significance in the newsletters. We have covered many issues of environment of the State in our previous publications.

This newsletter depicts on Impact of Climate Change on Honeybees. I hope that this publication will be useful to users.

Shri Shrawan Kumar Sinha, IFS
Director, CES-cum-Coordinator

Supported by:
Ministry of Environment, Forest & Climate Change
Govt. of India, New Delhi
The act of “pollination” occurs when pollen grains are moved between two flowers of the same species by wind or animals. Successful pollination results in the production of healthy fruit and fertile seeds, allowing plants to reproduce. Almost 90% of all flowering plants rely on animal pollinators for fertilization, and about 200,000 species of animals act as pollinators. Insect pollination (entomophily) is by far the commonest method of pollen transference and played vital role in the evolution of angiosperms. The associations between flowers and insects are the results of evolutionary forces which have been acting ever since insects first began to feed on flowers and their mutual association is believe to exist since 60-100 million years ago. Mc Gregor an eminent pollination scientist in United States had estimated that “One third of man’s diet is derived directly or indirectly from insect pollinated plants”. Presently about 80% of our food plants depend on insect pollination. Moreover, many wild plants in nature are being propagated through insect pollination which maintains the sustainability of ecosystems, environmental quality and help in the conservation of biodiversity. In recent decades, climate change resultant global warming has become issue of serious concern worldwide for existence of life on the earth (IPCC, 2007) including pollinators. Climate change has been a global phenomenon and dominant theme in several fora of science, environment and politics.

Climate and Climate change

Climate means the average pattern in which weather varies in time. The climate of region depends on the presence or absence of water, the reflection of solar radiation, evaporation, and the capacity to store heat, topography and texture of the region. Although they constitute only a fraction of the total land area of the earth, metropolitan areas emits the bulk of all air pollutants. These air pollutants influence temperature, visibility and precipitation as well as other climatic elements. “Global warming and climate change are terms frequently used for the observed century that refers to scale rise in the average temperature of the earth’s climate system and its related effects.
Climate change is a global phenomenon unbounded by geographical boundaries. Melting of ice in the Arctic, Antarctic and Himalayas have made climate erratic and almost unpredictable. Global climate change is defined as a lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions or the distribution of events around that average (e.g., more or fewer extreme weather events). The main causes of climate change are natural changes in the components of earth’s climate system and their interactions referred to as “internal forcing.” The external forcing mechanisms include orbital variations, solar output, volcanism and human influence. Over past hundred years, the global temperature has increased by 0.8°C and is expected to reach 1.1-6.4°C by the end of next century. On the other hand, CO₂ concentration in the atmosphere has increased drastically from 280 ppm to 370 ppm and is likely to be doubled in 2100 (IPCC, 2007).

Pollination as an important Ecosystem Service (ES)

ES are benefits that people derive from nature. One important ES is pollination (classified by the Millennium Ecosystem Assessment (MEA) as a regulating service), which is fundamental to the reproduction of flowering plants and essential for the production of about one-third of the human diet. It is one of the 15 ecosystem services identified by the MEA as currently being under threat. Commonly thought of as a free service, pollination nevertheless needs resources for its proper functioning. Whilst some plants can reproduce asexually or rely on wind or self-pollination, the majority of flowering plants require animal pollinators in order to produce fruit and seeds.

Barring the production enhancement in cereal crops, pollinators are essential for orchard, horticultural and forage crops production as well as the production of seed for many root, vegetable and fibre crops. Pollinators such as bees, birds and bats affect 35 per cent of the world’s crop production, increasing outputs of 87 of the leading food crops worldwide. Food security, food diversity, human nutrition and food prices all rely strongly on animal pollinators. The consequences of pollinator declines are likely to impact the production and costs of vitamin-rich crops like fruits and vegetables, leading to increasingly unbalanced diets and health problems. Maintaining and increasing yields in horticultural crops under agricultural development is critically important to health, nutrition, food security and better farm incomes for poor farmers.

In the past, pollination has been provided by nature at no explicit cost to human communities. As farm fields have become larger, and the use of agricultural chemicals has increased, mounting evidence points to a potentially serious decline in populations of pollinators under agricultural development. The process of securing effective pollinators to “service” agricultural fields are proving difficult to engineer, and there is a renewed interest in helping nature provide pollination services through practices that support wild pollinators. On a global level, the convention on biological diversity has identified the importance of pollinators with the establishment of the International Initiative for the conservation and sustainable use of pollinators (also known as the International Pollinators Initiative-IPI) in 2000, facilitated and coordinated by FAO. Other intergovernmental fora have also noted the importance of ecosystem services – such as pollination – to agriculture, including the commission on genetic resources for Food and Agriculture and the committee on agriculture of FAO.
Honeybee as pollinator

Bees are essential components of almost all of the world’s terrestrial ecosystems. They provide both pollination services and are excellent indicators of the state of terrestrial environments including responses to global warming. The long-term survival of farming worldwide relies in part on insect pollinators. In monetary terms, they contribute an estimated US$ 117 billion per year; around 35% of agricultural crops depend directly on pollinators and 84% of cultivated plant species are involved with the activity of these insects. The European Honeybee, *Apis mellifera*, is the most economically valuable pollinator of agricultural crops worldwide. The Honeybee is the only pollinator species that lives in perennial societies, whose members are connected via complex communication processes and demonstrate pronounced work-share behavior. A Honeybee colony reaches its most populous in early summer, at around the time of the longest day. Honeybees are by far the most efficient pollinator among all the insect species associated in pollination and are accurately described as the best pollinator because

- Honeybees have a social organization in which young ones are nursed and fed with mixture of honey and pollen by the adult bees throughout the year. The larvae and adults of bees depend fully on flowering plants to meet their dietary requirement there by effecting efficient pollination.

- Body of Honeybees is specifically adopted to carry the pollen. Entire body is hairy and the meta-thoracic pair of legs bears pollen baskets to carry pollen grains.

- Honeybees have evolved special communication systems by which thousands of field workers can be deployed when good food is available. Competitive forage sources when interfere with the pollination of a crop, it is possible to decondition and recondition the bees and direct them to a particular crop through simple manipulation.

- Forager bees from one hive may visit many species of plants in a given day, but individual forager displays flower fidelity or constancy. When a forager start collecting nectar or pollen from the flowers of one species of plant they will continue to visit flowers of only that species for at least one foraging trip and more often for several days or until the resource is exhausted fully. Pollen purity in Honeybee is 98 per cent which proves their floral constancy.

- Unlike other insect pollinators and solitary bees, the Honeybees work a long hour constantly on the same crop and the same field. *A. cerana indica* and *A. mellifera* collect nectar load of 15-30 and 30-40mg respectively in each trip. A bee brings about 10-20 full loads of nectar/day and for each load it attains 50-500 flowers. Similarly the pollen load in *A. cerana indica* and *A. mellifera* varies from 7-14mg and 12-29mg respectively which they collect from 50-200 flowers. Each pollen load is collected in 10-20 min time and as many as 47 loads are collected /day. This long period and intimate association of bees for nectar and pollen gathering facilitate high rate of pollination.

- Honeybees are the only pollinators which can be made readily available in considerable numbers, whenever and wherever needed. Like other agro-inputs (Fertilizer, seeds, pesticides, irrigation etc.) Honeybees can be exploited as another vital agro inputs to enhance crop productivity.

- Honeybees do not limit their pollination service to a single species or genus rather pollinate a wide range of agricultural, horticultural crops forest trees and innumerable shrubs and weeds, thus playing a vital role in conservation of floristic biodiversity.

- A farmer would be interested in keeping Honeybees as they also produce honey, beeswax, royal jelly, propolis bee venom etc. Exploitation of Honeybees for pollination service also enhances the yield of hive products giving back the monetary return to the bee keepers directly.

Impact of Climate change

The healthy functioning of ecosystem services ensures the sustainability of agriculture as it intensifies to meet growing demands for food production. Climate change, however, may have major impacts on key ecosystem services and
functions, such as pollination services. Ecosystem being very complex (Plants, Pollinators and their associated climate) interacting system, change in any component is likely to affect the other, but the change that will be exhibited by plant and the associated pollinators may not be same even though they have been coevolved. Among abiotic components rise in temperature is more pronounced. It has resulted not only marked change in plant and pollinator association but also decline in their population to an extent of serious human concern.

The International Union for the Conservation of Nature’s (IUCN) Red list of threatened species includes 41,415 species and 1,238 animal species are listed under the United States Endangered Species Act. At least two bats and 13 bird species on the US list are pollinators, but the number of listed pollinator insects remains unknown [NAPPC, 2002-2005]. However, a list of pollinator insects prepared by the American Xerces Society includes 59 endangered species of moths and butterflies and 58 species of bees [Xerces Society, 2005].

A. Impact of climate change on Honeybee

Although the precise impact of potential environmental changes on Honeybees is not very well known as a result of climate change, still plenty of information are available indicating that environmental changes have a direct influence on Honeybee development. Honeybees are very thermo sensitive and their normal activities is much influenced by the temperature as described below. Being ectothermic, the temperature of their surroundings environment determines the activity of bees and hence climate change, characterized by elevated temperatures, could drastically impact their biology, behavior and distribution. Indirectly too, the climate change affects bees through their floral resources and natural enemies.

Effect of temperature on bee activity

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33-36°C</td>
<td>Most favorable for colony build up, comb construction. Brood rearing</td>
</tr>
<tr>
<td>33-34°C</td>
<td>Favourable for queen to lay eggs</td>
</tr>
<tr>
<td>&gt; 34°C</td>
<td>Try to control hive temperature through fanning, reduce inner temperature of hive</td>
</tr>
<tr>
<td>&gt; 33°C</td>
<td>Some bee seal the entrance being congregated to reduce hive temperature</td>
</tr>
<tr>
<td>&lt; 27°C</td>
<td>Cover the entire brood frame to keep the brood frame warm</td>
</tr>
<tr>
<td>20°C</td>
<td>New queen stop nuptial flight for mating</td>
</tr>
<tr>
<td>16°C</td>
<td>Drone fails to move around the box.</td>
</tr>
<tr>
<td>14°C</td>
<td>Workers remain in group for sustain low temperature.</td>
</tr>
<tr>
<td>10°C</td>
<td>Workers cannot fly</td>
</tr>
<tr>
<td>&lt; 8°C</td>
<td>Lethal to the Honeybees</td>
</tr>
</tbody>
</table>

Adaptive features of bees

The European Honeybee, *Apis mellifera*, has the potential to adapt to hot climates. For instance, *Apis mellifera sahariensis* is found in the oases of the Sahara, where it has adapted to local bloom (such as palm flowers) and extreme heat. In the USA, Honeybees can develop in the Arizona Desert. The survival requirement for these bees is a supply of water, which they use in large quantities to raise their larvae and to regulate the brood temperature to between 34°C and 35°C.
an arid environment, desert flowers are unable to provide the bees with enough water and they die. According to climate change predictions, desert regions will become even drier, leading to the disappearance of oases and their Honeybees. *Apis mellifera sahariensis* is highly unlikely to migrate naturally to more favourable desert areas because oases are very isolated and not conducive to long-distance migration or swarming. It is therefore vital to envisage conservation measures to transfer this bee to zones favourable to its development, lest we lose this ecotype that is so valuable for world biodiversity.

Climate change can influence the Honeybee development cycle. It is generally agreed that each race of Honeybees develops at its own rate. Any sort of climate change or movement of a race of Honeybees from one geographical region to an alien one is therefore bound to have measurable consequences. In cool regions, Honeybees spend the winter clustered in a tight ball and use their honey stores to provide them with the energy they need to survive until spring. The honeybee’s capacity to accumulate energy reserves and to manage the colony’s development exerts significant adaptive pressure. In the spring, when the weather becomes more clement, the queen starts to lay eggs and the colony develops and increases the size of the worker population. A cold snap lasting several weeks may occur during which the honeybees are unable to harvest. The large size of the Honeybee population causes such a rapid depletion of stores that the colony can die of starvation. It is something that can easily happen to hybrid bees (crosses of several races by bee breeders), which develop very fast in spring.

In contrast, local ecotypes that are better adapted to the environmental conditions are more cautious and develop more slowly in spring until after this cold snap, when they breed very rapidly. In this way they avoid jeopardizing the colony’s survival. A distinction therefore needs to be made between local ecotypes, which need to adjust their development and stores to the climate, and hybrid bees selected by bee breeders. Hybrids have not been bred to build up food stores, the queen does not adjust her egg-laying and the workers do not adjust their larvae-rearing, with the result that the bees are unable to survive without the assistance of a beekeeper to provide them with unlimited supplies of sugar solution.

The variability of the honeybee’s life history traits as regards temperature and the environment shows such plasticity and genetic variability that this could give rise to the selection of development cycles suited to new climatic conditions. Bees adjust their behaviour to weather conditions. They do not go out when it rains and in extremely hot weather, they gather water to keep the colony cool. Bees of the *Apis* genus are distributed throughout the world in highly diverse climates. The *Apis mellifera* species, whose distribution range extends to sub-Saharan Africa, northern Europe and Central Asia, is found in a wide variety of environments, including the oases of the African desert, the Alps, the fringes of the tundra and the mists of the United Kingdom. Its ecotypes have adapted remarkably well to their biotopes. The other Honeybee species of the *Apis* genus are distributed around Asia, particularly tropical south-east Asia.

A change in climatic conditions is bound to have an impact on the survival of these ecotypes or of Honeybee species that are closely associated with their environment. Migration and changes in their life cycle and behaviour could help them to survive in new biotopes. As the Honeybees genetic variability will be crucial to its adaptation, preservation of this genetic variability should be ensured.

**Thermo regulative adoptive feature**

Honeybees, however settle in a wide range of climates, from the tropics to the cool-temperate zones. They have an excellent thermoregulation mechanism that enables them to survive the adverse weather conditions. A Honeybee is both exothermic and endothermic. Normally it is cold
blooded (Exothermic) like other insects, however unlike other insects, honeybees do not die off in the fall of temperature. Individual Honeybees are exothermic but hive collectively is endothermic. Some races of the Western honeybee (Apis mellifera L.) are able to survive cold northern winters as a whole colony. This is possible because at low temperatures they crowd tightly together in a winter cluster. Insulation by the tightly packed mantle bees is the decisive factor for survival at low temperatures, mostly ignoring the possibility of endothermic heat production. Insulation by the tightly packed outer bees of the cluster reduces heat loss drastically. The abundance of endothermic bees is highest in the core and decreases towards the surface. This shows that core bees play an active role in thermal control of winter clusters. Regulation of both the insulation by the mantle bees and endothermic heat production by the inner bees is necessary to achieve thermal stability in a winter cluster.

Migration to surpass adversity

Tropical climates may evolve towards more distinct seasons with dry periods. In this case, Asian Honeybees would need to rapidly step up their honey-harvesting strategy to amass sufficient stores to survive periods without flowers. Else they could develop a migration strategy, as has Apis dorsata, a giant Honeybee of the Apis genus. These Apis dorsata colonies build their nests in the open air, consisting of a very big, single comb of up to two meters in length. Apis dorsata tend to be gregarious, which gives them a distinct advantage in the joint defense of their nests against predators. They are very nomadic, readily migrate in response to seasons, flowering patterns or disruption. They abandon their nests and can fly distances of up to 200 kilometres to escape starvation or predators. After leaving their nests unoccupied for several months (or in some cases one or two years) the same Honeybee colony returns to colonise the same nest in the same tree every year.

If there is large-scale natural swarming, these species will be able to swarm to more favourable regions and abandon their regions of origin. Failing that, they will need to evolve rapidly towards a harvesting strategy to enable them to survive during periods with no flowers. A commonly-cited textbook example is that of the Landes ecotype in south-western France. In the Landes region, the colonies develop in step with heather bloom, which is the main natural resource for these Honeybees. The Landes ecotype has therefore modelled its development on that of the plant.

B. Impact of climate change on host plants

A change in climate is bound to alter the flora. Changing climates may cause changes in the time of growth, flowering and maturation of crops, with consequent impacts on crop-associated biodiversity, particularly pollinators. Key biological events such as insect emergence and date of onset of flowering need to occur in synchrony for successful pollination interactions. Effective crop pollination is heavily dependent on biological timing, of both the crop and its pollinators.

In a context of climate change, plant phenology will be modified, especially the flowering period. A new bioclimatic and economic balance will shape the types and distribution of agricultural crops, as well as those of spontaneous vegetation. Climate change could destabilize relationships between flowers and pollinators, and pollinators will need to be protected to ensure that they continue their pollination function, which is so important for the economy and for the ecological balance.

Differential response of insects and plants to changed temperature could create temporal (phenological) and spatial (distributional) mismatches with severe population fluctuation for the species involved and in addition the honey and pollen store, if it is a Honeybee species. Asynchrony may affect plant by reduced insect visitation and pollen deposition, while bees experience reduced food availability. Systematic studies to quantify the effects, adverse or otherwise, of climate change are very few.

Climate influences flower development and nectar and pollen production, which are directly linked with colonies foraging activity and development. Bees must build up sufficient honey stores to enable them to survive the winter. The nurse worker bees must consume enough pollen to feed the larvae through their pharyngeal glands.
A major effect of climate change on Honeybees stems from changes in the distribution of the flower species on which the bees depend for food.

The rainfall, another component of environment greatly influenced by climate change is also exhibit definite bearing on Honeybees. The impact that rain can have is the adverse effect on honey harvesting by bees. For instance, when Acacia flowers are washed by rain, they are no longer attractive to Honeybees as it dilutes their nectar too much. Likewise, an overly dry climate will reduce the production of flower nectar for Honeybees to harvest. Lavender flowers produce no nectar when the weather is too dry, which makes harvesting by bees a largely hypothetical matter. In extreme situations, Honeybees can die of starvation.

The honeydew produced by sucking insects from certain plant species is also climate-dependent. In Alsace, very special conditions are required for the development and growth of balsam fir aphid populations, whose honeydew is highly attractive to Honeybees. On the other hand, certain types of honeydews cause dysentery in Honeybees.

The food shortages stemming from an excessively dry climate reduces pollen production and impoverishes its nutritional quality. A pollen shortage induced by autumn drought will have the effect of depriving bees in winter, weakening their immune system and making them more susceptible to pathogens, and shortening their lifespan.

**Conclusion**

Pollinators are a key component of global biodiversity, providing vital ecosystem services to crops and wild plants. There is clear evidence of recent declines in both wild and domesticated pollinators, and parallel declines in the plants that rely upon them. Honeybees are the best pollinators and are crucial in maintaining biodiversity by pollinating numerous plant species whose fertilization requires an obligatory pollinator. Climate change is bound to bring the change in plants, pollinators and their natural enemies and many unknown factors linked in the food web and associated factors. Changes occurring and will continue to occur in the ecosystems. Organisms with greater genetic and behavioural plasticity will adjust under changing scenario while the other species will disappear, shift to other locations or get extinct. *Apis mellifera* is a species that has shown great adaptive potential, as it is found almost everywhere in the world and in highly diverse climates. In a context of climate change, the variability of the Honeybee’s life history traits as regards temperature and the environment shows that the species possesses such plasticity and genetic variability that this could give rise to the selection of development cycles suited to new environmental conditions. Inspite of all these ecological consequences, the most important is the anthropogenic activities that need to be planned and regulated to derive the benefits of ecosystem services to reach the sustainable developmental goals.