A DISSERTATION REPORT ON

ASSESSMENT OF POLLINATOR DIVERSITY IN NAVDANYA ORGANIC FARM, DEHRADUN, UTTARAKHAND

In Partial Fulfillment of the Requirement of Fourth Semester for the Award of Master of Forestry, (2009-2011).

Submitted by

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CERTIFICATE

This is to certify that the dissertation work entitled **"Assessment of Pollinator diversity in Navdanya organic farm, Dehradun, Uttarakhand"** is a bonafide work carried out by **Jiju J.S.**, student of M.Sc. (Forestry) course of Forest Research Institute (University), Indian Council of Forestry Research and Education (ICFRE), Dehradun submitted in partial fulfillment of the requirement for M.Sc. (Forestry) 2009-11. The work has been carried out under the supervision of **Dr. V.P.Uniyal**, Scientist 'E' , Wildlife Institute of India, Dehradun.

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DECLARATION

I, hereby, declare that the Dissertation work entitled "Assessment of Pollinator Diversity in Navdanya Organic Farm, Dehradun, Uttarakhand." has been done by me under supervision of Dr. V.P.Uniyal, Scientist- E, Landscape Level Planning and Management Division, WII, Dehradun, and is submitted to Forest Research Institute (FRI) University, Indian Council of Forestry Research and Education (ICFRE), Dehradun for partial fulfilment of the award of degree of Master of science in Forestry.

To the best of my knowledge the text is void of any theoretical error and I have thoroughly gone through all the written material in the Dissertation.

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4th Semester

2009-2011

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CHAPTER-1

INTRODUCTION

1. Introduction

1.1 The Pollinators

A pollinator is the biotic agent (vector) that moves pollen from the male anthers of a flower to the female stigma of a flower to accomplish fertilization or syngamy of the female gamete in the ovule of the flower by the male gamete from the pollen grain. Plants fall into pollination syndromes that reflect the type of pollinator being attracted. These are characteristics such as: overall flower size, the depth and width of the corolla, the colour (including patterns called nectar guides that are visible only in ultraviolet light), the scent, amount of nectar, composition of nectar, etc. Animal pollination is important to sexual reproduction of many crops (McGregor 1976; Crane & Walker 1984; Free 1993; Williams 1994; Nabhan & Buchmann 1997; Westerkamp & Gottsberger 2000) and the majority of wild plants (Burd 1994; Kearns et al 1998; Larson & Barrett 2000; Ashman et al 2004), which can also be important for providing calories and micronutrients for humans (Sundriyal & Sundriyal 2004). Furthermore, the decline of pollination species can lead to a parallel decline of plant species (Biesmeijer et al 2006).

Pollination is one of the most important mechanisms in the maintenance and promotion of biodiversity and, in general, life on Earth. Many ecosystems, including many agro-ecosystems, depend on pollinator diversity to maintain overall biological diversity. Pollination also benefits society by increasing food security and improving livelihoods. Pollinators are extremely diverse, with more than 20,000 pollinating bee species and numerous other insect and vertebrate pollinators. Therefore pollinators are essential for diversity in diet and for the maintenance of natural resources. The assumption that pollination is a "free ecological service" is erroneous. It requires resources, such as refuges of natural vegetation. Where these are reduced or lost they become limiting, and adaptive management practices are required to sustain livelihoods.

In the mid-1990s, scientists and agriculturists around the world became concerned by a decline in pollinator diversity. In order to sustain pollinator services associated with agricultural ecosystems, far more understanding is needed of the multiple goods and services provided by pollinator diversity and the factors that influence their decline and activity. It is necessary to identify adaptive management practices that minimize negative impacts by

humans on pollinators, promote the conservation and diversity of native pollinators, and conserve and restore natural areas necessary to optimize pollinator services in agricultural and other terrestrial ecosystems. This situation prompted policymakers, at the fifth meeting of the Conference of the Parties to the Convention on Biological Diversity, to establish an International Initiative for the Conservation and Sustainable Use of Pollinators.

The Convention's cross-cutting initiative on the conservation and sustainable use of pollinators aims to:

- Monitor pollinator decline, its causes and its impact on pollination services
- Address the lack of taxonomic information on pollinators
- Assess the economic value of pollination and the economic impact of the decline of pollination services
- Promote the conservation, restoration and sustainable use of pollinator diversity in agriculture and related ecosystems.

The conservation and sustainable use of pollinators intersect on a number of key issues. Pollinators contribute to biodiversity and life on Earth, on food security and to the global economy.

The cross-cutting initiative is to be developed within the context of the CBD's existing programme of work on agricultural biodiversity, with appropriate links to other thematic programmes of work, particularly those on forest biological diversity and the biodiversity of dry and sub-humid lands, and with relevant cross-cutting issues, particularly the Global Taxonomy Initiative and work on invasive alien species. The initiative provides an opportunity to apply the ecosystem approach. The initiative aims to reach outside the CBD process to strengthen the work of existing Partners & Initiatives concerned with conservation and sustainable use of pollinators.

The initiative on conservation and sustainable use of pollinators was formally established by VI/5 annex II of the Conference of the Parties, in 2002 and is built around four elements and their supporting activities. The mandate for establishing the initiative was provided by decision V/5. The framework for the initiative was developed considering the recommendations of the Sao Paulo Declaration on Pollinators, based on the results of the Workshop on the Conservation and Sustainable Use of Pollinators in Agriculture, held in Sao Paulo, Brazil, from 7-9 October 1998.

For tropical crops, Roubik (1995) provided a detailed list for 1330 species and compiled a list of potential breading systems and pollinating taxa. From this list, ca 70% of tropical crops seems to have at least one variety for which production is improved by animal pollination. For European crops, Williams (1994) assessed the pollinator needs for 264 crop species and concluded that the production of 84% of these depends at least to some extent upon animal pollination.

1.2 Types Of Pollinators

1.2.1 Invertebrates

Invertebrates, such as ants, bees, wasps, beetles, butterflies, moths, flies, mosquitoes, and midges all act as pollinators. The most recognized pollinators are the various species of bees, which are plainly adapted to pollination. Bees typically are fuzzy and carry an electrostatic charge. Both features help pollen grains adhere to their bodies, but they also have specialized pollen-carrying structures; in most bees, this takes the form of a structure known as the scopa, which is on the hind legs of most bees, and/or the lower abdomen (e.g., of megachilid bees), made up of thick, plumose setae. Honey bees, bumblebees, and their relatives do not have a scopa, but the hind leg is modified into a structure called the corbicula (also known as the "pollen basket"). Most bees gather nectar, a concentrated energy source, and pollen, which is high protein food, to nurture their young, and inadvertently transfer some among the flowers as they are working.

I. Honeybees

Honey bees travel from flower to flower, collecting nectar (later converted to honey), and pollen grains. The bee collects the pollen by rubbing against the anthers. The pollen collects on the hind legs, in a structure referred to as a "pollen basket". As the bee flies from flower to flower, some of the pollen grains are transferred onto the stigma of other flowers.

Nectar provides the energy for bee nutrition; pollen provides the protein. When bees are rearing large quantities of brood (beekeepers say hives are "building"), bees deliberately gather pollen to meet the nutritional needs of the brood. A honey bee that is deliberately gathering pollen is up to ten times more efficient as a pollinator than one that is primarily gathering nectar and only unintentionally transferring pollen.

(A) Apis mellifera

The European honey bee (Apis mellifera) is an almost global species. Honey bees (Apis spp.) can be found pollinating plants throughout northern Europe and Africa (honey bees are native on both continents) and they are also common in the Americas where they were introduced by humans during the early colonization of the continents. Honey bees are best known for their role in the production of honey. In North America, many native bee species, as well as some wasps, are also important pollinators. The bumble bee (Bombus spp.) is among the most important pollinators of temperate zone plants

(B) *Apis florea*

The dwarf honey bee is the smallest of the honey bee species, and is about 10 mm long. It is reddish colored and the abdomen is red. All honey bees have the same general life history. A colony consists of one breeding female, the queen; up to several thousand males, the drones; and a large number of non-breeding females, the workers. Eggs are laid singly in a cell in the hive. Larvae hatch and undergo several moltings; they then turn into pupae. Pupae rest for several days and emerge as adult honey bees. After a queen hatches it goes on a mating flight, leaving the hive to mate with several drones. New colonies are created by swarming - a queen and a large number of workers leave the hive to locate a new nest site. The dwarf honey bee sends multiple swarms out throughout the spring and summer.

These honey bees are open-air nesters and create the smallest nest of all honey bees, consisting of a single comb. The nest is covered with layers of worker bees clinging to each other forming a living protective curtain. The dwarf honey bee is found in tropical forests, woods, farming areas, and even some villages. This species is primarily found in warm climates from Oman, Iran, and Pakistan, through the Indian sub-continent and Sri Lanka, east to Indonesia. Its primary distribution center is southeast Asia.

(C) *Apis dorsata*

These bees are between 17 and 19 mm long. They are yellow in color with black stripes on the abdomen. All honey bees have the same general life history. A colony consists of one breeding female, the queen; up to several thousand males, the drones; and a large number of non-breeding females, the workers. Eggs are laid singly in a cell in the hive. Larvae hatch and undergo several molting; they then turn into pupae. Pupae rest for several

days and emerge as adult honey bees. After a queen hatches it goes on a mating flight, leaving the hive to mate with several drones. New colonies are created by swarming - a queen and a large number of workers leave the hive to locate a new nest site.

The giant honey bee migrates seasonally back and forth throughout its range to escape harsh environmental conditions. It is believed that the giant honey bee has a fixed pattern in its annual migratory route. These bees are open-air nesters and they produce a single-comb nest. Nests may be found singly or in groups of up to 20 nests in the same tree. These bees are aggressive in defending the hive; 3/4 of the worker bees are involved in defense of the colony and form a living protective curtain. Most colonies abscond at the end of the summer.

(D) Bombus spp.

Bumble bees are social bees. This means that they live colonially in hives or in bee communities. In contrast, non-social or solitary bees usually build and live in individual nests rather than in a hive or with a colony of bees.

Over 50 species of bumble bees or humble bees (Bombus spp.), named for the humming sound they make while flying, occur throughout North America (Canada, the United States, and Mexico). Forty-four bumble bee species are known to be native to the United States and Canada (Natural History Museum, 2009). These bees are large and robust, and are generally black and yellow often with white or orange bands. They are covered in branched hairs that pick up and transfer pollen. Female bumble bees have pollen baskets or corbiculae - a broad concave shiny segment rimmed with long hairs and found on the back legs to learn more about bee anatomy). The pollen baskets are used to carry pollen back to the nest. Additionally, they have relatively long mouth parts and are able to pollinate plants with deep nectaries, such as the blueberry (Vaccinium spp.). Bumble bees engage in a behavior called sonication, or buzz pollination. The bee places the anther in its jaw and vibrates each flower with its flight muscles, causing pollen to be dislodged. Tomatoes (Lycopersicon spp., syn. Solanum spp.) require buzz-pollination and bumble bees are important pollinators of this crop.

Bumble bees are generalist foragers and do not rely on one particular flower type. They are important pollinators of several wild flowering plants and crops like blueberry, tomato, eggplant (Solanum melongena), and pepper (Capsicum spp.), which is also a member of the Solanaceae family. They are also effective pollinators of some orchard crops like

almonds (Prunus dulcis, syn. Amygdalus dulcis), apples (Malus domestica), and cherries (Prunus spp.). These bees are even considered better pollinators than honey bees (Apis mellifera) in some instances because bumble bees can fly during rainy, cool, cloudy, and windy weather and they have longer tongues than honey bees so they can pollinate flowers with long, narrow corollas or flowers.

(E) Wasp

Paper wasps are ¾ to 1 inch (1.9 to 2.5 cm)-long wasps that gather fibers from dead wood and plant stems, which they mix with saliva, and use to construct water-resistant nests made of gray or brown papery material. Paper wasps are also sometimes called umbrella wasps, due to the distinctive design of their nests or other regional variants such as Trinidad & Tobago's use of Jack Spaniard.

The name "paper wasps" typically refers to members of the vespid subfamily Polistinae, though it often colloquially includes members of the subfamilies Vespinae (hornets and yellowjackets) and Stenogastrinae, which also make nests out of paper. Twenty-two species of Polistes paper wasps have been identified in North America and approximately 300 species have been identified worldwide. The Old World tribe Ropalidiini contains another 300 species, and the Neotropical tribes Epiponini and Mischocyttarini each contain over 250 more, so the total number of true paper wasps worldwide is about 1100 species, nearly half of which can be found in the Neotropics.

The nests of most true paper wasps are characterized by having open combs with cells for brood rearing, and a petiole, or constricted stalk, that anchors the nest. Paper wasps secrete a chemical which repels ants, which they spread around the base of the anchor to prevent the loss of eggs or brood.

Most social wasps of the family Vespidae make nests from paper; although some stenogastrine species, such as Liostenogaster flavolineata, use mud. A small group of eusocial crabronid wasps, of the genus Microstigmus (the only eusocial wasps outside the family Vespidae), also construct nests out of chewed plant fibers, though the nest consistency is quite different from those of true paper wasps, due to the absence of wood fibers, and the use of silk to bind the fibers.

Unlike yellow jackets and hornets, which can be very aggressive, polistine paper wasps will generally only attack if they themselves or their nest are threatened. Since their territoriality can lead to attacks on people, and because their stings are quite painful and can produce a potentially fatal anaphylactic reaction in some individuals, nests in human-

inhabited areas may present an unacceptable hazard. Most wasps are beneficial in their natural habitat, and are critically important in natural bio-control. Paper wasps feed on nectar, and other insects, including caterpillars, flies, and beetle larvae, and they are often considered to be beneficial by gardeners.

II. Butterflies

Butterflies are important pollinators. However, many species of butterflies and moths have been declining, partially due to loss of migratory and nectar corridors. Over 200 species of butterflies and moths undergo some type of migration, and the loss of appropriate habitat the distance of the migration routes has led to declining populations. Attempts to reverse this trend are being made by local jurisdictions, conservation organizations, and federal agencies. Compared to bees, butterflies and moths are often less efficient at transferring pollen between plants because frequently pollen does not stick to their bodies and they lack specialized structures for collecting pollen. Butterflies and moths probe for nectar and prefer flat clustered flowers that they can use as a landing pad.

Butterflies and moths are members of the order **Lepidoptera**. Butterflies differ from moths in several aspects: butterflies fly during the day, possess clubbed antennae, are brightly coloured, and lack a frenulum (a wing coupling mechanism common in moths).

III. Beetles

Early beetles appear to have been among the primary visitors of primitive flowering plants. An improvement over wind pollination, beetles likely played an important role in the evolution of flowering plants. Odour, often foul or unpleasant, is thought to act as a primary attractant for many beetle and fly pollinators. Beetle-pollinated plants additionally produce heat. The odour may mimic a food source; the heat is thought to help spread the odour and provide a direct energetic benefit to pollinating insects.

IV. Hover flies

Hover Flies (known in America as Flower flies) belong to a large family of small to big flies. They are true flies or Diptera, with only one pair of wings in the Family **Syrphidae.** (Wasps and bees have two pairs).

Hoverflies have spots, bands or stripes, of yellow, brown against a dark-coloured background, sometimes with dense hair covering the body surface (emulating furry bumble

bees). Hovering is a specialty although other flies can also hover - the head of the insect remains absolutely still whilst in flight. They may be seen "Nectaring" on many wild and garden flowers where they are amongst the most frequent of visitors. In Holland and Belgium alone over 300 species exist!. In Britain About 270 species are known at present, but significant species and numbers can migrate like butterflies with powerful flight such as the Red admiral or Painted lady. The Marmalade Fly Episyrphus bateaus is one of the most common hoverflies to be seen in the garden. The distinctive double stripes on the abdomen make it almost unmistakable.

Many are seen in the summer season in number mixing with butterflies, bees, bumble bees and other flower dependent insects. Male Hovers tend to emerge and mature first, earlier in the season to ensure reproduction is successful. Many species are useful to the gardener since their larvae eat pest aphids on garden plants and crops. The degree to which they contribute to pollination is also ironically poorly investigated but no doubt are important for Carrot, Onion and fruit Trees.This group is a useful indicator for evaluating site ecology, being a day active, with a varied range of larval habitat specializations.

V. **Ants**

Ants are highly social insects and are often associated in one way or another with plants. Ants sometimes form mutualistic relationships with plants, which may benefit from ant predation on plant herbivores or seed dispersal by ants. However, there are relatively few examples of pollination by ants.

In some cases, ants actually appear to interfere with pollination, sometimes reducing plant reproductive output: they may consume nectar without providing the plant with any reproductive benefit; they are aggressive toward other insects, including pollinators; they can destroy floral tissue; and their secretions may reduce pollen viability. Some plants appear to have evolved means of minimizing ant visitation to their flowers.

1.2.2 Vertebrates

As many as 1,500 vertebrates act as pollinators, including mammals like fruit bats, primates, and marsupials, avian species like hummingbirds, white-winged doves, sunbirds, sugarbirds, and honeyeaters, and even some rodent and reptile species. However, of these vertebrate pollinators at least 82 mammalian and 103 avian pollinators are considered threatened or

extinct, according to the International Union for Conservation of Nature and Natural Resources (IUCN).

I. **Birds**

Birds, particularly **hummingbirds, honeyeaters and sunbirds** also accomplish much pollination, especially of deep-throated flowers. Other vertebrates, such as monkeys, lemurs, possums, rodents and lizards have been recorded pollinating some plants

II. **Humans**

Humans can be pollinators, as many gardeners have discovered that they must hand pollinate garden vegetables, whether because of pollinator decline or simply to keep a strain genetically pure. Tomato blossoms are self fertile, but (with the exception of potato-leaf varieties) have the pollen inside the anther, and the flower requires shaking to release the pollen through pores. This can be done by wind, by humans, or by a sonicating bee (one that vibrates its wing muscles while perched on the flower), such as a bumblebee. Sonicating bees are extremely efficient pollinators of tomatoes, and colonies of bumblebees are quickly replacing humans as the primary pollinators for greenhouse tomatoes.

1.2.3 General Anatomy of Hymenoptera

All insects have a hard exoskeleton, six legs, and three main body parts: the head, thorax, and abdomen. Bees, wasps, ants and sawflies are members of the Hymenoptera family and share several characteristics. All have four membranous wings, chewing or sucking mouthparts, compound eyes, and each undergoes complete metamorphosis. Bees, wasps, and ants are in the Suborder Apocrita. They are characterized by having a distinct waist - the first segment of the abdomen is incorporated into the thorax. Additionally, their larvae are maggot-like.

Bees and wasps are similar in many ways. However, there are differences between the two types of insects. One of the main differences is in the sting and how each injects its venom. Both bee and wasp stingers have barbs, or small backward-pointed hooks. The barbs allow the stinger to advance further into the victim. However, wasp barbs are smaller than bee barbs, allowing the wasp to extract the stinger from the victim and to sting again. Bee

stingers remain embedded in the victim and are ripped away from the bee's abdomen, causing it to die after stinging just once. Another difference between bees and wasps is bees have very hairy legs to aid in pollen collection. Wasps tend to have far fewer hairs (Fig. 1).

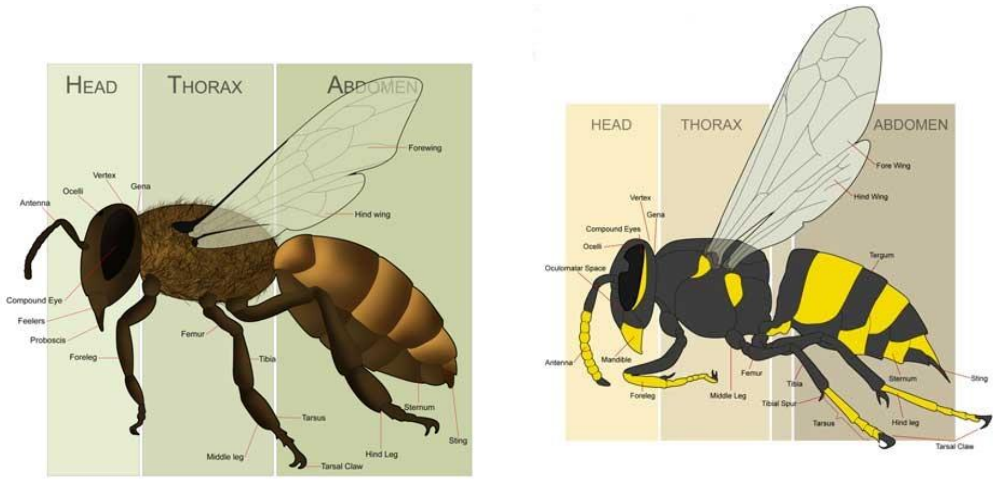


Fig 1. Morphology of Hymenoptera (Bees and wasp).

CHAPTER-2

REVIEW OF LITERATURE

2. Review of Literature

Pollination by wild animals is a key ecosystem service. To adequately evaluate the importance of animal pollination for plant products in our food supply, and for economic analysis of crop pollination by animals, we need a global review of crops considering their breeding systems, their flower visiting fauna and the level of production increase resulting from animal visitation and pollination, as supported by experimental evidences (Keven & Phillips 2001). Honeybee, mainly *Apis mellifera*, remain the most economically valuable pollinators of crop monocultures worldwide (McGregor 1976; Watanabe 1994; also shown for several single crops, e.g. Roubik 2002 for coffee in Panama) and yields of some fruits, seeds and nut crops decrease by more than 90% without these pollinators (Southwick & Southwick 1992). When wild bees do not visit agricultural fields, managed honeybee hives are the only solution for farmers to ensure crop pollination.

Kevan *et al.* (1998) illustrated that numerous countries have improved their orchard and crop yields by using and managing colonies of *Apis mellifera* L., but, in some cases, better results have been obtained working with more specialized bees to pollinate alfalfa, clover, and tomatoes. In Canada and the United States, the introduction of foreign bumble bees is prohibited and only local species are reared (Ruijter 1997). Even trans-continental movements are strongly discouraged. Pesticides seriously affect bees when foraging on flowering plants, and produce important effects on their populations.

Matheson *et al.* (1996) stated that although there are conclusive data that indicate 1200 wild vertebrate pollinators may be at risk, data on the status of most invertebrate species that act as pollination agents is lacking. Worldwide, nearly 200 species of wild vertebrate pollinators may be on the verge of extinction (Nabhan 1996), along with an untold number of invertebrate pollinators.

Pollinators and pollination are crucial in the functioning of almost all terrestrial ecosystems including those dominated by agriculture because they are in the front line of sustainable productivity through plant reproduction. Pollinators are bioinidicators as individuals and populations in that they can be used to monitor environmental stress brought about by introduced competitors, diseases, parasites, predators as well as by chemical and physical factors, particularly pesticides and habitat modification. Honeybees are useful as

samplers of the environments in which they are kept and have been used to assess atmospheric and other types of pollution. 21 Globally, over 100 species of birds and mammals in sixty genera of vertebrate pollinators are already listed as endangered, and untold numbers of invertebrates are at risk as well. In Costa Rica, wild bee diversity in degraded forest land dropped from 70 to 37 species in just 14 years. Population declines have also been confirmed for butterflies, moths, flying foxes and a host of other pollinators of food crops.

The risks to pollinator biodiversity in Canada are examined through a generalized model with inputs on environmental sensitivity, pressure indices, and societal response as they relate to the agriculture/environment interface. About 3,500 species of bees occur in America north of Mexico. Few genera are found in the USA and Canada that do not also occur in Mexico, however there are far fewer species in Canada. Canada has focused on the development on a few non-*Apis* species as well as the European honey bee as managed pollinators for specific crops with success for the alfalfa leafcutter bee, *Megachile rotundata*. The economic value of bee-affected pollination in Canada is great. Canadian agriculture depends mainly on four groups of bees, which are managed commercially for pollination of its crops. These are the honey bees, the alfalfa leafcutter bees, bumble bees and mason bees.

Pollination is vital process in plant reproduction and in quality seeds and fruit production of plant species including agricultural crops. More than 75 % of the world's principal crops and over 80% of all flowering plants are depending upon animal pollinators. Of this about 80 % of major food crops are pollinated by wild bees and other wildlife species. Only 15 % of food crops are pollinated by domestic bee species. Bond (1994) stated that the number of threats to pollinators has been identified. These include habitat alteration, introduction of alien pollinators, and pesticide poisoning.

Keeping in view, the importance of pollinators and its association for crop production and its impact of climatic change and global warning, further the study has been carried out in navdanya organic farm with the objectives.

Objectives

The main objectives of the study are:-

- *To assist the diversity pollinators in the Navdanya Farm.*
- *To identify the specific pollinators for specific crops.*
- *To identify the common pollinators of the farm.*

CHAPTER-3

STUDY AREA

3. Study Area

3.1 Organic Farm- Navdanya

The name Navdanya means Nine Seeds. This name was chosen because it connotes the agricultural practice of sowing nine varieties at one time. It was chosen because it evokes new life, and it evokes diversity. It was also chosen for its symbolic power. A symbol is not imposed from outside, but emerges organically from the shared wisdom of the community, serving to strengthen and inspire- seed represents the centuries-long accumulation of peoples knowledge and, as a reflection of the options open to them, it represents their choice.

Navdanya is a network of seed keepers and organic producers spread across 16 states in India. Navdanya has helped set up 54 community seed banks across the country, trained over 500,000 farmers in seed sovereignty, food sovereignty and sustainable agriculture over the past two decades, and helped setup the largest direct marketing, fair trade organic network in the country. Navdanya has also set up a learning center, Bija Vidyapeeth (School of the Seed) on its biodiversity conservation and organic farm in Doon Valley, Uttranchal, north India. Navdanya is actively involved in the rejuvenation of indigenous knowledge and culture. It has created awareness on the hazards of genetic engineering, defended people's knowledge from biopiracy and food rights in the face of globalisation and climate change. Navdanya is a women centred movement for the protection of biological and cultural diversity. Navdanya started as a program of the Research Foundation for science, Technology and Ecology (RFSTE), a participatory research initiative founded by Dr. Vandana Shiva.. Navdanya means nine crops that represent India's collective source of food security. The main aim of the Navdanya biodiversity conservation programme is to support local farmers, rescue and conserve crops and plants that are being pushed to extinction and make them available through direct marketing. Navdanya is actively involved in the rejuvenation of indigenous knowledge and culture. It has created awareness on the hazards of genetic engineering, defended people's knowledge from biopiracy and food rights in the face of globalisation. It has its own seed bank and organic farm spread over an ares of 20 acres in Uttarakhand, North India.

At Navdanya’s biodiversity farm in Doon Valley work on compiling a register has been underway for many years. This organic farm was started on land that had been desertified

with more than two decades of eucalyptus plantation and is now home to a rich variety of crops. More than twelve hundred varieties of plants now flourish on the farm, including five

hundred rice varieties, seventy-five wheat varieties, and diverse varieties of millets, pulses, oilseeds, vegetables, and medicinal plants. The farm's register serves as a record of these local indigenous varieties of indigenous knowledge. It also serves as a document for assertion of intellectual rights and as a seed catalogue from which interested individuals and groups can get access to organic seeds.

3.2 Major Crops Grown In The Study Area

The Navdanya farm supports organic farm and produces their own organic and indigenous seed. The farm has its own seed bank. The the crops grown in the the farm are pulses, vegetables, fruits, cash crops and fibre crops. Some of the common crops grown in the farm is listed below in the table.

S No.	CROP NAME	BOTANICAL NAME
1	Rice	*Oryza sativa*
2	Wheat	*Triticum aestivum*
3	Finger millet	*Eleusine coracana*
4	Foxtail millet	*Setaria italic*
5	Barnyard millet	*Echinochloa frumentaceum*
6	Little millet	*Panicum miliare*
7	Kodo millet	*Paspalum scrobiculatum*
8	Pearl millet	*Pennisetum typhoideum*
9	Proso millet	*Panicum miliaceum*
10	Buckwheat	*Fagopyrum esculentum*
11	Jowar	*Sorghum bicolor*
12	Maize	*Zea mays*
13	Rajma	*Phaseolus vulgaris*
14	Blackgram	*Phaseolus mungo*
15	Greengram	*Phaseolus radiates*

16	Rice bean	*Vigna umbellate*
17	Soyabean	*Glycine max*
18	Horsegram	*Dolichos biflorus*
19	Field bean	*Dolichos lablab*
20	Pigeon pea	*Cajanus indicus*
21	Lentil	*Lens esculenta*
22	Bengal gram	*Cicer arietinum*
23	Amaranth	*Amaranthus frumentaceous*
24	Chenopodium	*Chenopodium album*
25	Mustard	*Brassica spp.*
26	Sesame	*Sesamum indicum*
27	Niger	*Guizotia oleifera*
28	Safflower	*Carthamus tinctorius*
29	Castor	*Ricinus communis*
30	Radish	*Raphanus sativus*
31	Garlic	*Allium sativum*
32	Onion	*Allium cepa*
33	Potato	*Solanum tuberosum*
34	Elephant foot yam	*Amorphophallus spp.*
35	Bottle gourd	*Lagenaria sicenaria*
36	Bitter gourd	*Momordica charantia*
37	Cucumber	*Cucumis sativus*
38	Peas	*Pisum sativum*
39	Spinach	*Spinacea oleracea*
40	Pumpkin	*Cucurbita spp.*
41	Lady finger	*Abelmoschus esculentus*
42	Tomato	*Lycopersicon esculentum*
43	Brinjal	*Solanum melongena*
44	Water melon	*Citrullus vulgaris*
45	Coriander	*Coriandium sativum*
46	Fenugreek	*Trigonella foenum –graecum*
47	Ginger	*Zingiber officinale*
48	Chilli	*Capsicum spp.*

49	Turmeric	*Curcuma longa*
50	Basil	*Ocimum sanctum*
51	Sapota	*Achras sapota*
52	Subabul	*Lencaena lencocephala*
53	Cotton	*Gossypium herbaceum*
54	Sunn hemp	*Crotalaria juncea*
55	Flax	*Linum usitatissimum*

CHAPTER-4

MATERIALS AND METHODS

4.1 Collection of insects

Insect collecting is the collection of insects for hobby, scientific study or profit. Historically insect collecting has been widespread and a very popular educational hobby. Since most types of insects have hard exoskeletons that retain their appearance after the insects dies, it is easy and practical to form a collection. With many thousands of colorful and attractive species known, a collection may become quite large. The collecting of butterflies is perhaps most popular, with beetles in second place.

Insect collection was mainly done with the help of insect net. The insect collected with net was put to the killing bottle for killing the insects. After killing the insects it was stretched and dried for preserving. The chemical used in the killing bottle was benzene. For butterflies and moths the stretching board was used for the purpose of stretching. In case of syrphid flies, bees, wasps moths and butterflies pinning was done through thorax. Camera was used to taking the photographs of the pollinators as well as the birds.

The reading of the insects was taken every day during the dissertation period. The reading was taken four times in a day. The time chosen were 8:30 am, 11:30 am, 2:30 pm and 5:30 pm. The reading was taken on a particular crop everyday during the above mentioned time. Two quadrants were laid for taking the readings. The first quadrant was of 5m*5m and the other one was 1m*1m. In the first quadrants the number of plants or crops was counted and in the second quadrants in a particular plant or crop number of flowering buds was counted.

CHAPTER-5

RESULTS & DISCUSSIONS

The Following Results Have Been Derived From The Study Carried Out In The Dissertation Work:-

5.1 Identification and number of pollinators visiting the major crops of the farm

The study was carried out for the identification and calculation of the number of the pollinators of major crops of the farm. The major crops during the period of study were :- Mango (*Mangifera indica)*, Carrot (*Daucus carota*), Lime (*Citrus aurantifolia*), Camomile (*Matricaria chamomilla*), Fenugreek (*Trigonella foenum-graecum*) (Table 1).

Table 1- Pollinators visiting particular Crops.

S No	POLLINATORS	CROP NAME					
	ORDER WISE CLASSIFICATION	species	*Mangifera indica*	*Daucus carota*	*Citrus aurantifolia*	*Matricaria chamomilla*	*Trigonella foenum-graecum*
	Diptera						
1	Tachinid fly	*Hysticia abrupt*	-	2	-	2	-
2	Green bottle fly	*Lucilia sericata*	-	1	-	-	-
3	March fly	*Scaptia sp.*	-	1	-	-	-
4	Housefly	*Musca domestica*	-	14	12	1	-
5	Drone fly	*Eristalis tenax*	-	7	2	6	-
6	Flesh fly	*Sarcophaga spp.*	-	5	-	1	-
7	Lesser house fly	*Fannia canicularis*	9	2	-	-	-
8	Syrphid flies	*Simosyrphus grandicornis*	82	384	215	685	155
	Hymenoptera						
9	European bee	*Apis mellifera*	-	2	114	1	4
10	Rock bee	*Apis dorsata*	-	-	12	1	1
11	Dwarf bee	*Apis florea*	-	205	53	15	-
12	Wasp	*Polistes sp.*	-	8	2	-	-
13	Ant	*Camponotus spp.*	-	44	11	-	-
	Coleoptera						
14	Asian lady beetle	*Harmonia axyridis*	31	138	21	9	2
15	Altica (blue beetle)	*Montipora spp.*	-	2	1		
16	Orange beetle		-	25			
	Hemiptera						

17	Red cotton bug	*Dysdercus koenigii*	-	1	-	-	-
	Lepidoptera						
18	Cabbage white	Pieris brassicae	-	2	1	24	-
19	Mottled emigrant	*Catopsilia pyranthe*	-	4	-	1	2
20	Grass yellow	*Eurema daira*	-	1	2	6	-
21	Blue Glassy Tiger	*Tirumala limniace*	-	4	-	-	-

5.1.1 Common pollinators found in the Navdanya farm.

Table 2- Some of the common pollinators found in the navdanya farm is listed below wit there family and scientific name.

COMMON NAME	SCIENTIFIC NAME	FAMILY
Tachinid fly	*Hysticia abrupta*	Tachinidae
Green bottle fly	*Lucilia sericata*	Calliphoridae
March fly	*Scaptia sp.*	Tabanidae
Housefly	*Musca domestica*	Muscidae
Drone fly	*Eristalis tenax*	Syrphidae
Flesh fly	*Sarcophaga spp.*	Sarcophagidae
Lesser house fly	*Fannia canicularis*	Muscidae
Syrphid flies	*Simosyrphus grandicornis*	Syrphidae
European bee	*Apis mellifera*	Apidae
Rock bee	*Apis dorsata*	Apidae
Dwarf bee	*Apis florea*	Apidae
Wasp	*Polistes sp.*	Vespidae
Ant	*Camponotus spp.*	Formicidae
Asian lady beetle	*Harmonia axyridis*	Coccinellidae
Altica (blue beetle)	*Montipora spp.*	Chrysomelidae
Orange beetle	*Ischyrus quadripunctatus*	Erotylidae
Red cotton bug	*Dysdercus koenigii*	Pyrrhocoridae
Cabbage white	Pieris brassicae	Pieridae
Mottled emigrant	*Catopsilia pyranthe*	Pieridae
Grass yellow	*Eurema daira*	Pieridae
Blue glassy tiger	*Tirumala limniace*	Nymphalidae

Table 3- Major Pollinators in different crops

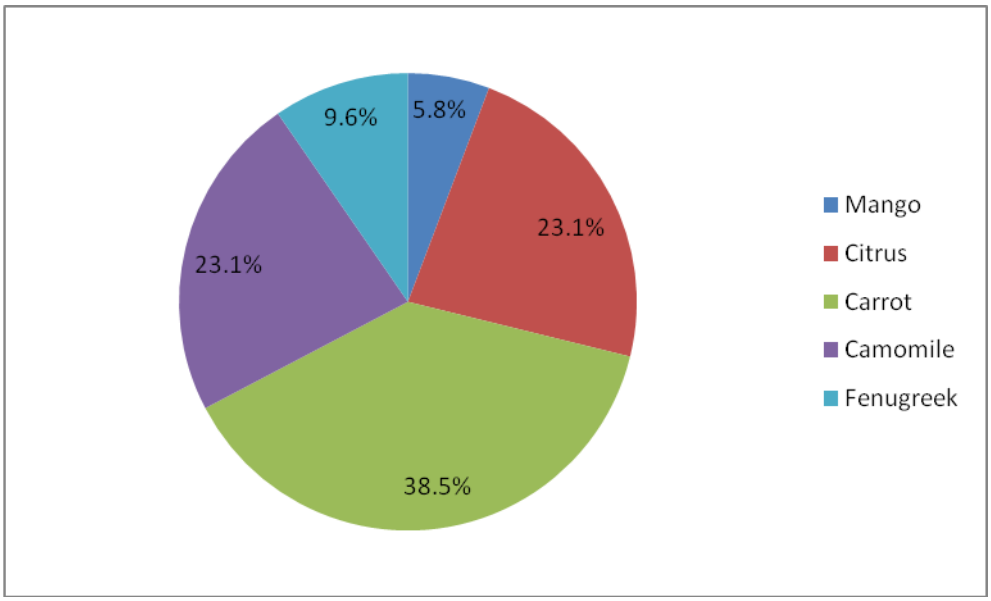
S No	Crop	Botanical Name	Family	Insect Species (No.)	Major Pollinators	Other Pollinators
1	Mango	*Mangifera indica*	*Anacardiaceae*	3	Syrphid Flies	Lady beetle
2	Citrus	*Citrus aurantifolia*	*Rutaceae*	12	Bees 3 spp.	Lady Beetle
3	Carrot	*Daucus carota*	*Umbellifereae*	20	Dwarf bees	Syrphid Flies
4	Camomile	*Matricaria chamomilla*	*Asteraceae*	12	Syrphid Flies	Bees and Butterflies
5	Fenugreek	*Trigonella foenum-graecum*	*Fabaceae*	5	Syrphid Flies	Bees and Lady Beetles

5.2 Identification of specific pollinators for each crop

Table 4- Percentage of Insects Species Pollinating Specific Crop

S No.	Crop	Botanical Name	Family	Insect Species (No.)	Total Insects	% of Insect Species
1	Mango	*Mangifera indica*	*Anacardiacea e*	3	52	**5.8**
2	Citrus	*Citrus aurantifolia*	*Rutaceae*	12	52	**23.1**
3	Carrot	*Daucus carota*	*Umbellifereae*	20	52	**38.5**
4	Camomile	*Matricaria chamomilla*	*Asteraceae*	12	52	**23.1**
5	Fenugreek	*Trigonella foenum-graecum*	*Fabaceae*	5	52	**9.6**

Fig.2



5.3 Classification of Pollinators according to the order:-

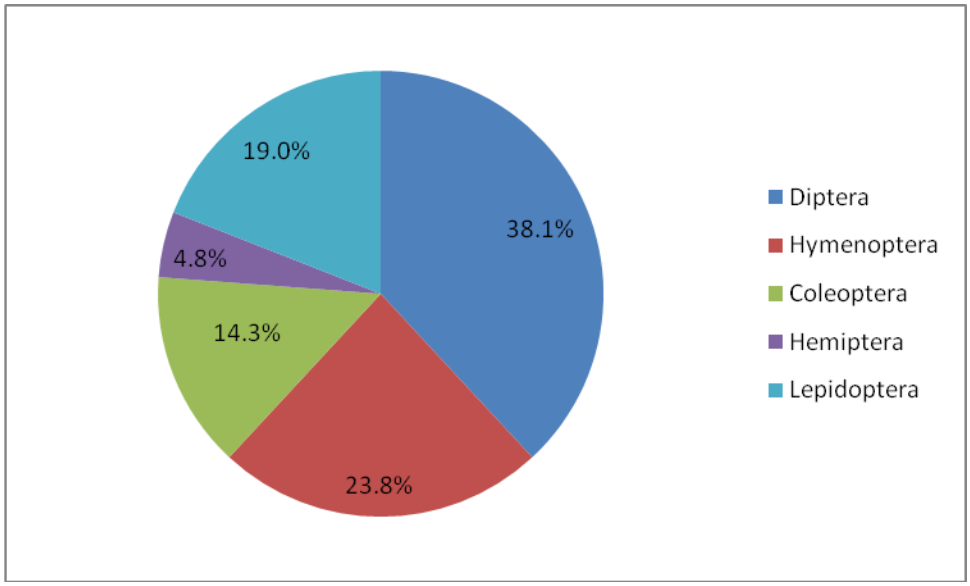
Table 5:

DIPTERA	HYMENOPTERA	COLEOPTERA	HEMIPTERA	LEPIDOPTERA
Tachinid fly	European bee	Asian lady beetle	Red cotton bug	Cabbage white
Green bottle fly	Rock bee	Altica (blue beetle)	-	Mottled emigrant
March fly	Dwarf bee	Orange beetle	-	Grass yellow
Housefly	Wasp	-	-	Blue glassy tiger
Drone fly	Ant	-	-	-
Flesh fly	-	-	-	-
Lesser house fly	-	-	-	-
Syrphid flies	-	-	-	-

Table 6: Percentage of Pollinators in each Order

ORDER	Species of Pollinators in each order	Total No. of Pollinator Species	% of Pollinator Species per order
Diptera	8	21	**38.1**
Hymenoptera	5	21	**23.8**
Coleoptera	3	21	**14.3**
Hemiptera	1	21	**4.8**
Lepidoptera	4	21	**19.0**

Fig.3



5.4 Crop having Maximum Pollinators % of pollinators per crop

Table 7.

POLLINATORS	*Mangifera indica*	*Daucus carota*	*Citrus aurantifolia*	*Matricaria chamomilla*	*Trigonella foenum-graecum*
Tachinid fly	-	2	-	2	-
Green bottle fly	-	1	-	-	-
March fly	-	1	-	-	-
Housefly	-	14	12	1	-
Drone fly	-	7	2	6	-
Flesh fly	-	5	-	1	-
Lesser house fly	9	2	-	-	-
Syrphid flies	82	384	215	685	155
European bee	-	2	114	1	4
Rock bee	-	-	12	1	1
Dwarf bee	-	205	53	15	-
Wasp	-	8	2	-	-
Ant	-	44	11	-	-
Asian lady beetle	31	138	21	9	2

Altica (blue beetle)	-	2	1	-	-
Orange beetle	-	25	-	-	-
Red cotton bug	-	1	-	-	-
Cabbage white	-	2	1	24	-
Mottled emigrant	-	4	-	1	2
Grass yellow	-	1	2	6	-
Blue glassy tiger	-	4	-	-	-
Total	**122**	**852**	**446**	**752**	**164**
%	**5.3**	**36.4**	**19.0**	**32.2**	**7.1**

5.5 Percentage of Individual Pollinators visiting the farm

Pollinators	***Mangifera indica***	***Daucus carota***	***Citrus aurantifolia***	***Matricaria chamomilla***	***Trigonella foenum-graecum***	**Total**	**%**
Tachinid fly	-	2	-	2	-	**4**	**0.17**
Green bottle fly	-	1	-	-	-	**1**	**0.04**
March fly	-	1	-	-	-	**1**	**0.04**
Housefly	-	14	12	1	-	**27**	**1.16**
Drone fly	-	7	2	6	-	**15**	**0.65**
Flesh fly	-	5	-	1	-	**6**	**0.26**
Lesser house fly	9	2	-	-	-	**11**	**0.47**
Syrphid flies	82	384	215	685	155	**1521**	**65.1**
European bee	-	2	114	1	4	**121**	**5.18**
Rock bee	-	-	12	1	1	**14**	**6.0**
Dwarf bee	-	205	53	15	-	**273**	**11.69**
Wasp	-	8	2	-	-	**10**	**0.43**
Ant	-	44	11	-	-	**55**	**2.35**
Asian lady beetle	31	138	21	9	2	**201**	**8.99**

Altica (blue beetle)	-	2	1	-	-	**3**	**0.13**
Oorange beetle	-	25	-	-	-	**25**	**1.07**
Red cotton bug	-	1	-	-	-	**1**	**0.04**
Cabbage white	-	2	1	24	-	**27**	**1.16**
Mottled emigrant	-	4	-	1	2	**7**	**3.0**
Grass yellow	-	1	2	6	-	**9**	**0.36**
Blue glassy tiger	-	4	-	-	-	**4**	**0.17**
						2336	**100**

PLATE-I

Dwarf Bee (*Apis Florea)*

European Bee (*Apis mellifera)*

Syrphid Fly (*Simosyrphus grandicornis*)

Asian Lady Beetle (*Harmonia axyridis*)

Wasp (*Polistes sp.*)

Common Sailor (*Neptis hylas*)

CHAPTER-6

CONCLUSION

The study was carried out in the Navdanya farm during the period of March to May in 2011. The study was done on the pollinators which pollinate the common crops of the farm. The study was carried out on Mango (*Mangifera indica*), Carrot (*Daucus carota*), Lime (*Citrus aurantifolia*), Camomile (*Matricaria chamomilla*), Fenugreek (*Trigonella foenum-graecum*).

The major pollinating species was found to be that of Syrphid flies (1521) followed by *Apis mellifera* (273) and *Apis florae* (121). The other pollinating species having the major role in pollination were Asian lady beetle, Rock bee, housefly and members of Lepidoptera.

It was observed that, Carrot (*Daucus carota*), has the maximum number of pollinating species diversity, that is, 20 species. The maximum numbers of pollinating species were also found in Carrot, that is, 852 which constituted 36.4 % of the total number of pollinators visiting the farm.

Though the number of the bee species was less in comparison with the Syrphid flies, in case of Carrot and Citrus spp. The pollination efficiency of the bees is more than flies. This is due to the presence of hairs on body, pollen comb, pollen basket present in the legs of the bees. Because of this the bees are considered as the major pollinators of Carrot and Citrus spp. in the farm.

While taking the reading, it has been observed that during the morning and evening sessions, diversity of Syrphid was very high. For example, in Carrot from 8 a.m. to 9 a.m., the number of Syrphid flies was very high and after that it starts declining, which was replaced by the high population of bees, then eventually the number of Syrphid flies increases again with the onset of dawn.

The highest population of the pollinators in the farm was found to be that of Syrphid flies which is, 65.1%, which was followed by dwarf bee, 11.69% and the Asian Lady beetle,8.99%. This high percentage of Lady beetle shows that the area is ecologically balanced and biological controlled as it is the indicator of the healthy environment.

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Common Birds Found In Navdanya Farm

Navdanya organic farm is very rich in bird diversity due to the nearby Sal forest which is in close proximity of the Rajaji National Park. Due to this the birds from the forest visits Navdanya farm as it has rich availability of food for the birds.

Some of the common birds found in the farm are listed below:-

S No.	Bird Species	Scientific Name	Distribution	Habitat
1	Green Bee-eater	*Merops orientalis*	Widespread resident	Open country, cultivation and villages
2	Common Myna	*Acridothres tristis*	Widespread resident	Human habitation
3	Black Drongo	*Dicrurus macrocercus*	Widespread resident	Human habitation
4	Jungle Babbler	*Turdoides striatus*	Widespread resident	Open forest
5	Rufous Treepie	*Dendrocitta vagabunda*	Widespread resident	Open forest
6	Himalayan Bulbul	*Pycnonotus leucogenys*	Resident Himalayas	Dry Scrubland
7	Spotted Dove	*Streptopelia chinensis*	All Indian Union excepting the arid northwestern parts	Open country, cultivation and villages
8	Rose-ringed Parakeet	*Psittacula krameri*	Widespread resident	Human habitation
9	Asian Koel	*Eudynamys scolopacea*	Widespread resident	Human habitation
10	Red-wattled Lapwing	*Vanellus indicus*	Widespread resident	Open country, cultivation and villages
11	Spotted Owlet	*Athene brama*	Widespread resident	Open country,

				cultivation and villages
12	Indian Grey Hornbill	*Ocyuros birostris*	Resident Himalayas	Open forest
13	White-throated Kingfisher	*Halcyon smyrnensis*	Plains and lower hills throughout India	Near water bodies, cultivation and villages
14	Shikra	*Accipiter badius*	Widespread resident	Open country, cultivation and villages
15	Black Kite	*Milvus migrans*	Widespread resident	Open country, cultivation and villages
16	Eurasian Thick-knee	*Burninus oedicnemus*	Widespread resident	Open dry forest
17	Rock Pigeon	*Columba livia*	Widespread resident	Sub alpine
18	Cattle Egret	*Bubulcus ibis*	Widespread resident	Open country, cultivation and villages
19	Purple Sunbird	*Nectarinia asiatica*	Widespread resident	Open forest
20	Crimson Sunbird	*Aethopyga siparaja*	Resident Himalayas	Moist-decidous and ever-green forest
21	House Crow	*Corvus splendens*	Widespread resident	Human habitation
22	Red-vented Bulbul	*Pycnonotus cafer*	Widespread resident	Open forest

PLATE-II

Black Drongo (*Dicrurus macrocercus*)

Jungle Babbler (*Turdoides striatus*)

Asian Koel (*Eudynamys scolopacea*)

Spotted Dove (*Streptopelia chinensis*)

Cattle Egret (*Bubulcus ibis*)

Green Bee-eater (*Merops orientalis*)

Spotted Owlet (*Athene brama*)

Red-wattled Lapwing (*Vanellus indicus*)

Eurasian Thick-knee
(*Burninus oedicnemus*)

Rose-ringed Parakeet (*Psittacula krameri*)

House Crow (*Corvus splendens*)

Common Myna (*Acridothras tristis*)

CHAPTER-7

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