SEASONAL CYCLE IN INDIAN INSECTIVOROUS BIRDS

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DOCTOR OF PHILOSOPHY IN ZOOLOGY

By

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SEPTEMBER, 2008

DECLARATION

I hereby declare that the thesis entitled '*Seasonal Cycle In Indian Insectivorous Birds*' submitted to the University of Calicut for the award of the Degree of Doctor of Philosophy in Zoology is a bonafide work done by me and that it has not been submitted earlier in part or in full to any other University for award of any degree or diploma.

Jansamma Thomas

Devagiri,
03-08-08

CERTIFICATE

This is to certify that the thesis entitle 'Seasonal Cycle In Indian Insectivorous Birds' submitted by Sr. Jansamma Thomas to the University of Calicut for the award of the degree of Doctor of Philosophy in Zoology is a bonafide record of the research work done by her under the supervision and guidance of Dr. V. J. Zacharias and myself. This has not been formed previously the basis for the award of any degree or diploma.

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CHAPTER 1

GENERAL INTRODUCTION

The survival of birds depend on the development of an efficient timing programme, permitting adjustments of important physiological functions to favourable periods of the year (Immelman, 1971). Reproduction, because of its heavy physiological demands is the most critical event that should be timed to a period of minimum stress on adults and maximum probability for the survival of the parents and the young. Moult and migration are the other important events in the annual cycle of birds. The main moult normally follows the breeding season whereas migration is fitted between moult and reproduction. This gives the required temporal separation of functions that compete for energy and food resources and ensures that each event in the life cycle occurs at the time that maximizes the chances of the survival of the individual (Jenni and Winkler,1994). The timing of reproduction, migration and feather replacement must be regarded as highly adaptive (Immelman, 1971).

Insectivorous Birds

Insectivorous birds feed their youg ones predominantly on insects. In the adult stage most of these feed on other types of food but during their breeding season they are primarily insect feeders. The adult birds change over to different types of food when there is fluctuations in the abundance of insects in the environment (Inozemtsev,1963).

Breeding Season

Reproduction is the part of the life cycle with the greatest environmental dependence. The total span of the breeding season for a bird species depends in part on the time required to raise a brood, the interval between destruction of a nest and re-nesting and the interval between the fledging of one brood and the start of another nest (Van Tyne and Berger,1976).

Annual differences in the start of egg laying which are controlled by factors such as temperature, precipitation, amount of sunshine, available food and condition of the habitat exist for a number of species. The date at which laying takes place each year is an important adaptation for breeding (Lack ,1968). Each species of bird, has presumably evolved the timing of its breeding so that it can raise many offsprings (Lack 1954). This view has been supported by subsequent researchers (Perrins, 1970). The response to external photofluctuations enables many vertebrates to breed at the period of the year when food for the young is more plentiful (Marshall, 1961). The characteristics of the geographical area also act as an important factor in the breeding of birds (Moreau,1950).

In the temperate zone most migratory birds begin to nest shortly after their return to the breeding grounds in spring. But in tropics, where majority of species are non-migratory, some species nest during every month of the year. There is a pattern but cannot be explained by reference to any single stimulus. If any autonomic or climatic cycle tends directly to

stimulate the reproductive activities of birds, their action is so weak that any species which finds conditions particularly favourable for reproduction at some divergent seasons of the year may escape its control (Skutch, 1950a). The studies on Central American birds showed that some nests were found in each month of the year bur 80% of the nests were found during a period when food appeared to be abundant for the majority of the species (Skutch,1950 b). Annual differences in the initiation of the nesting season for some of these species are correlated with annual fluctuations in rainfall, but others appear to be independent of this factor. Dependency on a particular food supply partly accounts in for the nesting of certain species at other times of the year (Van Tyne and Berger, 1976). The age of the bird act as a minor factor modifying breeding dates, as individuals laying for the first time usually do so a little later than older ones (Lack,1968). Birds like Sooty Tern *Sterna fusca* do not exhibit annual cycles as the individuals cycle depends on success or failure of its nesting attempts. (Van Tyne and Berger, 1976).

Moult in Birds

Moult is the periodic replacement of feathers, proceeding in a regular replacement on each tract and usually occurs at the end of the breeding season, after reproductive activities have been completed. In birds with two moulting per year the second one also often takes place outside the breeding season. A bird's energy is so "budgeted" that moulting being fitted into rather short periods or in other cases, distributed over a

considerable period of time (Palmer, 1972). The control of the time and rate of moulting is important in the lives of birds. The adaptive significance of periodic moult is related to the wear and tear of the plumage as birds usually moult before their feathers are excessively worn. The separate scheduling of moult and breeding has been recognized as an ecological adaptation permitting these events to co-exist in the annual cycle with a minimum energetic stress.

In majority of birds in high latitudes and tropics, there is no overlap of moult with the breeding activity. Moult may be temporarily arrested in birds with seasonal or prolonged periods of moult, during a period of nesting and neighboring feathers are not dropped until breeding has been completed (Payne, 1972).

Moulting, breeding and migration are events that are essentially exclusive in time; many fascinating adaptive compromises have developed between moult and other phases of annual cycles (Stressmann and Stressmann, 1966). Physiological basis of control of the time and rate of moulting and integration of moult into the annual cycle are of considerable interest and their discovery remains as a challenge to comparative physiologist (Payne, 1972).

Primary Moult

Primary moult is the shedding and replacement of the primary feathers. The flight feathers attached to the hand (manus) are called the primary feathers (Van Tyne and Berger,1976).Their number is constant

within most bird groups and are renewed annually. Most of the members of order Passeriformes (passerines) have ten primaries but the tenth or outermost primary is much reduced. Primary moult is symmetrical and orderly in most birds commencing from the first which is the innermost primary and ending with the tenth or outermost (Naik and Naik,1965; Newton,1966; Middleton,1977). It may be a slow process shedding one feather at a time from first to last (Newton, 1967) or all are dropped within a few days of each other (Birkhead and Taylor, 1977).

SCOPE OF THE STUDY

Seasonal cycles of birds including breeding, moult and migration have been studied extensively in Australia, Africa, Europe, North America and Indonesia in Southeast Asia. But no detailed studies have been carried out on the subject in India in spite of its rich avifauna. Some studies on the endocrine/testicular cycles of birds have been carried out in recent years at Baroda (Ambadkar and Chauhan,1976; Naik and Razack,1967) and at Varanasi (Chaturvedi and Thapliyal,1980; Kumar and Tewary,1982). There are only a few original field studies on the subject in India (Price,1979; Gaston *et al*.,1979;Gaston,1981). This subject is one in which the amateur ornithologist can make substantial contribution in the field and by means of captive birds (Marshall,1961). Kerala, with a number of amateur ornithologists, can hence collect valuable information on the subject. Information on breeding including the seasons and habitat requirements are necessary for conserving birds. Similarly there is immense potential for a

study on moult of birds, a topic received little attention in South India and the mainland as a whole. Information on moult and migration are also important in formulating conservation action plan for species especially those which are endangered. Since an extensive study in the mainland is not feasible in a short time, available information from different parts of the country has been reviewed and analysed along with the data collected from Kerala in recent years. The study is expected to provide motivation for further studies on this little studied topic.

OBJECTIVES OF THE STUDY

Indian mainland experiences a variety of tropical and subtropical climates differing in their rainfall and temperature regimes. The timing of breeding season for insectivorous passerine birds differs among geographical areas. The present study has been undertaken with the following main objectives

1. To analyse the trends in the breeding of different species of insectivorous birds.
2. To compare the breeding season of prevalent species of insectivorous birds in the different bio-geographic regions of India.
3. To study the influence of rainfall on breeding species.
4. To collect information on timing and pattern of primary moult from different regions of the Indian mainland.
5. To compare the breed-moult interrelationship of prevalent species in different regions in India.

CHAPTER 2

REVIEW OF LITERATURE

Breeding in birds

Long-term studies on breeding seasons of birds have been carried out in temperate and tropical zones; only the major ones are mentioned here. Lack (1954;1968) emphasized food as an important factor in breeding based on his studies in England. Moreau (1950) discussed the influence of geographic areas in breeding by comparing different areas in Africa. Based on his studies in Central America, Skutch (1950a,1950 b) mentioned food as a major factor though there were others. In the desert regions of Australia, Keast and Marshall (1954) found precipitation as an important stimulus for breeding. Seasonal breeding in Indonesia in Southeast Asia was discussed by Voous (1950). Perrins (1970) reviewed the factors controlling breeding season.

The Indian mainland harbours about 1200 species of birds, which is about 15% of the total number of bird species in the world (Ali and Ripley,1987). In spite of its rich fauna very few studies have been carried out on the breeding biology of birds of the mainland. The only available information on the subject was provided by early naturalists, like Jerdon (1863; 1864), Hume (1879) and Whistler (1915). The four volumes “Nidification of birds of the Indian empire by Baker (1932; 1933;1934;1935) is a classical work on the topic. Notes on breeding of

birds documented by several bird watchers were included in ‘Handbook of birds of India and Pakistan’ published by Ali and Ripley (1987). ‘A bibliography of ornithology of the Indian mainland for the period 1772-1992’ compiled by Burg *et al*. (1994) includes all the ornithological information published during that period.

The following is a list of publications on the breeding biology of Indian birds published till date in various regions. Most of those listed by Burg *et al*.(1994) is not included in the bibliography to reduce its size. Date of egg-laying and other aspects of breeding of birds in the Himalayas and adjacent areas were described mostly by Binham (1880), Inglis (1901), Whitehead (1910), Hopwood (1912), Magrath (1912), Jones (1916), Osmaston (1927), Price and Jamdar (1990), Zahlre, *et al*. (1998),Wesley (1999) and Sharma (2005).

Breeding data of Punjab, Delhi and other semi-arid regions were provided by Curie (1916), Jones (1920), Whistler (1923), Edwards (1926), Parasharya (1982), Green (1986), Monga and Naoroji (1999), Kacher (2000), Bhargava (2001) and Lal (2003).

Data from Western Ghats include those of Davidson (1882), Neelakantan (1932), Betts (1952), Ambedkar (1976), Shukkur (1978), Johny (1990), Nair (1995), Zacharias (1997), Santharam (1998),Gokula (2001), Katdare,*et al*. (2004) and Prasad (2005).

Breeding records from Northeast India were provided by Inglis (1877), Stevens (1914), Betts (1947), Deka and Bhattacherjee (1990),

Robson (2001), Das and Bayan (2005).

Informations on nidification of birds of Deccan Peninsula waerecollected by Davidson and Wenden (1872), Wright (1942), Briggs (1956), Holmes and Wright (1964), Rangaswamy and Sridhar (1993), Quader (2004), Santharam (2004), Thejaswi (2004) and Van Guisen (2004).

Breeding data for birds of the Indian Desert were provided by Barnes (1886), Shivrajkumar (1962), Rana and Idris (1986), Rahmani (1997), Sharma (1997), Singh (2000), Sood (2001), Sangha and Naoroji (2004) and Tehsin *et al*. (2005)

Ornithological documentations for the Gangetic plain was made by Cripps (1872), Osmaston (1913), Dutt (1932), Briggs (1934), Dasgupta and Bhattacharyya (1988), Urfi and Jethua (1998) and Jha (2001).

Breeding data of Eastern Ghats were provided by Ali and Whistler (1932), Whistler and Kinnear (1933), Price (1979), Santharam (1996) and Mishra (2000).

Primary Moult

Important moult studies include those of Snow and Snow (1964) and Snow (1969) who compared the process in passerine and non passerine birds. Pattern and tempo of primary moult was studied by Newton (1966), Zeidler (1966), Palmer (1972), Netto and Gosler (2006). The classical work is by Stressmann and Stressmann (1966) who studied the factors controlling moult. Ashmole (1962) and Newton (1966;1967), proposed a

system to record the progress and state of moult using scoring system, Yuri and Rohwer (1997) explained the rules of primary feather replacement and Evans (1966) who reported the eccentric moult, are worth mentioning. Other studies worth mentioning include those of Payne (1969; 1972), Zann (1985), Earle (1988) and Gwinner (1996). Different stages of moult breed interrelations were observed by Payne (1969), Hemborg (1999), Hulley *et al*.(2004) while simultaneous breeding and moult were observed by Wilkinson (1983) and Craig (1983). Moult breeding overlap during second breeding season and moult interruption was reported by Greenwood (1983) and Hall (2001). Effect of food deprivation on moult was studied by Swaddle and Witter (1997).

In the Indian mainland, moult was studied only with a few species. At Baroda in Gujerat, moult of House Swift, House Sparrow, Starlings and the Jungle Babbler were studied. Time and duration of primary moult in House Swift was studied by Naik and Naik (1965) and Naik and Shivnarayan (1969), in the Jungle Babbler by Naik and Andrews (1966), in the House Sparrow by Mathew and Padmavati (1985) and Mathew and Naik (1986). In North India, Gaston (1981) studied the seasonal breeding and moult of birds at Delhi and found that availability and abundance of insect influences breeding and moult. In South India, Shukkur (1978) studied the moult of Black Drongo, *Dicrurus adsimilis* at Calicut; Johny (1990) studied the moult of Magpie Robin *Copsychus saularis* at Trichur. These two studies showed that there is a clear separation of breeding and

moult periods in Black Drongo and Magpie Robin. Zacharias, *et al*. (1994) studied the moult of Babblers (*Turdoides* spp) at Calicut, and found that breeding and moult overlap in them. Balachandran *et al*. (1995) studied the moult of Bulbuls (*Pycnonotidae*) at the Thirupthi hills. Balachandran (1999) studied the moult of birds at the Palani hills where he found complete separation of breeding and moult periods in the species he studied. Moult-breeding interrelations were studied by Gaston (1981) and Mathew and Naik (1986)

Seasonality and species diversity of insects which form the main food of insectivorous birds was discussed by Wolda (1988), Gadagkar *et al*.(1990), Reddy and Venkataiah (1990), Ananthakrishnan (2000), Murakami (2002) and Arun and Vijayan (2004).

CHAPTER 3

MATERIALS AND METHODS

Bio-geographic regions of India

India constitutes a major part of the Oriental realm, with wide latitudinal (08°04' to 37°60ˈN) and longitudinal (68°07'to 97°25ˈE) extents, and is situated within the tropical monsoon belt (Sharma *et al*.,2004).

The Indian mainland could be divided into ten bio-geographic regions (Rodgers and Panwar,1988) and these bio-geographic regions were considered for this study.

1. Trans-Himalayan region:- Consists of Ladakh in Jammu and Kashmir, Lahul-Spithi in Himachal Pradesh and small areas of Sikkim.
2. Himalayan region: - Consists of four subregions: 1) Northwest Himalaya which extends from Kashmir to the river Sutlej in Himachal Pradesh. b) Western Himalaya which comprises Garhwal and Kumaon and includes eight hilly districts of Uttaranchal. c) Central Himalaya, most of the regions fall in Nepal and d) Eastern Himalaya which includes kingdom of Bhutan and Indian states of Sikkim and Arunachal Pradesh (Fig 2.1).
3. Northeast India**:-**Consist of states of Assam, Meghalaya, Manipur, Missoram, Nagaland and Tripura.

4. Indian Desert**:-**Indian Desert covers nearly 12% of land, most of which is located in the state of Rajasthan. In the north it extends into Punjab through Ferozpur, Sangrur and Bhatinda districts and in the Northeast it joins with desert areas of Haryana in parts of the Mahendragarh and Hissar Districts. The Aravally mountains, starting from Champanur in north Gujarat and extending up to Delhi form the eastern boundary. In the west are the Thar-Parkar, Cholistan and Thal deserts of Pakistan. In the South, it extends into Gujarat mainly in the Kutch, Mehsana and Banaskantha districts and to some extend in the Saurashtra region.
5. Semi-arid region:- It consists of the Deccan plateau in Central India, Malwa plateau in Northwest India, and Saurashtra region in Gujarat. The Semi-arid region merges with the Desert on the western side and with the Gangetic plain in the north. The Semi-arid region occurs in eastern Rajasthan, Gujarat except Kutch, western Madhya Pradesh, parts of Uttar Pradesh, Haryana, Punjab and Southern parts of Jammu and Kashmir.
6. Western Ghats**:-** Western Ghats on the northwest coasts of India extends from the river Tapthi in the north to Kanyakumary in the South. Except for 25 km. Palghat gap, the Western Ghats stand unbroken, but the peaks vary greatly. It consists of a chain of ancient mountains parallel to the west coast of the Indian peninsula and occupies only 5% of India’s land area (about 13,2604 sq.km.).

7. Deccan peninsula:- Deccan peninsula has five divisions. Deccan plateau north, Deccan plateau South, Eastern high lands, Chhota Nagpur and Central high lands. The Northern plateau is very dry. Eastern highland is a small province and it also consists of Eastern Ghats and moist hills and valleys of Chattisgarh-Dandakarunya area. Central highland includes both Vindhya and Satpura hill ranges. Southern Deccan plateau falls in states of Karnataka, Andhra Pradesh, Tamil Nadu and Kerala and possibly Orissa. The Central Indian forests include Eastern Madhya Pradesh, Northwest Maharashtra and Northwest Orissa.
8. Eastern Ghats: It spreads through Orissa, Andhra Pradesh and Tamil Nadu. They extend over a length of 1,750 km. between the river Mahanadi in the North and Vaigai in the South along the east coast of India. Northern boundary is Mahanadi basin and Southern boundary is the Nilgiri hills. In the west it merges with the tips of Basthar, Telungana and Karnataka plateau and Tamil Nadu uplands, while coastal area in the east limits its eastern part. The Middle Eastern Ghats extends from the river Krishna to near about Chennai, including the Nallamalai, Palakonda, Velikonda-Seshachalam hills. South Eastern Ghats run towards the Western Ghats and meet in the Nigiris.This section includes the Javadi hills, the Kollimalai, the Pacchamalai, the Kalrayan, the Shevrois and the Biligirirangan Hills.

9. **Gangetic plain**:-It includes regions adjacent to Terrai-Bhabar tracts in Uttar Pradesh, Bihar and West Bengal.

10**. Coastal areas –**Includes the Coastal areas of different states.

Climate of Indian Bio-geographic Regions

Wide difference in terrain makes for a wide variety of climatic conditions in the Indian mainland. It's varied topography, considerable insolation, and monsoon climate, imparts to it enormous complexity and habitat diversity (Sharma *et al*., 2004). Though it experiences four climatic seasons, there is much variation in the intensity and extend of climatic features in different geographic regions, which has its effect on the biotic life (Banerji, 1952). Therefore it is possible to study the breeding biology of a wide range of birds in similar habitats and of similar/same species in diverse habitats providing an excellent opportunity for simultaneous analysis of various ecological factors.

Summer in Northwest India extends from April to July and in the rest of the county, from March to June. Hottest month for the western and southern region is April while for the northern region it is May (Banerji,1952). South-West monsoon strikes Kerala coasts and the far northeast by late May or by first days of June as a torrential current and produces heavy rain. It moves north and northeast bringing rain on its way. It reaches Mumbai and Kolkata between 5^{th} and 10^{th} of June (Fig 2.2). But when it approaches the northern parts of India like Kashmir by the middle of July, most of its moisture would have been lost and produces only feeble

rain. Much difference occurs in the intensity of rain between different regions of India (Siddhartha, 1999). South-West monsoon rain begins to retreat from the northwest parts of India in the beginning of September and usually withdraws completely by mid-October. But rain continues in the Southern peninsula and in the Southeast India and about half the annual rain, falls between October and mid December due to Northeast monsoon. In most of the northern part of the mainland there is generally clear, dry weather in October, November and early December (Grimmet *et al*.,1999). In Himalayas peak rainfall occurs in winter (December to March) and the monsoon rains comprise only little of the total rainfall in Trans-Himalayas (Padmanabhan and Yom-Tov,2000). There is considerable variation in monthly mean rainfall of different bio-geographic regions (Table 3.1).

METHODS OF STUDY

STUDY OF BREEDING

Breeding data were collected for insectivorous birds belonging to order Passeriformes, Galliformes, Charadriiformes, Cuculiformes, Caprimulgiformes, Apodiformes, Coraciformes and Piciformes. Majority of insectivorous birds for which breeding data collected belong to order Passeriforms under families of Pittidae, Alaudidae, Hirundinidae, Laniidae, Oriolidae, Dicruridae, Artamidae, Sturnidae, Corvidae, Campephagidae, Irenidae, Pycnonotidae, Muscicapidae, Paridae, Sittidae, Motacillidae, Dicaeidae, Nectariinidae, Zosteropidae, Fringillidae and Emberizidae. Breeding data were collected for non-passerine families of insectivorous

birds like Apodidae belonging to order Apodiformes, Caprimulgidae of order Caprimulgiformes, Charadriidae of order Charadriiformes, Cuculidae of order Cuculiformes, Phasianidae of order Galliformes, Alcedinidae and Meropidae of order Coraciformes and Picidae of order Piciformes.

Data collection

a) From the field:-Bird watching was conducted in the field using 8 x 40 binoculars, at Calicut, Pariyaram of Kannur District and Pala of Kottayam District for a period of three years (2003-2006). Data on the seasonal distribution of breeding activities were collected from the following sources:(1) nests found with eggs, young or brooding adults (2) birds carrying nest materials (3) fledglings just out of the nest fed by parents and (4) hole nesting birds regularly entering nesting holes. Information from amateur bird watchers were also collected.

b) Breeding data from Ornithological Publications:- Part of the data from Kerala and the whole data from other parts of the mainland were collected from different ornithological publications from libraries of Bombay Natural History Society,Mumbai, Zoological Survey of India, Kolkatta,Salim Ali Centre for Ornithology and Natural History, Coimbatore and Kerala Forest Research Institute, Peechi. Articles and short notes of publications reviewed in the 'Hand book of birds of India and Pakistan' (Ali and Ripley,1987) and 'Ornithology of the Indian Mainland-1872-1992 an annotated Bibliography' (Burg *et al*.,1994) were referred.

From the breeding data obtained, dates of egg laying were calculated, when not given directly; most passerines take 4 to 6 days to complete nest building and 13 to 14 days for hatching of eggs and another 13 to 14 days for the chicks to leave the nests. Egg laying dates of each species from different bio-geographic regions of India were calculated.

Analysis of Breeding Data

Breeding data from different sources were analysed. Only a few records of breeding were obtained from Trans-Himalayan region and Indian Coasts. So data from these regions were considered along with the data of the adjacent bio-geographic regions. The bio-geographic regions from which breeding data collected were Deccan Peninsula, Indian Desert, Eastern Ghats, Gangetic Plain, Himalayan Region, Northeast India, Semi-Arid Region and Western Ghats.

Breeding data of species, which enjoy prevalent distribution and found in four or more bio-geographic regions (prevalent species) and those restricted to one to three bio-geographic regions (restricted species) were analysed separately. Numbers of species laying eggs in each month were found out for the total species as well as for prevalent species. Percentages of species laying eggs in each month were compared. Months of egg laying initiation were studied for prevalent species. Peak time for egg-laying was also found out for each region.

Percentages of prevalent species breeding each month in a bio-geographic region were graphically related to the monthly rainfall of that

region. Since mean rainfall varies locally in a bio-geographic region, only rainfall of a sample locality is compared with percentage of breeding species of that region (Padmanabhan and Yom-Tov, 2000).

Breeding data of prevalent species like Common Myna, House Crow, Black Drongo, Jungle Babbler and Redvented Bulbul from each bio-geographic region were analysed to get the period of egg laying in each.

Breeding season of species restricted to Western Ghats and Himalayan region were also analysed.

STUDY OF PRIMARY MOULT

Primary moult studies of insectivorous birds were carried out at Bombay Natural History Society and Zoological Survey of India, Kolkatta. Preserved bird skins in the museums of these institutions were used for the study. Both wings of each specimens of a species were checked to find any primary feather under moult. Birds showing signs of primary moult were from those collected between 1902 and 1985.

The primary feathers which are replaced first in the moult series are the 'Nodal feathers' (Yuri and Rohwer,1997). These are more fully grown than the adjacent feathers. 'Terminal feathers' are those replaced last and are always less fully grown than adjacent feathers. Other growing feathers provide directional information showing whether replacement proceeds proximally to distally or distally to proximally.

Study of primary moult using museum specimens were done earlier in Dunlins (Greenwood,1983) and in Grey Vireo (Voelker, 2000).Each

primary feather was represented by the notation'H'. The first primary feather 'H1' is considered as the 'nodal feather' as it would be dropped / replaced, first. Subsequent primaries would be dropped in the order until the tenth 'H10' is reached. This sequence would indicate proximal to distal replacement of primaries and because 'H10' is dropped last, it is the 'terminal feather' in the series.

Using forceps and needle all the primary feathers on both wings of each bird were checked to find signs of moult. Sequencial order of old, missing, growing and new feathers were carefully noted down (Newton,1966). Dates of collection of birds with moulting primaries were copied down from the label attached to each speecimen. Primary moult data were analysed to get the pattern of moult in North and South Indian regions of the same species as well as related species. Season and duration of moult were analysed for all species selected for study.

Breed-moult interrelationship were studied in insectivorous species of North and South Indian regions. Breeding data were collected for the species in which primary moult were studied. Monthly breeding data of these species were collected mainly from the ornithological publications. Part of the breeding data of local birds were collected from the field. These data were pooled to get the breeding season of each species. The data were analysed to the get the season of breeding and moult in each species. Extend of breed-moult overlap and moult arrest was also studied.

STATISTICAL ANALYSIS

Monthly breeding data of common birds were compared using bar diagrams.

Correlation analysis : It was done to find the degree of correlation between the monthly average rainfall and the number of species laying eggs in each bio-geographic region. Monthly rainfall (mm) and percentage of species laying eggs were taken as the independent and dependent variables. Using the formula

$$r = \frac{\sum xy}{\sqrt{\sum x^2 y^2}}$$

the coefficient of correlation was calculated for each region. The data of rainfall published by Meteorological Department of India, Poona (2006) were used for the purpose. Percentages of species breeding each month were related to rainfall graphically using line and bar diagrams.

Pimm's method: It was adopted for calculating the duration of moult. This method is less flawed than the regression methods for estimating duration of moult because it overcomes the problem of heteroscendasticity in moult data (Underhill and Zucchini,1998). Primary moult data of individual bird was consolidated to get the time of moult initiation and termination of the population. From this duration of moult was calculated for each species.

Table 3.1 Monthly rainfall (mm) in different bio-geographic regions of Indian mainland during 2006

Months	Bio-geographic regions							
	Deccan Peninsula	Indian Desert	Eastern Ghats	Gangetic Plains	Himalayan region	Northeast India	Semi-arid region	Western Ghats
	Hyderabad	Jaipur	Bhuvaneshwar	Patna	Srinagar	Gawhati	NewDelhi	Calicut
Jan	3.2	7.9	12.4	18.9	56.5	11.4	20.3	9.2
Feb	5.2	11.7	24.2	10.7	64.9	12.8	15	7.2
Mar	12	6.1	24.2	11.4	98.5	57.7	15.8	18.2
April	21	4.1	21.8	7.6	87.5	142.3	6.7	88.4
May	37.3	16.2	55.5	33.3	71.9	248	17.5	279.6
June	96.1	66	196.4	134.2	37.2	350.1	54.9	903.6
July	163.9	216.3	325.3	305.8	48.7	353.6	231.5	940.9
Aug	171.1	231.2	329.5	274.4	69.7	269.9	258.7	494.4
Sept	181.5	80.3	287.6	226.9	33.3	166.2	127.8	260.4
Oct	90.9	22.6	208	93.8	36.4	79.2	36.3	249.3
Nov	16.2	3.2	37.4	8.9	27	19.4	5	146.2
Dec	6.1	3.3	5.5	4.1	43.3	5.1	7.8	33.5

*Data source-Meteorological Department of India, 2006

Table 3.2 Species selected for the study of Primary Moult

Sl.No	Species Studied	Family	Distribution
1	*Acridotheres fuscus*	Sturnidae	North India
2	*Acridotheres tristis*	Sturnidae	North and South India
3	*Sturnus contra*	Sturnidae	North India
4	*Sturnus malabaricus*	Sturnidae	North and South India
5	*Dicrurus adsimilis*	Dicruridae	North and South India
6	*Dicrurus paradiseus*	Dicruridae	North India
7	*Dicrurus caerulescens*	Dicruridae	North India
8	*Dendrocitta vagabunda*	Corvidae	North and South India
9	*Corvus splendens*	Corvidae	North and South India
10	*Corvus macrorhynchos*	Corvidae	North and South India
11	*Oriolus xanthornus*	Oriolidae	North and South India
12	*Oriolus oriolus*	Oriolidae	North India
13	*Lanius excubitor*	Lanidae	North India
14	*Lanius schach*	Lanidae	North and South India
15	*Lanius tepronotus*	Lanidae	North India
16	*Pycnonotus cafer*	Pycnonotidae	North and South India
17	*Pycnonotus jocosus*	Pycnonotidae	North India
18	*Turdoides caudatus*	Muscicapidae	North and South India
19	*Turdoides malcolmi*	Muscicapidae	North India
20	*Turdoides striatus*	Muscicapidae	North and South India
21	*Pomatorhinus schisticeps*	Muscicapidae	North and South India
22	*Garrulax jerdoni*	Muscicapidae	South India
23	*Garrulax pectoralis*	Muscicapidae	North India
24	*Garrulax striatus*	Muscicapidae	North India
25	*Garrulax albogularis*	Muscicapidae	North India

Fig 3.1 India - Biogeographic Regions

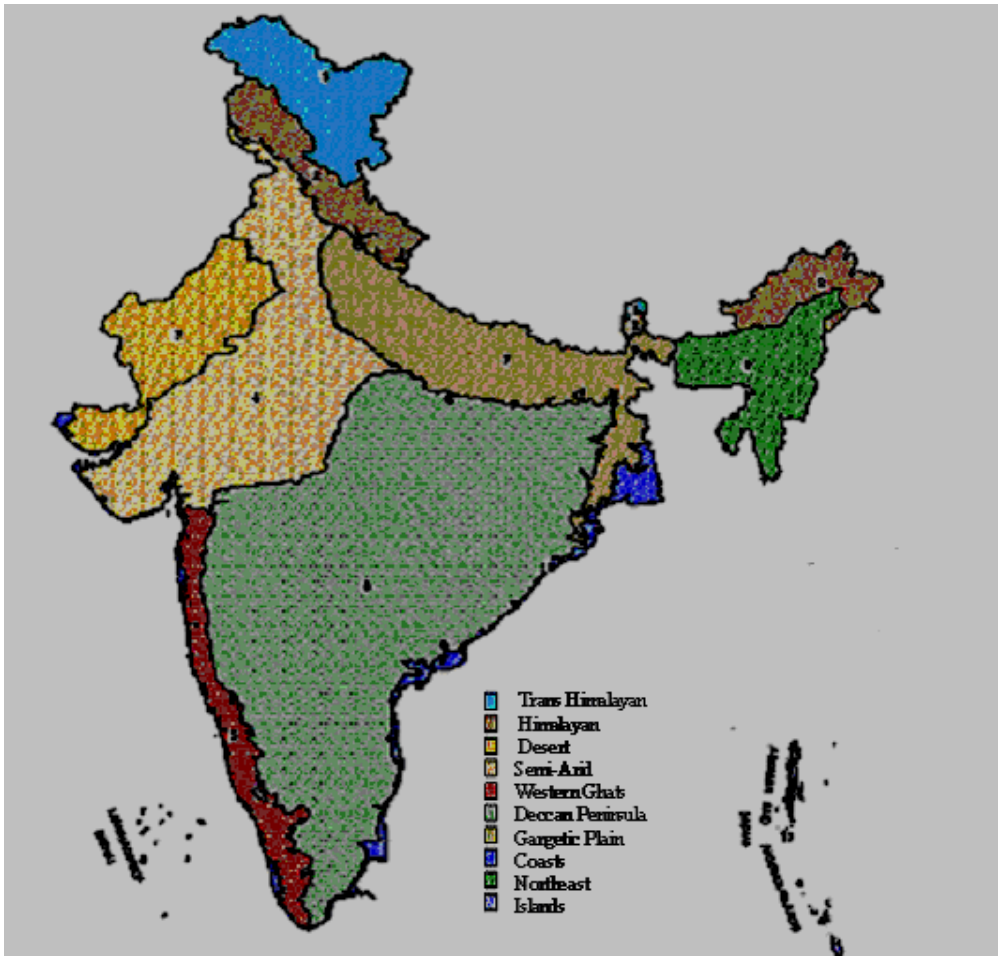
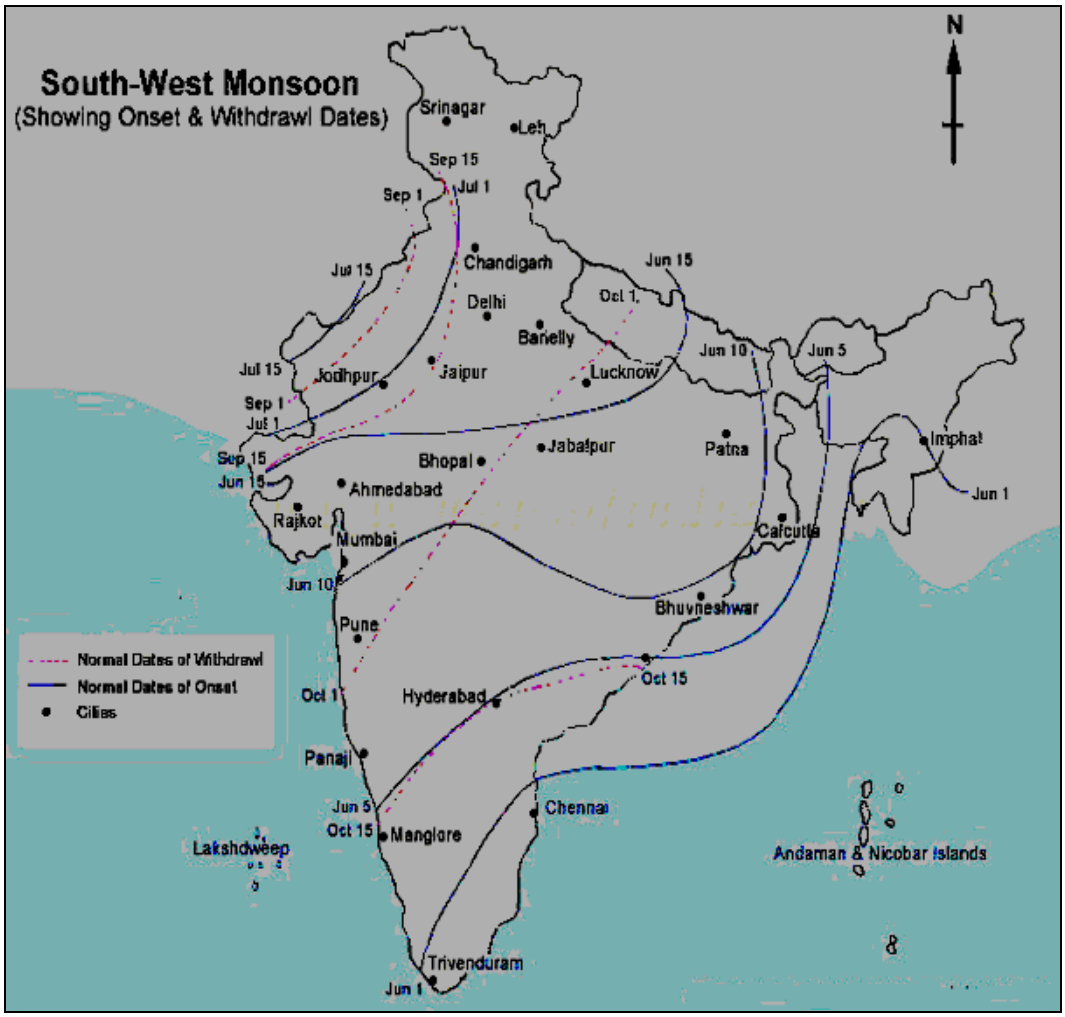


Fig 3.2 Onset and Withdrawal of South-West monsoon in India



CHAPTER 4

BREEDING SEASON OF INSECTIVOROUS BIRDS OF INDIAN MAINLAND

INTRODUCTION

Reproduction of birds is a continuous chain of events from nest building to the fledging of the young and this chain of events once started occurs at the species-specific speed and cannot be staggered or speeded up (Immelmann, 1971). Every species of birds tend to breed at the time of the year when it can raise its young most efficiently (Lack, 1954). In order to produce eggs the female has to spend much energy and so the season of egg laying corresponds to the time of maximum availability of food (Perrins, 1970). The date on which the first egg of a clutch is laid has been taken to indicate the onset of breeding. The date of first egg could be inferred exactly or almost exactly by backdating, eggs normally being laid on consecutive days (Newton, 1964). In the tropics, avian breeding season extends throughout the year in keeping with the extended favourable conditions; nevertheless, breeding in individual species is essentially periodic (Thapliyal,1978).

Reproductive success of birds in warm arid climate is related to rainfall. The onset of rain acts as a direct trigger for seasonal activity in tropics (Wolda,1988). Most species do not breed until rain arrives and success is diminished when rain is insufficient (Li and Brown,1999). High

temperature after rainfall ensures rapid grass growth inducing insect abundance (Lloyd, 1999). Changes in day length, rainfall and humidity during the course of the year may influence the onset of breeding (Thapliyal and Biur, 1991). The most important factor for breeding is the availability of adequate food supply (Lack, 1954). The period in which adult or mature insects appear, or in which reproduction occur must meet certain minimum standards. There must be adequate food and tolerable physical conditions (Wolda,1988). The availability of insects followed by rich vegetative growth induces birds to breed in a particular geographic region. The time of egg laying is so programmed that the eggs hatch out when there is enough food, available in the habitat. It has been found that the breeding season of certain species of birds vary regionally within the mainland (Lamba, 1977).

METHODOLOGY

Breeding data of insectivorous birds of the eight major bio-geographic regions were collected mainly from the ornithological publications. Data from South Western Ghat regions like Kozhikodu, Kottayam and Kannur were collected from the field also. Data were pooled to get the number of species laying eggs in each month as well as duration of laying season in each region. Total breeding species were grouped into two: i) Prevalent species- breeding in four or more bio-geographic regions. ii) Restricted species- breeding in one to three regions.

Number of species laying eggs in each month were analysed for each bio-geographic region. Percentages of prevalent species laying eggs were

related to the monthly rainfall (mm). Months of egg-laying initiation of the prevalent species were studied. Monthly egg-laying frequency of prevalent species like Common Myna, House Crow, Black Drongo, Jungle Babbler and Redvented Bulbul were studied in each region. Time of egg laying of species restricted to far apart regions like Himalayan Region and Western Ghats were also analysed.

RESULTS

Breeding data were collected for 400 species of insectivorous birds from the eight major bio-geographical regions of the Indian mainland: 163 of these were breeding in the Deccan peninsula, 100 in the Indian Desert, 89 in the Eastern Ghats, 102 in the Gangetic plain, 327 in the Himalayan region, 230 in the Northeast India, 205 in the semi arid region and 227 in the Western Ghats (Table 4.1).

Prevalent and restricted species

Breeding data of the total number of species were categorised into the prevalent species which breed in four or more regions and restricted species which breed only in 1-3 bio-geographic regions. In the present study, breeding data were collected for 154 prevalent species (Appendix 1). Of these 54 initiated egg laying in January (Appendix 2.1), 39 in February (Appendix 2.2), 43 in March (Appendix 2.3), 15 in April (Appendix 2.4),1 in May and 2 in June (Appendix 2.5).

In the present study 246 species were restricted ones, breeding only in 1 to 3 bio-geographic regions. Of these 48 were breeding exclusively in the

Himalayan region (Appendix 3.1) and 15 in the Western Ghats (Appendix 3.2).

Monthly record of egg laying species

Egg laying initiated in January itself in most of the bio-geographic regions. Of the total 400 species, 64 initiated laying in January and 44 of these were in the Western Ghats. No egg laying was reported from the Indian Desert in January but 16 species were recorded nesting in the Deccan Peninsula, 11 in the Himalayan region, 7 species each were recorded laying in the Semi-Arid region and Northeast India, 5 in Eastern Ghats and 3 in the Gangetic plain (Table 4.1).

Out of the 154 prevalent species, each of which breeding in four or more bio-geographic regions, 54 recorded egg laying in January. Of these 41 were reported from the Western Ghats and 15 from the Deccan Peninsula. The numbers of prevalent species laying eggs in the Himalayan Region were 9, in the Eastern Ghats 5, in the Semi-arid regions 6, in the Northeast India 5 and in the Gangetic plain 3 (Table 4.3).

Numbers of prevalent species laying eggs increased in all bio-geographic regions from February. In Deccan Peninsula, maximum number of species was laying in April. The number of egg laying species showed a steady decline from August. Number of breeding species fluctuated in the same pattern in the Eastern Ghats, in the Gangetic plain and in the North-east India. In Western Ghats with highest number of species were laying eggs in April. The Himalayan and Semi-arid regions showed the same

pattern of fluctuation but more number of species were laying eggs in June (Table 4.3).

Comparison of egg-laying in common birds

Breeding data of common species like Common Myna (Fig 4.1), House Crow (Fig 4.2), Black Drongo (Fig 4.3), Jungle Babbler (Fig 4.4) and Redvented Bulbul (Fig 4.5) from all the bio-geographic regions were analysed. Number of laying birds increased in all the species from March. Egg laying season was long in Western Ghats and Deccan Peninsula than the other regions and House Crows in Western Ghats were laying eggs in all months of the year.

Breeding in insectivorous species and Rainfall

In the Deccan Peninsula higher percentage of prevalent insectivorous species were laying eggs from March to August. In April, 37.6% and in July, 33.77% recorded laying (Table 4. 4). In February only 16.88% and in September, 18.83% species were laying eggs. The main rainy season in this region is from June to September and average rainfall of 163.9mm, 171.1mm and 181.5mm were measured in July, August and September (Fig 4.6.1). In the Indian Desert highest amount of rainfall was recorded in July (216.3mm). Percentages of species laying eggs were high in July and August, 25.32% and 23.37% respectively (Fig 4.6.2). In the Eastern Ghats, higher amount of rainfall occurred in July and August, 325.3 mm and 329.5 mm each (Fig 4.6.3). Here the highest percentages of prevalent birds were breeding in April (20.07%).

In the Gangetic plain, rainy season extended from June to September. Mean rainfall recorded in July, August and September were 305.8 mm, 274.4 mm and 226.9 mm respectively. Highest percentages of egg-laying species were observed in April and June, 22.08% each but decreased to 15.58% in July (Fig 4.6.4). In the Himalayan region, highest percentages of prevalent species were laying eggs in June (51.28%). In April 45.45% and in July 42.89% were recorded. Rainfall was highest in March (98.5mm). It was 87.5 mm in April and 71.9 mm in May, but decreased afterwards (Fig 4.6.5). In Northeast India, rainfall was high in June and July (350 mm and 353.6 mm). In May it was 248 mm and in August 269.9 mm. Highest percentage of prevalent species were breeding in April (47.41%). In May 16.88% and in June 28.57% were laying eggs (Fig 4.6.6).

The Semi-Arid region had a peak rainfall of 258.7 mm in August and 31.5 mm in July. Highest percentage of species (53.24%) was laying eggs in June (Fig 4.6.7). In the Western Ghats the main breeding season was from February to October (Fig 4.6.8) with a peak in April (55.2%). Mean rainfall was highest in July (940.9 mm).

The number egg-laying species showed positive correlation with the monthly average rainfall in the Indian Desert, with a coefficient of correlation (0.73). Semi-arid and Himalayan regions showed slight correlation with ‘r’ values (0.45) and (0.43) respectively, while no significant correlation was observed in other regions. The corresponding values of coefficients of correlation obtained for Northeast India was 0.4;

Deccan Peninsula, 0.39; Western Ghats, 0.28; Gangetic plain 0.24 and Eastern Ghats only 0.11.

DISCUSSION

Breeding season

Latitudidinal gradient of increase in biological species richness from the temperate region to tropics may explain the richness of species (Gadagkar,*et al*.,1990) of insectivorous birds in the present study (Table 4.1). Breeding season of insectivorous species varied in different bio-geographic regions of the Indian mainland. In the Indian Desert it is of short duration confined mainly to the South-West monsoon but many species in the Western Ghats, the Deccan Peninsula and the Semi-Arid regions had long breeding season extending six to eight months or even throughout the year (Table 4.3).

In species having prolonged breeding season, there would be one or two peak periods when majority of birds breed (Adams,1957). In the present study this is observed in the Western Ghats, Deccan Peninsula and Semi-arid Region (Table 4.3). In the Western Ghats intense breeding occurred in March-April and first half of June. In the Deccan Peninsula it was in March-April and June-August. In Redvented Bulbul of Semi-arid region it is observed in April-May and July (Fig 4.5). Similar instances were reported in the breeding cycle of individual species like House Sparrows of Hyderabad, where clutch initiation took place in all the twelve months but intense breeding was from February to April and August to September

(Kumudanathan *et al*.,1983). Active nests of Jungle and House Crows could be observed during the present study at Calicut, Kottayam and Kannur in all the months except during heavy rains.

Factors affecting breeding season

In the Western Ghats where favourable climatic conditions prevailed most part of the year except heavy rains of July and August, many birds have long breeding season and would be laying eggs most part of the year (Table 4.3). Breeding season of birds coincides with the season of abundant food availability for the young one (Lack,1950) and eggs would be produced at a time when female birds could find enough insect food to feed on (Perrins,1970). Availability of food is a leading factor in regulating breeding cycle of birds and it is correlated with general increase in insect population (Vijayan,1980). Adequate food and tolerable physical conditions are the necessary pre-requisites for insect abundance (Wolda,1988). In all bio-geographic regions of the mainland except the Indian Desert, peak season for egg laying was before the outbreak of monsoon rains (Table 4.1).

Prolonged breeding season in the Western Ghat region might be due to the availability of insect food throughout the year. Invertebrates would be in plenty during and after South-West monsoon in areas of the South Western Ghats (Zacharias and Gaston, 1983). So there would be enough food for the young ones. The rich canopy and herbaceous ground layers with their tightly packed species guilds, contribute considerably to insect diversity (Ananthakrishnan, 2000).

In South Western Ghat areas like Periyar, sprouting of new leaves would begin from November-December and most of the trees would be in new leaves by early February (Petrisia, 1999). Plants like *Artocarpus integrifolia, A.lakoocha, Havea brazilensis* and *Eugenia jambolana* were with new leaves in the first week of December in Kerala. In areas of North Western Ghats, leaf flushing occurs in pre-monsoon times with a peak in February (Bhatt, 1992). Two peaks are there for flowering-March and December. Coincided with early sprouting of leaf or flower buds and associated increase of insect population, a number of species would start egg laying in January itself with peak breeding in March-April (Table 4.1). Another peak in laying was observed in June at the beginning of Southwest monsoon after the dry summer.

Effect of monsoon on breeding season

Breeding of birds in different bio-geographic regions of India could be related to rainfall, mainly South-West and North-East monsoons. The dates of commencement of monsoon vary in different bio-geographic regions (Siddhartha,1999). South-West monsoon touches the Southern regions of Western Ghats by the last days of May or first days of June and the showers will be available in most part of Western Ghats, Deccan peninsula and Northeast India in the first half of June. By June 10^{th} whole of Western Ghats would have been wet while it reaches the Indian Deserts only between 1^{st} and 15^{th} of July (Fig 3.2). The duration and intensity of South-West monsoon vary from place to place. Kerala lying in the Southern part of

the Western Ghats gets a good amount of rain while Tamil Nadu, lying in rain-shadow region of Western Ghats, gets very little precipitation during South-West monsoon. The Northeast India also gets much rain in June (Table 3.1). The North-East monsoon produces rain primarily in the states of Tamil Nadu, Orissa, Andhra Pradesh, Kerala and Southern corner of Karnataka. In Tamil Nadu, November is the wettest month of the year. But for the rest of the country, this system supplies only 20% of annual rainfall.

In Southern regions of Tamil Nadu leaf flushing would take place from late November, because of North-East monsoon rains in October and November (Katti and Price,1996). Peak emergence of new leaves occurs in February and March and flowering takes place mainly in March and in small rates in December (Sundarapandian *et al*.,2005). In Siruvani forest lying in the rain-shadow region of South Western Ghats new leaf growth was observed in March as well as during South-West monsoon (Arun and Vijayan, 2004). The new leaves and flowers would attract arthropod fauna.

In regions of extreme climatic conditions, breeding of birds would be limited to a short period with favourable conditions. So in the Indian Desert, highest numbers of species were laying eggs in July and August, the time of Southwest monsoon (Fig 4.6.2). Most species do not breed until rains arrive and success is diminished when rain is insufficient (Li and Brown,1999). But a number of species were found breeding in summer months of May and June (Table 4.3). Breeding in drought condition was reported in resident insectivorous species of South African arid zone birds (Lloyd,1999). In

Indian Deserts like Jodhpur and Rajasthan annual rainfall is only 300 mm. distributed over twenty rainy days (Bohra and Goyal, 1992) while in Alwar District it is restricted to July and August with an average rainfall of 695 mm confined to fifty to seventy days (Sharma, 1992). With the onset of rain the whole region becomes fresh and green (Ali, 1941). The birds begin to lay eggs when the insects become abundant during rainy season, in arid regions. Breeding rate would come down when the temperature rises again after the short monsoon showers. Breeding success therefore tends to be sensitive to the duration and amount of rainfall in an area (Sinclair,1978).

In the Semi-Arid region major portion of egg laying occurred between February and September. Though highest number of species were laying eggs in June, a good number laid in March, July and August (Table 4.3). In general reproductive success of birds in warm arid climates is related to rainfall.

In Himalayan region number of species breeding increased in February and many of them were with eggs till August (Fig 4.6.5). In low altitude areas of this region, birds would become active earlier after the winter months (Price and Jamdar, 1990) and so breeding also commences earlier. In Dehra Dune for example, birds which usually start breeding in February delays it to March or April in the years of prolonged winter rains (Narang *et al.*,1980). In this place leaf-flushing and associated insect abundance begins by March-April (Beeson,1941). But in Kashmir and other regions, rain and mist would continue even in May. This might be the reason

for highest number of species laying eggs only in June (Table 4.1). These regions have heavy rainfall in winter, from December to March (Padmanabhan and Yom-Tov, 2000). When cold weather prevents the emergence of adult insects, wind and rain cause them to seek cover and become inactive. Thus feeding of birds would be affected in these months (Coulson, 1956). Temperature is instrumental in activating many insects and in determining development rates and adult reproductive activity (Wolda, 1988). Many migrant birds come to breed in this region during months of April and May when climatic conditions become favourable (Pfister, 2001).

In Northeast India, number of species laying eggs increased in March with a peak in April (Table 4. 3). Here also number of species breeding increases when the temperature rises up and plants sprout out new leaves and flowers after the chilling cold of winter season. In the Assam forests though most of the trees were bare due to shedding of leaves in winter season, the flowering trees like Simul, Erythrina and the Asoka would be coming into bloom by mid-February (Betts,1947). Number of species laying eggs decreased in May but a considerable number continued egg laying till October. A good amount of rain is obtained from May to August with heavy showers in June and July. The number of breeding species declined in this bio-geographic region during heavy rains (Fig 4.6.6). Many birds do not breed in heavy rains (Serle, 1981; Zacharias and Gaston, 1983).

In the Eastern Ghats and Gangetic Plain most of the species were breeding from April to June, because these regions would get short summer

rains, an important factor to promote plant and insect life. In this region significant increase in Arthropod population occurs in April-May (Price, 1979). While insect species in leaf litter samples were high in May (Pragassan and Parthasarathy, 2005), soil-surface arthropods increased during the rainy season (Reddy and Venkataiah, 1990).

In the Gangetic Plain, birds would initiate breeding when the winter cold recedes and temperature goes up. Here peak breeding occurred before the outbreak of monsoon, in April and June (Table 4.3). Deciduous trees of these regions are generally summer-flushing; vegetative buds open in dry summer months of April and May.But there are plants which begin leaf-flushing in March-April (Singh and Kushwaha,2005). A small percentage of new leaf-buds open in these plants during October-November also.

Out of the 154 species which possibily breed in four or more bio-geographic regions, 82 started egg laying earlier in Western Ghats than the other regions. Breeding season was long for many species in this region. This might be due to availability of abundant insect food. The activity of tropical species of insects tend to be longer and percentage of species active around the year higher relative to their counterparts at higher latitudes (Wolda, 1988).

In North Indian regions, trees shed their leaves with the advent of winter season and at high altitudinal regions like the Himalayas may remain leafless till May. Here the snow persists even in May and recedes only by June (Price and Jamdar, 1990). In order to tide over the extreme climate of

winter season, insects and other invertebrates suspend their life activities and would enter into diapause (Beeson, 1941). In Kashmir flowering and seed formation of trees like conifers occurs in summer, providing food for insects. Leaf flushing is mainly from last week of May to mid-June and arthropods would be increased from May to July (Moza and Bhatnagar,2005). Consequently the number of species laying eggs increased from April with the highest number of species in June (Table 4.3).

Low temperature at certain early phases of avian breeding cycle delays nesting (Snow, 1955).Low temperature also increases maintenance costs for females thus preventing them from forming eggs (O'Connor and Morgan, 1982). Insects, in the northern parts of their breeding range, either hibernate or migrate to warmer regions during winter (Wolda,1988). So in the first quarter of the year numbers of insectivorous bird species laying eggs were very few in northern regions.

In southern regions of India temperature would be rising up earlier, promoting growth of new leaves, which in turn bring about rich insect fauna. The percentages of species laying eggs were high in these regions in the first three months of the year. Therefore a prevalent species would start breeding late in Himalayas and adjacent regions than in the southern states (Table 4.4). The cold season at Dehra Dune begins in November when average minimum temperature drops to 6ºC and hot season begins from mid-March, when average maximum temperature shoots up to 26ºC (Narang *et al.*,1980).

Insects come out from diapause and would begin to multiply in this area when winter cold recedes (Beeson, 1941).

Since most species of birds avoid breeding in heavy monsoon (Zacharias and Gaston,1983), in Western Ghats major portion of breeding would be in pre-monsoon months of March and April (Fig 4.6.8). In addition to the flooding of nests, heavy rains would interfere with the feeding of nestlings (Moreau, 1939). Thus birds would be able to find much less food for their young during heavy rain (Lack,1948). In monsoon season, the rainfall may be continuous for several days in succession in the Western Ghats. The need to take shelter during rain may reduce the time available to birds for foraging (Foster, 1974).

In Indian Desert regions peak breeding would be during rainy season (Fig 4.6.2), which is of short duration. The reproductive success of birds in warm arid climate is related to rainfall because most species do not breed until the arrival of rain and success is diminished when rain is in insufficient quantity (Li and Brown,1999). This might be the reason for the higher rate of egg laying during South-West monsoon in Indian Desert.

In Semi-Arid regions also peak time for egg laying was pre-monsoon season. In Baroda earliest clutches of the year appeared in February when the temperature started rising (Naik and Mistry,1980). Different species of perennial plants would sprout out new leaves, flowers and fruits from February to May and a more active period of vegetative growth starts with

monsoon, in June and terminates in August-September. This will promote the arthropod increase and provide enough protein diet for the nestlings.

Considerable decrease in number of laying species observed in May might be due to the inter-breeding periods between two successive broods and most species would be with nestlings at this time. High temperature of summer season also might reduce the number of species laying eggs in that month. Number of laying species increased in June, might be the second brood of the season. Rainfall is high in all bio-geographic regions in June except the Himalayan region. Increase in precipitation would have induced insect abundance and breeding of birds. When the intensity of rain increased further in July, number of egg-laying species decreased (Fig 4.6.1). This might be because many species avoid breeding in heavy rains (Zacharias and Gaston, 1983).

In most of the geographic regions, major part of egg laying occurred in pre-monsoon times whereas in Indian Desert where rainfall is limited to a few rainy days of South-West monsoon, highest number of species were breeding in that season. But in Himalayan region maximum number of species would be laying eggs after the withdrawal of winter rains (Padmanabhan and Yom-Tov, 2000). In the present study it is observed in June, before commencement of South-West monsoon in the first week of July (Fig 3.2). The climate is favourable for breeding in this season and insects would be in plenty attracted by the blooming plants.

When majority of birds avoid breeding during heavy rains in regions other than Indian Desert a few prefer to breed at that time. The Weaver birds, Tailor birds and Wren warblers were found to breed in heavy rains of July in the Western Ghats (Ali and Ambedkar, 1956; Neelakantan, 1976). This might be due to their fine and resistant nests which would withstand heavy downpours and roaring winds. These birds would keep the number of laying species high in July (Fig 4.6.8).

The present study clearly states that egg laying in birds occur mainly in pre-monsoon times in regions with heavy monsoon showers, avoiding the heavy showers (Becking, 1981; Zacharias and Gaston, 1983; Zacharias and Mathew, 1988). The short pre-monsoon summer showers influence breeding from April to June (Shukkur, 1978).

In regions like Himalaya where there is winter rains from December to March (Padmanabhan and Yom-Tov,2000) and downpours due to South-West monsoon in July and August, number of species laying eggs increase when the winter cold receded (Price and Jamdar,1991) and comes down before the commencement of South-West monsoon. In Semi-Arid region peak time for egg laying was June, before the heavy downpours of South-West monsoon in July. A good number of species were laying in July and August (Table 4.3). Compared to Western Ghats, the amount of precipitation in these regions were very low (Table 3.1) and so it would not have hindered breeding during monsoon. Thus in the dry arid climate breeding is preferred in rainy season (Gaston, 1981; Li and Brown, 1999).

Breeding season of the common birds studied

The common birds like Common Myna (Fig 4.1), House Crow (Fig 4.2), Black Drongo (Fig 4.3), Jungle Babbler (Fig 4.4) and Redvented Bulbul (Fig 4.5) showed higher numbers of egg-laying individuals in pre-monsoon times in regions like Western Ghats, Deccan Peninsula, Eastern Ghats and Himalayan region while in the Indian Desert and Semi-Arid regions it was during the monsoon. This might be due to availability of abundant food supply in these seasons of the year (Davis, 1971).

The positive correlation in number of species laying eggs and rainfall noticed in Indian Desert might be because egg laying in dry arid regions is mainly confined to South-West monsoon (Gaston,1981). In other regions peak egg laying occurred before the onset of monsoon. Thus each species in a particular bio-geographic region laid their eggs at the appropriate time of the year. Depending on climatic and other ultimate factors time of egg laying varied slightly in different bio-geographic regions of India.

Table 4.1

Total number of insectivorous species laying eggs in different bio-geographic regions of the Indian mainland

Bio-geographic Region	Months												Number of Species
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Deccan Peninsula	22	41	65	74	33	65	79	61	34	20	11	11	163
Indian Desert		8	24	21	20	34	45	42	8	7		-	100
Eastern Ghats	8	6	19	29	7	27	18	11	9	6		3	89
Gangetic Plains	3	6	18	39	9	36	25	16	3	1	5	1	102
Himalayan Region	11	38	55	153	163	228	158	83	10	6	5	4	327
Northeast India	7	20	51	130	43	79	45	30	12	8		4	230
Semi-Arid Region	7	41	90	73	67	110	81	81	30	14	4	2	205
Western Ghats	44	70	112	102	68	87	81	77	40	43	18	26	227

Table 4.2 Percentage (%) of total species laying eggs in each month in different bio-geographic region of the Indian mainland

Bio-geographic Region	Months											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Deccan Peninsula	4	8.25	14.5	17.25	6.25	14.75	16	13.25	8	5	2.75	2.75
Indian Desert	-	2	6	5.25	5	8.5	11.25	10.5	2	1.75	-	-
Eastern Ghats	1.25	1.5	4.5	7.75	1.75	6.75	4.5	2.75	2.25	1.50		0.75
Gangetic Plains	0.75	1.5	4.5	9.75	2.25	9	6.25	4	0.75	0.25	1.2	0.25
Himalayan Region	2.75	9.5	13.7	38.25	40.75	57	39.5	20.75	2.5	1.5	1.25	1
Northeast India	1.75	5	12.75	32.5	10.75	19.75	11.25	7.5	3	2	-	1
Semi-Arid Region	1.75	10.25	22.25	18.25	16.75	27.5	20.25	20.25	7.5	3.5	1	0.5
Western Ghats	11	17.5	27.5	28	17	21.75	20.25	19.25	10	10.75	4.5	6.5

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Table 4.3 Number of prevalent species laying eggs in each month in different bio-geographic regions of the Indian mainland

Bio-geographic Region	Months											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Deccan Peninsula	15	26	49	58	22	52	52	45	29	18	8	9
Indian Desert		7	23	19	18	30	39	36	7	5	-	-
Eastern Ghats	5	6	19	24	6	21	17	10	7	6	3	3
Gangetic plain	3	6	16	34	9	34	24	15	3	1	2	1
Himalayan Region	9	26	40	70	60	80	66	48	8	5	2	3
Northeast India	5	18	32	73	26	44	26	22	9	8	-	4
Semi-Arid Region	6	30	67	59	46	82	67	64	27	12	2	1
Western Ghats	41	51	84	85	55	68	63	59	31	32	10	18
Total prevalent species laying eggs in each months	54	87	130	131	94	130	125	107	59	53	20	36

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Table 4.4 Percentage (%) of prevalent species laying eggs in each month in different bio-geographic regions of the Indian mainland

Bio-geographic Region	Months											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Deccan Peninsula	9.74	16.88	31.82	37.66	14.29	33.77	33.77	29.22	18.83	11.69	5.20	5.85
Indian Desert	-	4.55	14.94	12.33	11.69	19.48	25.32	23.37	4.55	3.24	-	-
Eastern Ghats	3.25	3.9	12.33	20.07	3.9	13.64	11.03	6.49	4.55	3.9	1.94	1.94
Gangetic plain	1.94	3.90	10.38	22.08	5.84	22.08	15.58	9.74	1.95	0.64	1.29	0.64
Himalayan Region	5.85	16.88	25.98	45.45	38.96	51.28	42.85	31.16	5.20	3.25	1.29	1.94
Northeast India	3.25	11.68	20.77	47.41	16.88	28.57	16.88	14.28	5.85	5.19	-	2.60
Semi-Arid Region	3.90	19.48	43.50	38.31	29.87	53.24	43.50	41.55	17.53	7.79	1.29	0.64
Western Ghats	26.62	33.12	54.55	55.20	35.72	44.16	40.91	38.31	20.12	20.77	6.49	11.69

Fig 4.1 Monthly data of the number of eggs laid by Common Myna in different bio-geographic regions of Indian mainland

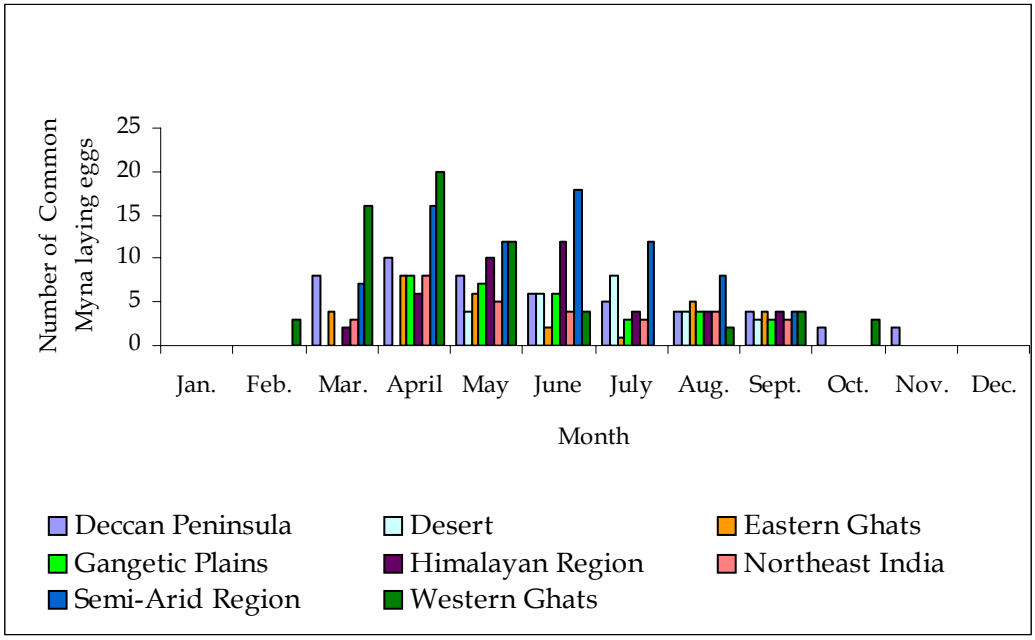


Fig 4.2 Monthly data of the number of eggs laid by House Crow in different bio-geographic regions of Indian mainland

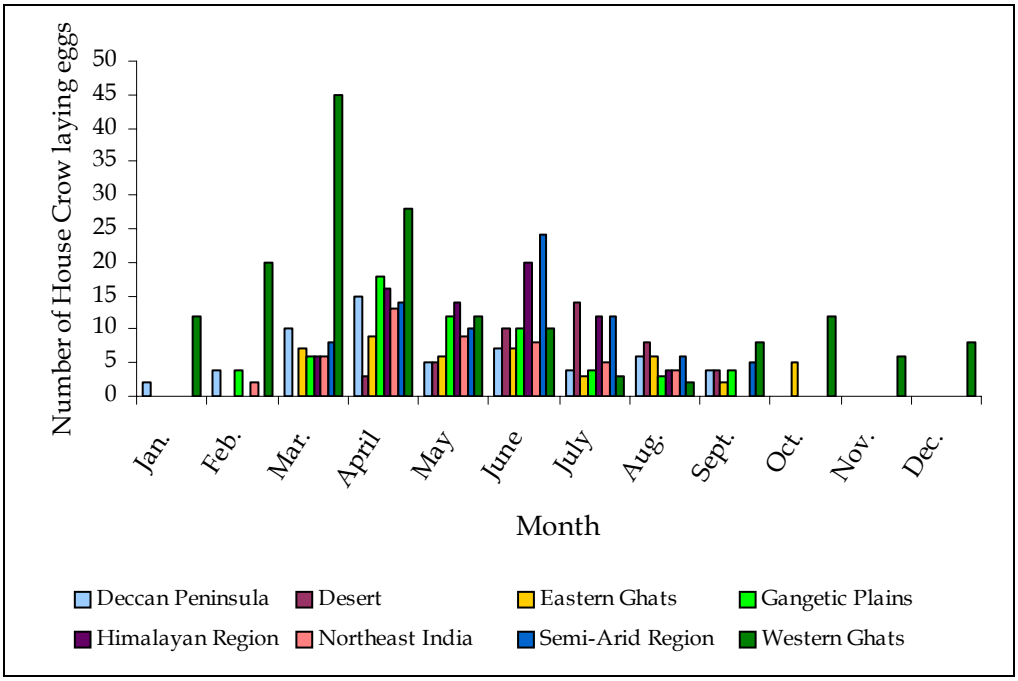


Fig 4.3 Monthly data of the number of eggs laid by Black Drongo in different bio-geographic regions of Indian mainland

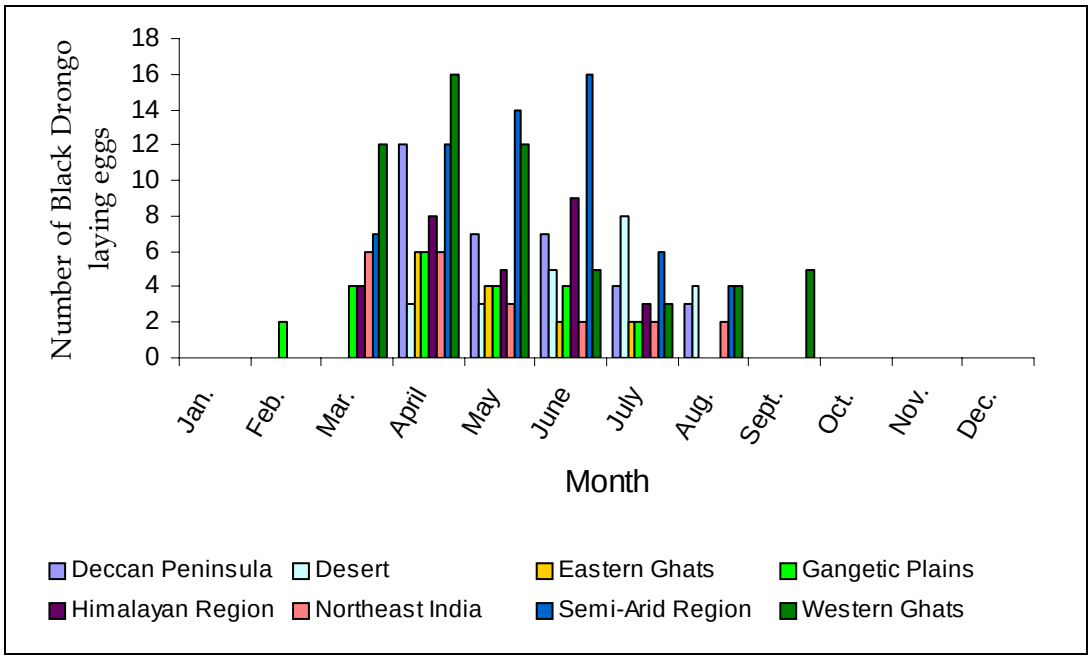


Fig 4. 4 Monthly data of the number of eggs laid by Jungle Babbler in different bio-geographic regions of Indian mainland

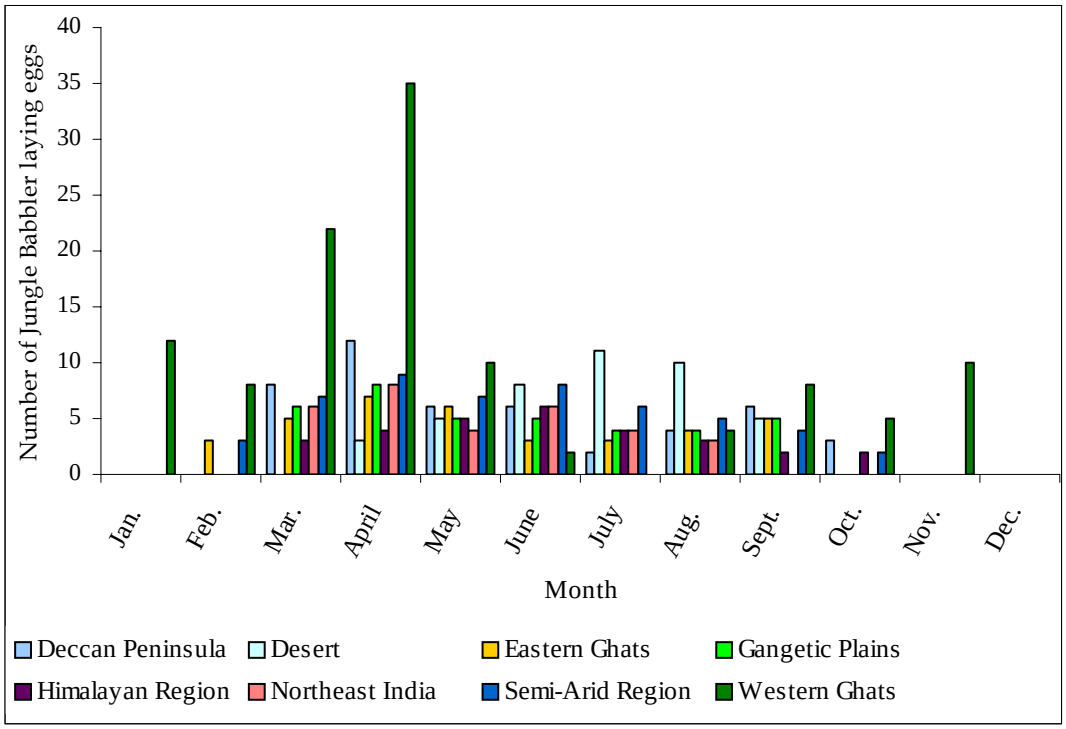


Fig 4.5 Monthly data of the number of eggs laid by Redvented Bulbul in different bio-geographic regions of Indian mainland

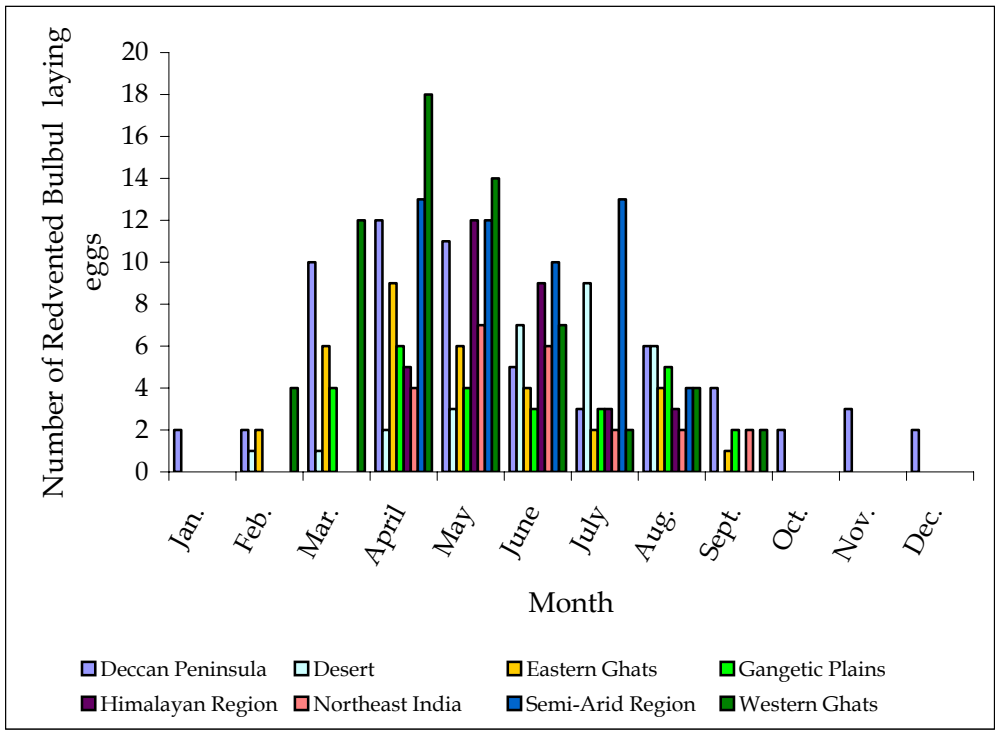


Fig 3.6.1 Relationship between percentage of egg laying in prevalent species and monthly rainfall in Deccan Peninsula during 2006

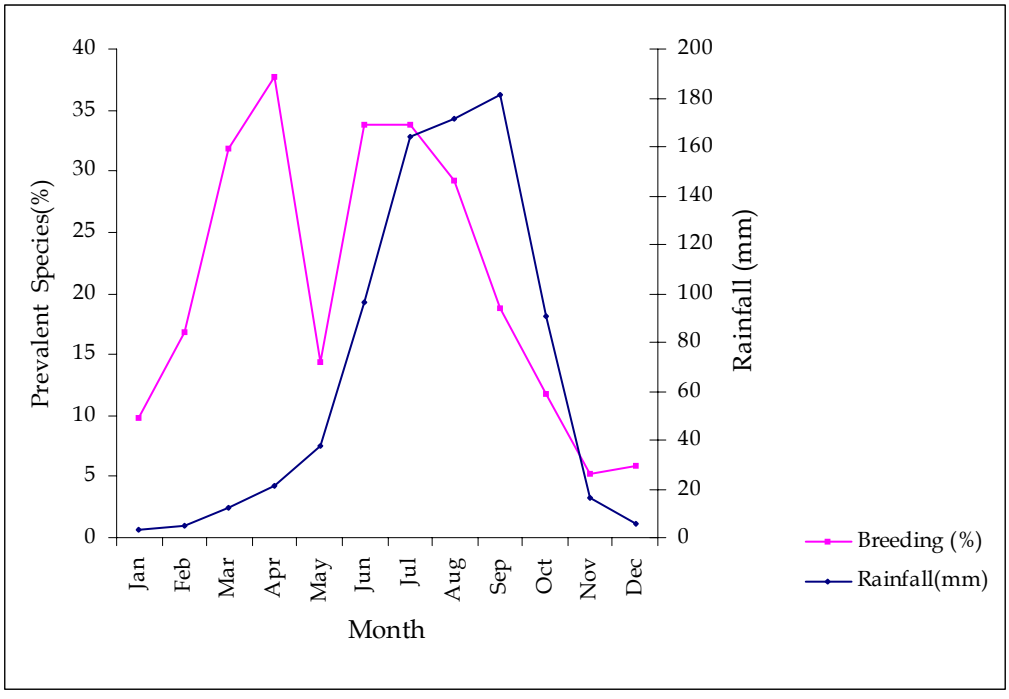


Fig 4.6.2 Relationship between percentage of egg laying in prevalent species and monthly rainfall in Indian Desert during 2006

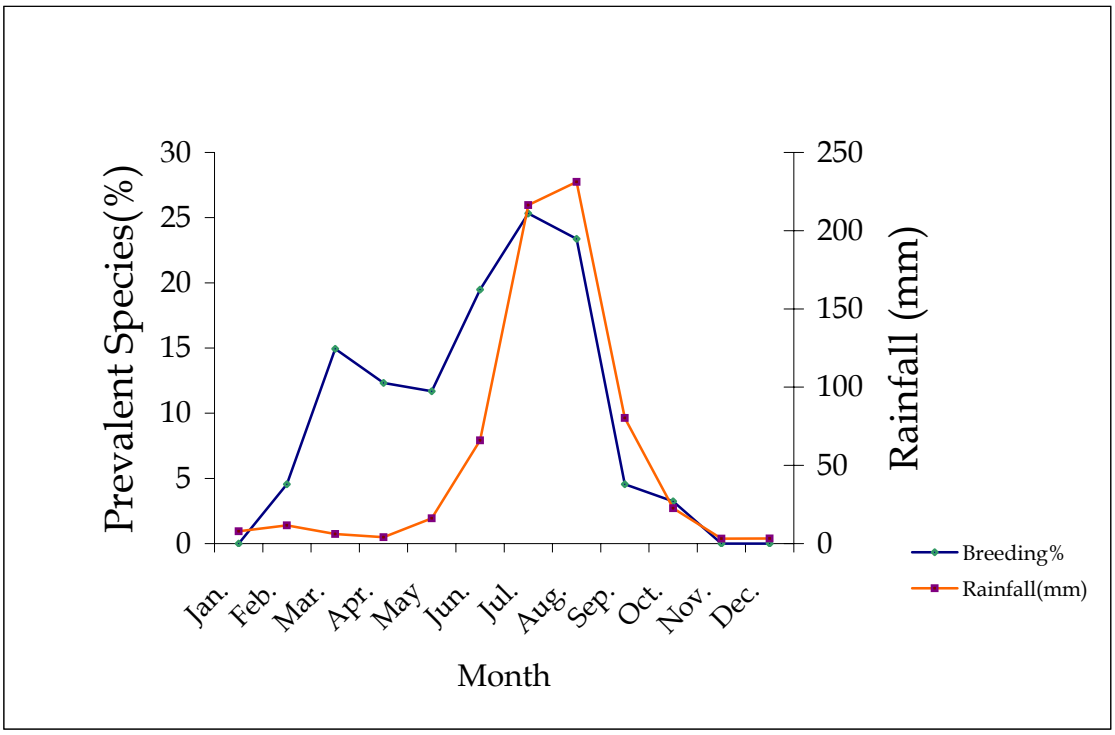


Fig 4. 6.3 Relationship between percentage of egg laying in prevalent species and monthly rainfall in the Eastern Ghats during 2006

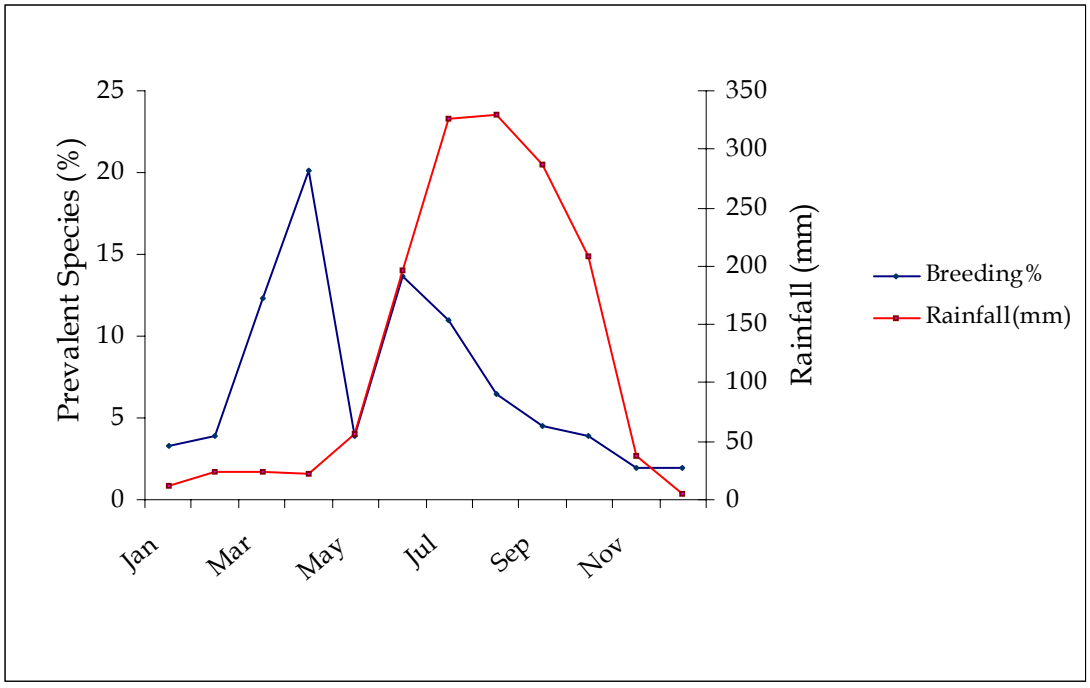


Fig 4.6.4 Relationship between percentage of egg laying in prevalent species and monthly rainfall in the Gangetic plain during 2006

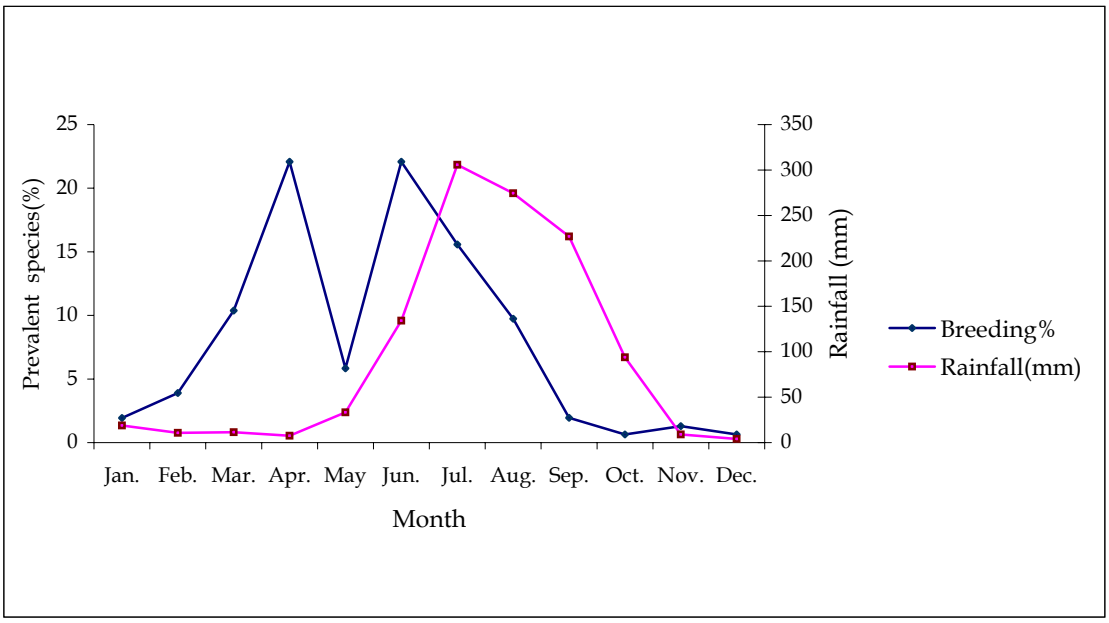


Fig 4.6.5 Relationship between percentage of egg laying in prevalent species and monthly rainfall in the Himalayan Region during 2006

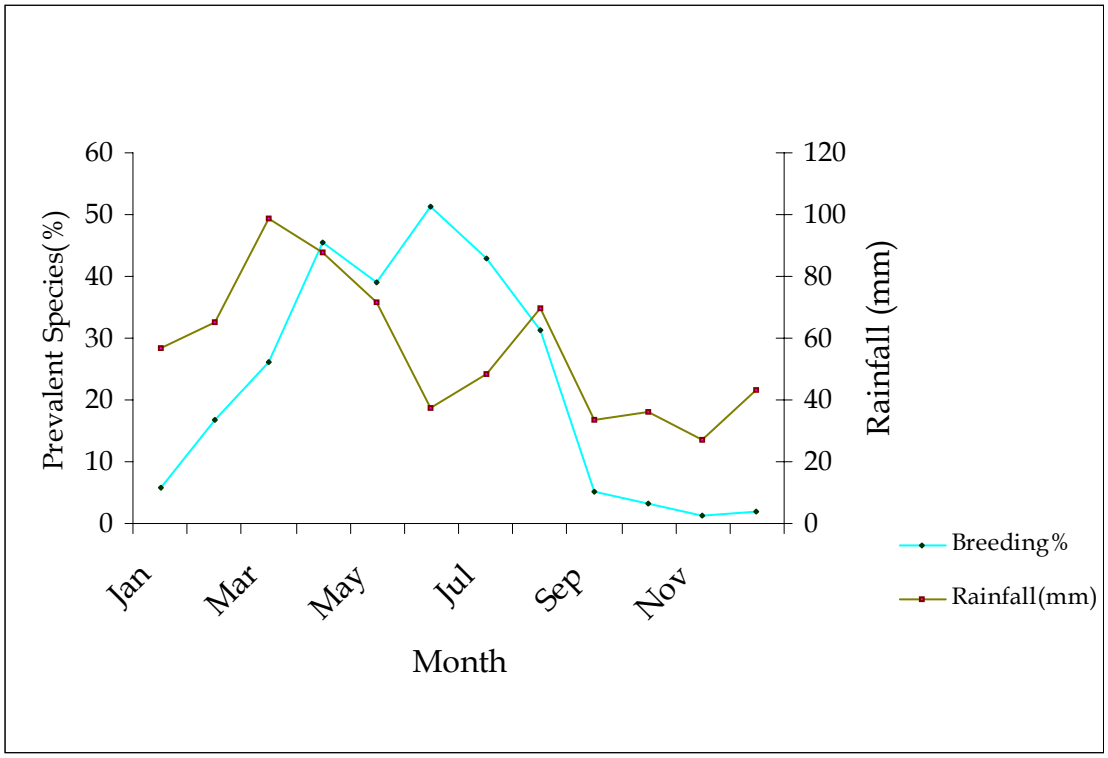


Fig 4.6.6 Relationship between percentage of egg laying in prevalent species and monthly rainfall in the Northeast India during 2006

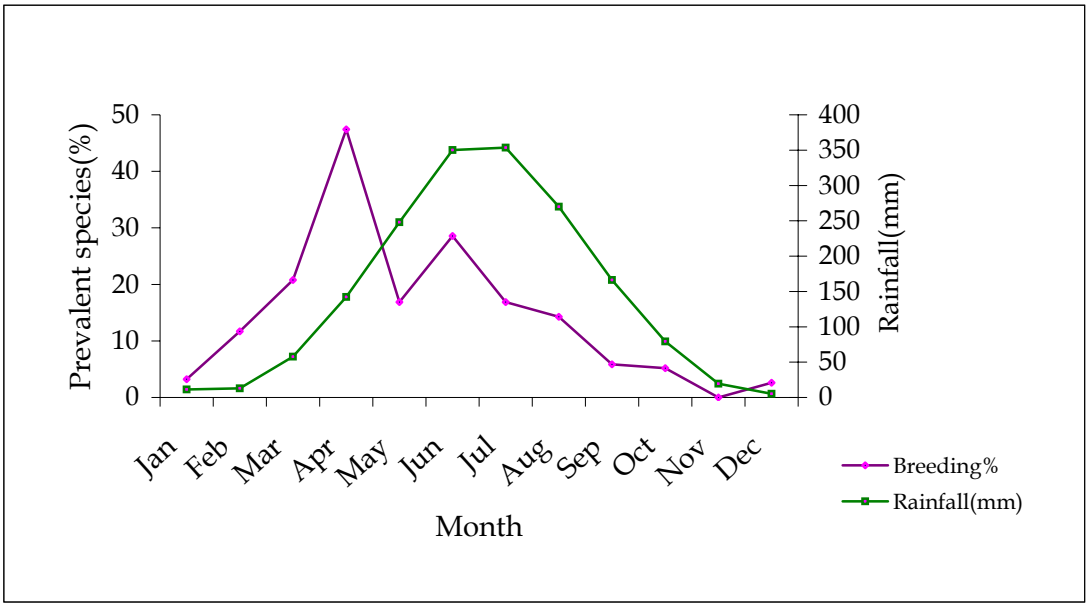


Fig 4.6 .7 Relationship between percentage of egg laying in prevalent species and monthly rainfall in the Semi-Arid Region during 2006

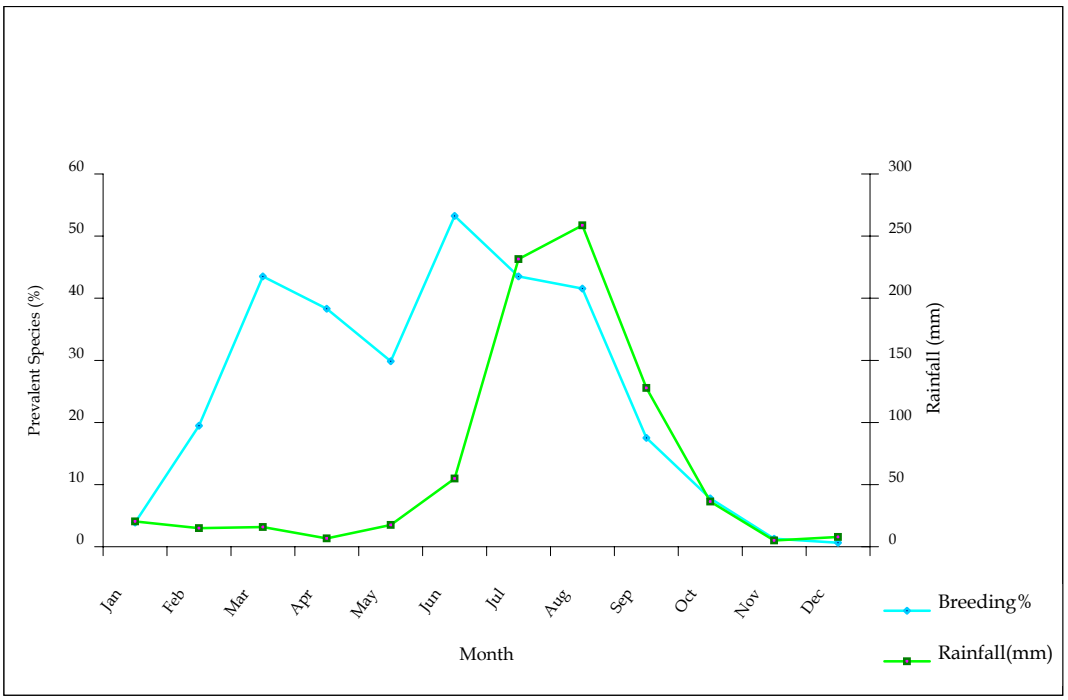
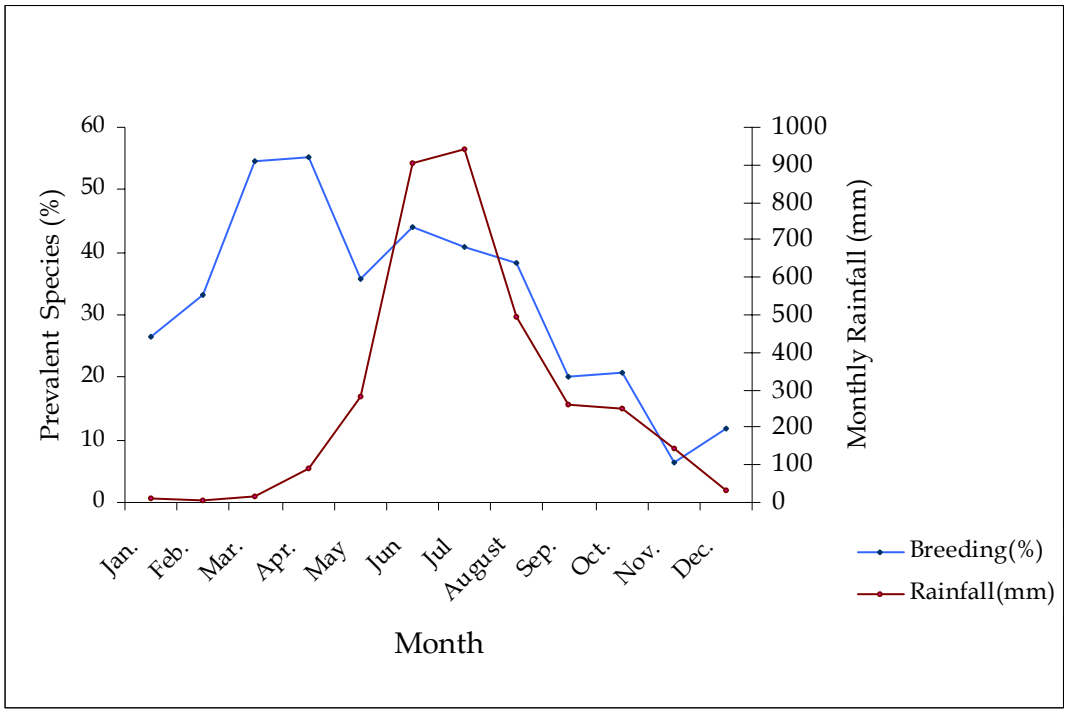


Fig 4.6.8 Relationship between percentage of egg laying in prevalent species and monthly rainfall in the Western Ghats during 2006



CHAPTER 5

PRIMARY MOULT OF INSECTIVOROUS BIRDS IN NORTHERN AND SOUTHERN INDIA

INTRODUCTION

A single annual moult is characteristic of many species of birds, but a few have a second moult. Prolonged moult often is limited to flight feathers and is a means of renewing flight feathers without losing the ability to fly (Palmer, 1972).

The most common pattern is commencing of primary moult with the first primary, which is the innermost and ending with the tenth or outermost (Naik and Naik, 1965; Middleton, 1977; Hunter, 1984; Newton and Rothery, 2000). The tempo of moult varies among members of a species. It may be a slow process of shedding one feather at a time from the first to the last (Newton, 1967) or all are dropped within a few days of each other (Birkhead and Taylor, 1977). Moult occurs at a fast tempo in migrating birds of temperate regions so that they could complete moult and depart early for autumn migration (Hall and Fransson, 2001). In insectivorous birds of Indian mainland having only local migrations, small variations in time of initiation and duration of primary moult have been reported for the same species in different regions as well as for different species in a particular region (Mathew, 1977; Gaston, 1981; Zacharias, *et al*., 1994; Balachandran, *et al*.,1995, and Balachandran, 1999).Onset and completion of primary

moult delimits virtually the entire moult period in most passerines (Jenni and Winkler,1994).

Moult is very closely synchronized with the reproductive cycle and with the seasons of the year (Zeidler, 1966). Short days increase the rate of moult and initiate earlier onset and completion whereas long days decrease the rate of moult and delay the time of onset and completion (Dolnik and Gavrilov, 1980).

The present study is to find out the pattern and tempo of primary moult of insectivorous birds in North and South Indian regions. The duration of moult is studied in each species. Regional differences in time and pattern of primary moult were studied in birds of a species collected from North and South Indian regions as well as from different species of a particular family. . Large number of species was selected in the present study to find out the similarities as well as difference in the pattern and duration of moult between members of the same genus as well as related ones.

METHODS OF STUDY

Primary moults were studied in preserved specimens of museums of BNHS, Mumbai and ZSI, Kolkata. Insectivorous species belonging to order Passeriformes were selected for the study. Of the twentyfive species studied, twentyfour were collected from North Indian regions and thirteen from South India. These species belonged to family Sturnidae, Dicruridae, Corvidae, Oriolidae, Laniidae, Pycnonotidae and Muscicapidae.

Primary feathers, which are replaced first in a moult series, are called

'Nodal feathers' (Yuri and Rohwer, 1997). 'Terminal feathers' are those replaced last and are always less fully grown than adjacent feathers. Other growing feathers provide directional information showing whether replacement proceeds proximally to distally or distally to proximally.

Using forceps and needle all the primary feathers on both wings of each bird were checked to find signs of moult. Old, missing, growing and new feathers were carefully studied. Feathers missing and at different stages of growth from 'pin' stage to nearly fully grown are regarded as moulting feathers (Mulvihill and Rimmer, 1997). Dates of collection of moulting specimens were noted down. Since primary moult is symmetrical on both wings (Wilkinson,1983; Balachandran,1999; Newton and Rothery,2000), in the present study moulting primaries of only one wing (right wing) of each bird is represented in the tables and figures. Moult data were analysed to get the pattern and tempo of moult.

RESULTS

Primary moult of twentyfive species of insectivorous birds belonging to seven familes of order Passeriformes were studied studied (Table 3.2). Twentyfour of these were collected from Northern India while thirteen from South India. Of these *Garrulax jerdoni* is endemic to Western Ghats.

Acridotheres fuscus of Northern India began moulting primary feathers in June. Primaries H1 to H3 were moulting in June and July, H3 to H6 in August, H5 to H8 in September, H7 to H10 in October, H8 to H10 in November, and H10 in December (Fig.5.1).

Acridotheres tristis of Northern India were moulting primaries H1, H2 and H3 in June, H1 to H4 in July, H1 to H5 in August, H5 to H9 in September, H6 to H9 in October H6 to H10 in November and H9 and H10 in December (Fig 5.2). In Southern India moult began in June and primaries H1 and H2 were moulting in that month, H1 to H4 in July and August, H4 to H8 in September, H7 to H10 in October, H9 and H10 in November and December (Table 5.1).

Sturnnus malabaricus, of Northern India were moulting primaries H1 and H2 in June, H1 to H3 in July, H3 to H5 in August, H7 to H10 in September, H9 and H10 in October and November. In Southern India moult started in June. Primaries H1 were moulting in June, H1 to H3 in July, H3 to H5 in August, H6 to H9 in September, H8 to H10 in October and H9 and H10 in November (Fig 5.3).

In S*turnus contra*, a species distributed mainly in North and East India, primaries H1 and H2 were moulting June, H1 to H4 in July, H3 to H5 in August, H4 to H7 in September H5 to H9 in October and H8 to H10 in November (Fig. 5.4).

Corvus splendens of Northern India were moulting primaries H1 and H2 in May, H1 to H4 in June, H3 to H5 in July, H4 to H6 in August, H6 to H10 in September, H8 to H10 in October and November (Fig 5.5).In Southern India, primaries H1 and H2 were moulting in May, H1 to H4 in June and July, H5 to H7 in August, H6 to H9 in September, H7 to H10 in October, H9 and H10 in November.

Corvus macrorhynchos of Northern India were moulting primaries H1 and H2 in May, H1 and H3 in June, H1 to H4 in July, H6 to H8 in August, H8 and H9 in September and H8 to H10 in October and November (Fig 5.6). In Southern India they were found moulting primaries H1 to H3 in May, H1 to H4 in June, H2 to H5 in July, H6 and H7 in August, H7 to H10 in September, H8 to H10 in October, H9 and H10 in November.

Dendrocitta vagabunda of Northern India were moulting primaries H1 and H2 in May, H1 to H4 in June, H2 to H4 in July, H3 to H5 in August, H5 to H8 in September and H8 to H10 in October and November. In Southern India moult began in May. Primaries H1 and H2 were moulting in May, H1 to H3 in June, H1 to H4 in July, H3 to H7 in August, H7 to H10 in September, H8 to H10 in October and H9 and H10 in November (Fig 5. 7).

Dicrurus adsimilis of Northern India started moult in June by replacing primaries H1. They were moulting primaries H1 to H3 in July, H3 to H5 in August, H5 to H8 in September, H7 to H10 in October and H9 and H10 in November (Fig 4. 8). In Southern India primaries H1 were moulting in June, H1 to H3 in July, H3 to H5 in August, H6 to H9 in September and H8 to H10 in October (Table 5.1).

Dicrurus paradiseus of Northern India were moulting primaries H1 and H2 in June, H1 to H3 in July, H2 to H4 in August, H3 to H6 in September, H6 to H10 in October and H9 and H10 in November (Fig 459).

Dicrurus caerulescens of Northern India were moulting primaries H1 and H2 in June, H2 to H5 in July, H4 to H7 in August, H7 to H9 in

September and H8 to H10 in October (Fig 5 . 10).

Oriolus xanthornus of Northern India were moulting primaries H1 and H2 in June, H2 to H4 in July, H3 to H5 in August, H5 to H7 in September, H7 to H10 in October and H8 to H10 in November. In Southern India moult started in May. Primaries H1 were moulting in May, H1 and H2 in June, H2 to H5 in July , H4 to H7 in August, H6 to H9 in September and H7 to H10 in October (Fig 5. 11).

Oriolus oriolus, a migrant which moults in Northern India were renewing primaries H1 and H2 in June, H2 to H4 in July, H3 to H6 in August, H6 to H8 in September and October , H8 to H10 in November (Fig. 5.12).

Lanius excubitor, a summer visitor in Northern India were moulting primaries H1 and H2 in May, H1 to H4 in June, H4 and H5 in July, H4 to H7 in August, H7 to H10 in September, H8 to H10 in October and in H9 and H10 November (Fig. 5.13).

Lanius schach of Northern India, were moulting primaries H1 and H2 in May, H1 to H3 in June, H3 to H5 in July, H4 to H6 in August, H6 to H9 in September, H7 and H10 in October and H8 to H10 in November. In Southern India moult began in June. Primaries H1 to H3 were moulting June, H1 to H4 in July, H3 to H6 in August, H6 to H9 in September, H7 to H10 in October and H8 to H10 in November (Fig 5.14).

Lanius tepronotus an altitudinal migrant in Northern India began moult in May. Primaries H1 and H2 were moulting in May, H1 to H3 in

June, H3 to H5 in July, H4 and H5 in August, H6 and H7 in September, H7 to H10 in October and H9 and H10 in November (Fig. 5.15).

Pycnonotus cafer of Northern India were moulting primaries H1 and H2 in June, H1 to H4 in July, H1 to H3 in August, H5 to H8 in September, H7 to H10 in October, H8 to H10 in November and H10 in December (Fig 5.16). In Southern India they were moulting primaries H1 in June, H1 to H4 in July, H3 to H6 in August, H6 to H8 in September, H7 to H10 in October and November, H9 and H10 in December.

Pycnonotus jocosus of North India were moulting primaries H1 in June, H2 and H3 in July, H4 to H6 in August, H6 and H7 in September, H8 to H10 in October, H9 and H10 in November (Fig 5. 17).

Turdoides caudatus of Northern India were moulting H1 primaries in May, H1 to H3 in June, H3 and H4 in July, H4 to H6 in August, H6 to H10 in September, H8 to H10 in October and H9 and H10 in November. In Southern India moult began in April. Primaries H1 were moulting in April, H1 and H2 in May, H1 to H3 in June, H2 to H4 in July, H5 to H7 in August, H7 to H10 in September, H9 and H10 in October and November (Fig 5.18).

Turdoides malcolmi of Northern India were moulting primaries H1 in May, H1 and H2 in June, H3 to H5 in July, H5 and H6 in August, H7 to H9 in September, H8 to H10 in October, H9 and H10 in November (Fig. 5.19).

Turdoides striatus of Northern India were moulting primary feathers H1 and H2 in May, H1 to H3 in June, H3 to H5 in July, H5 to H7 in August, H6 to H9 in September, H7 to H10 in October as well as November (Fig 5.20). Southern Indian varieties primaries H1 and H2 were moulting in April, H1 to H3 in May, H1 to H4 in June, H3 to H6 in July, H4 to H8 in August, H6 to H10 in September, H8 to H10 in October and H8 to H10 in November.

Pomatorhinus schisticeps of Southern India were moulting primaries H1 and H2 in May, H1 to H4 in June, H3 and H4 in July, H4 to H6 in August, H6 to H8 in September, H7 to H10 in October and H9 and H10 in November (Fig.5. 21).

Garrulax jerdoni, a South Western Ghat species were moulting H1 primaries in May, H1 and H2 in June, H2 to H4 in July, H3 and H4 in August, H5 to H7 in September, H7 to H9 in October and H9 and H10 in November (Fig 5.22).

Garrulax pectoralis, distributed only in Northern India were moulting H1 and H2 primaries in June, H2 to H5 in July, H3 to H5 in August, H5 to H7 in September, H7 to H9 in October and H9 and H10 in November (Fig.5.23).

Garrulax *striatus* found only in Northern India were moulting primaries H1 and H2 in June, H1 to H4 in July, H3 to H6 in August, H5 to H7 in September, H7 to H10 in October and H8 to H10 in November (Fig.5.24).

In *Garrulax albogularis* distributed only in Himalaya and Northeast India were moulting primaries H1 and H2 moulting in May, H1 to H3 in June, H2 to H5 in July, H4 to H6 in August, H4 to H7 in September, H7 to H10 in October, H9 as well as H10 in November (Fig 5.25).

DISCUSSION

Primary moult started in May or June in all species studied except *Turdoides caudatus* and *Turdoides striatus* of Southern India in which moult initiated in April itself (Table 5.1). Moult of the primary feathers were observed in late April in *Turdoides* species of Southern Western Ghats (Zacharias *et al*.,1994).

Pattern of Primary Moult

Primary moult initiated from the proximal to distal feathers so that the primary feather 'H1' moulted first. This pattern was observed in all the species studied, confirmed by the presence of new and growing feathers at the proximal end and old ones towards the distal end (Yuri and Rohwer, 1997). The same pattern of moult was observed in *Turdoides* species of Baroda (Naik and Andrews,1966), in Bullfinches of Wytham Woods, Southern England (Newton and Rothery, 2000) and in Grey Vireos of Southwest U.S (Voelker,2000).

Time of moult for the individual bird is most immediately affected by the date of termination of last nesting attempt (Snow,1969). So the difference in time of moult initiation observed in both Northern and Southern Indian regions of a species might be due to difference in time of

completion of last clutch. A slight variation in time of primary moult initiation was observed in Bullfinches inhabiting Wytham Woods in Southern England (Newton and Rothery,2000). This variation in time of moult initiation is demonstrated in moulting a particular primary feather in the sequence in different months (Table 5.1). A few *Corvus macrorhynchos* were moulting primaries 'H1', in May while others in June (Fig 5.6). In the present study a *Turdoides striatus* from South India was moulting primaries H7 and H8 in August while two members of the same species were moulting H4 (Fig 5.20).So successive primaries are not shed at regular intervals but at intervals that differed from bird to bird as in Bullfinches of England (Newton,1967).

Season and duration of Primary Moult

In most of the species studied, termination of primary moult occurred between September and November (Table 5.1). In arid zone birds, moulting seasons is much more constant than breeding season year to year (Keast,1968). Moult is a more rapid process in passerines than in non-passerines and can be fitted into the annual cycle more easily (Snow,1969). In the present study primary moult of most of the species occurred between May/June to October/November taking sixteen to twenty weeks. Primary moult in House Sparrows of Baroda extended from April/May to December/January (Mathew and Naik, 1986) and of House Swift from February to September/October (Naik, 1969). In resident birds of Kodaikanal hills primary moult takes place between July and August

(Balachandran,1999). But in the present study no bird was found to complete moult before September. Primary moult is more prolonged in birds of Thirupathi Hills, Eastern Ghats (Balachandran *et al.*,1995). In Whitebrowed Bulbul it occurred from mid June to early November, in Redwhiskered Bulbul, from mid August to third week of November and in Redventd Bulbul from mid July to end of October.

Marked regional variations in time of moult initiation was not observed in the birds studied, as it began in all species from the middle of April to second week of June. The Glossy Starlings of tropical regions like Kenya, Africa also initiated moult in April, May and June (Dittami, 1987).

Primary moult occurs mainly in the dry seasons and provided fresh plumage for the ensuing wet periods (Miller,1961). In all birds observed in the present study from Northern and Southern India, moult started in the dry summer months of April to June and terminated in the period from September to December (Table 5.1). Since food deprivation affects the moulting birds with reduction in growth rate of moulting feathers (Swaddle and Witter, 1997), normal sized primary feathers observed in the birds studied might be due to abundance of food in the study area. In the present study, birds moulted their primary feathers during the hot summer season and heavy rains of South-West monsoon (Table 5.1). Rich supplies of plant food available during these seasons promote insect abundance (Katti and Price 1996; Arun and Vijayan, 2004).

Insect Abundance and Primary moult

Moult is costly in terms of time and energy required to produce new feathers, increased thermoregulation cost caused by impaired feathers and increased flight cost due to reduced wing area (Netto and Gosler,2006). In starlings of South Africa moult occurred while the birds were resident in an area of abundant food and so coincided with the breeding season (Craig,1983). A few species of birds would move to areas of food abundance during the season of moult (Voelker,2000). In the Indian bio-geographic regions, insects which form the major food of the different birds studied, become abundant by April/May in regions like Western Ghats (Shukkur,1978) and in Eastern Ghats (Price,1979). Insects will also be abundant during and after South-West monsoon in arid regions (Gaston, 1981). Insect abundance occurs during the South-West monsoon in Deccan Peninsula (Arun and Vijayan,2004; Reddy and Venkataiah,1990). Arthropod population increased in this region with dry season flower and leaf growth, in particular with the tremendous growth of new leaves, towards the end of April to high levels during monsoon season. Primary moult season coincides with the season of insect abundance in the present study (Table 5.1).

Number of Primary Feathers Moulting Simultaneously

Usually primary feathers are shed one at a time and the next one is shed only after the preceding one is grown fully. The same pattern of primary moult occurs in Zebra Finches of Southeast Australia (Zann, 1985). But occasionally a primary feather may start moulting before the preceding

one completes its growth. Two or three primary feathers moulting together is frequently observed. In the present study simultaneous moult of two primary feathers on each wing was observed (Table 5.2). Three primary feathers moulting simultaneously was also observed but the frequency was more for the terminal feathers (Table 5.3). Two primaries moulting simultaneously on each wing was reported in Redwinged and Pied Starlinga of Australia (Craig,1983) and in *Turdoides* sp. of Calicut, Kerala (Zacharias *et al*., 1994), Simultaneous moult of more than two feathers were observed in House Swifts of Gujarat (Naik and Naik,1965). Simultaneous moulting of three feathers of a wing was reported in Cape Glossy Starling (Craig, 1983). Several feathers growing simultaneously at all times were observed in Lesser Redpolls of Northumberland, England (Evans,1966).

Species considered for the present study had long moult periods and first primaries were shed from April to June and last primaries between September and December (Table 5.1). In most small passerines, the moult of flight feathers spans the entire moult period (Newton, 1967). In many groups of birds the moult begins each year on a definite seasonal schedule (Payne,1969).The duration of primary moult is a species-specific trait and it does not vary significantly between regions (Hulley *et al*.,2004).

So primary moult is prolonged in the Indian passerines and it depends on seasonal abundance of food. It begins after the peak breeding period, a time of intermittent summer rains and continue during the heavy showers of South West monsoon and the period after that. It requires sixteen to twenty

weeks for its completion. No major difference in time and tempo of moult was observed between birds of the same species in Northern and Southern India or between members of a genus or family. The pattern of moult was same in all the birds studied.

Table 5.1 Monthly data of the number of insectivorous birds moulting different primary feathers in Northern and Southern India during the study period

Species Studied	Region	Period of moult of the different primary feathers									
		H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
Acridotheres fuscus	N.India	June-July	June-July	June -Aug	August	Aug-Sept	Aug-Sept	Spt-Oct	Sept-Nov	Oct-Nov	Oct-Dec
Acridotheres tristis	N.India	June-Aug	June-Aug	June -Aug	July-Aug	Aug-Sept	Sept-Nov	Sept-Nov	Sept-Nov	Sept-Dec	Nov-Dec
Acridotheres tristis	S.India	June-Aug	June-Aug	July-Aug	July-Aug	September	September	Sept-Oct	Sept-Oct	Oct-Dec	Oct-Dec
Sturnus malabaricus	N.India	June-July	June-July	July-Aug	August	August		September	September	Sept-Nov	Sept-Nov
Sturnus malabaricus	S.India	June-July	July	July-Aug	August	August	September	September	Sept-Oct	Sept-Nov	Oct-Nov
Sturnus contra	N.India	June-July	June-July	July-Aug	July-Sept	Aug-Oct	Sept-Oct	Sept-Oct	Oct-Nov	Oct-Nov	Nov
Corvus splendens	N.India	May-June	May-June	June-July	June-Aug	July-Aug	Aug-Sept	September	Sept-Oct	Sept-Nov	Oct-Nov
Corvus splendens	S.India	May-July	May-July	June-July	June-July	August	Aug-Sept	Aug-Oct	Sept-Oct	Sept-Nov	Oct-Nov
Corvus macrorhynchos	N.India	May-July	May-July	June-July	July		August	Aug-Oct	Aug-Nov	Sept-Nov	Sept-Nov
Corvus macrorhynchos	S.India	May-June	May-July	May-July	June-July	July	August	August	Sept-Oct	Sept-Nov	Oct-Nov
Dendrocitta vagabunda	N.India	May-June	May-July	June-Aug	June-Aug	Aug-Sept	September	September	Sept-Nov	Oct-Nov	Oct-Nov
Dendrocitta vagabunda	S.India	May-July	May-July	June-Aug	July-Aug	August	August	Aug-Sept	Sept-Oct	Sept-Nov	Sept-Nov
Dicrurus adsimilis	N.India	June-July	July	July-Aug	August	Aug-Sept	September	Sept-Oct	Sept-Oct	Oct-Nov	Oct-Nov
Dicrurus adsimilis	S.India	June-July	July	July-Aug	August	August	September	October	Sept-Oct	Sept-Oct	October
Dicrurus paradiseus	N.India	June-July	June-Aug	July-Sept	Aug-Sept	September	Sept-Oct	October	October	Oct-Nov	Oct-Nov
Dicrurus caerulescens	N.India	June	June-July	July	July-Aug	July-Aug	August	Aug-Sept	Sept-Oct	Sept-Oct	October
Oriolus xanthornus	N.India	June	june-July	July-Aug	July-Aug	Aug-Sept	September	Sept-Oct	Oct-Nov	Oct-Nov	Oct-Nov
Oriolus xanthornus	S.India	May-June	June-July	July	July-Aug	July-Aug	Aug-Sept	Aug-Oct	Sept-Oct	Sept-Oct	October
Oriolus oriolus	N.India	June	June-July	July-Aug	July-Aug	August	Aug-Oct	Sept-Oct	Sept-Nov	November	November

Continued ……..

Species Studied	Region	Period of moult of the different primary feathers									
		H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
Lanius excubitor	N.India	May-June	May-June	June	June-Aug	July-Aug	August	Aug-Sept	Sept-Oct	Sept-Nov	Sept-Nov
Lanius schach	N.India	May-June	May-June	June-July	June-July	July-Aug	Aug-Sept	Sept-Oct	Sept-Nov	Sept-Nov	Oct-Nov
Lanius schach	S.India	June-July	June-July	June-Aug	June-July	August	September	Sept-Oct	Sept-Nov	Sept-Nov	Oct-Nov
Lanius tepronotus	S.India	May-June	May-June	June-July	July-Aug	July-Aug	September	Sept-Oct	October	Oct-Nov	Oct-Nov
Pycnonotus cafer	N.India	June-Aug	June-Aug	July-Aug	July	September	September	Sept-Oct	Sept-Nov	Oct-Nov	Oct-Dec
Pycnonotus cafer	S.India	June-July	July	July-Aug	July-Aug	August	Aug-Sept	Sept-Nov	Sept-Nov	Oct-Dec	Oct-Dec
Pycnonotus jocosus	S.India	June	July	July	Aug	August	Aug-Sept	September	October	Oct-Nov	Oct-Nov
Turdoides caudatus	N.India	May-June	June	June-July	July-Aug	August	Aug-Sept	September	Sept-Oct	Sept-Nov	Sept-Nov
Turdoides caudatus	S.India	April-June	May-July	June-July	July	August	August	Aug-Sept	October	Sept-Nov	Sept-Nov
Turdoides malcolmi	N.India	May-June	June	July	July	July-Aug	August	September	Sept-Oct	Sept-Nov	Oct-Nov
Turdoides striatus	N.India	May-June	May-June	June-July	July	July-Aug	Aug-Sept	Aug-Nov	Sept-Nov	Sept-Nov	Oct-Nov
Turdoides striatus	S.India	April-June	April-June	May-July	June-Aug	July-Aug	July-Sept	Aug-Oct	Aug-Nov	Sept-Nov	Oct-Nov
Pomatorhinus schisticeps	N.India	May-June	May-July	June-July	June-Aug	August	Aug-Sept	Sept-Oct	Sept-Oct	Oct-Nov	Oct-Nov
Garrulax jerdoni	S.India	May-June	June-July	July-Aug	July-Aug	September	September	Sept-Oct	October	Oct-Nov	November
Garrulax pectoralis	N.India	June-July	June-July	July-Aug	July-Aug	July-Sept	September	Sept-Oct	October	Oct-Nov	November
Garrulax striatus	N.India	June-July	June-July	July-Aug	July-Aug	Aug-Sept	Aug-Sept	Sept-Oct	Oct-Nov	Oct-Nov	Oct-Nov
Garrulax albogularis	N.India	May-June	May-July	June-July	July-Sept	July-Sept	Aug-Sept	Sept-Oct	October	Oct-Nov	Oct-Nov

Table 5.2 Frequency of birds moulting two primary feathers simultaneously

Species	Region	No.of birds moulting two Primaries moulting simultaneously								
		H1 & H2	H2 & H3	H3 & H4	H4 & H5	H5 & H6	H6 & H8	H8 & H8	H8 & H9	H9 & H10
Acridotheres fuscus	N.India					2				1
Acridotheres tristis	N.India				1		2			2
Acridotheres tristis	S.India						2			2
Sturnus contra	N.India								1	1
Sturnus malabaricus	N.India		1					2		1
Dendrocitta vagabunda	N.India				2				2	1
Dicrurus adsimilis	N.India				1			1		
Dicrurus adsimilis	S.India				1				1	2
Dicrurus paradiseus	S.India				1					1
Corvus splendens	N.India					3	1			1
Corvus splendens	S.India		2							1
Corvus macrorhynchos	N.India						1			2
Corvus macrorhynchos	S.India								1	2
Oriolus xanthorneus	N.India							2		1
Oriolus xanthorneus	S.India				2				3	
Lanius schach	N.India					1		1		2
Lanius schach	S.India					2	1			2
Lanius excubitor	N.India		1							2
Pycnonotus cafer	S.India		1					4		2
Turdoides caudatus	N.India		1					1		2
Turdoides caudatus	S.India	1			1					2
Turdoides striatus	N.India			1		1	1		1	2
Turdoides striatus	S.India		2		1	1		2		3
Garrulax striatus	N.India	1		2				1		2
Garrulax jerdoni	S.India					1		1	1	

Table 5.3 Frequency of birds moulting three primary feathers simultaneously

Species	Region	Primary feathers moulting simultaneously					
		H1 -H3	H2 -H4	H3 -H5	H6 -H8	H8 -H9	H8 -H10
Acridotheres tristis	N.India						1
Dendrocitta vagabunda	N.India						1
Dicrurus adsimilis	N.India					2	
Dicrurus adsimilis	S.India						2
Corvus splendens	N.India						1
Corvus macrorhynchos	N.India				1		1
Corvus macrorhynchos	S.India						2
Oriolus xanthornus	N.India						2
Lanius tepronotus	N.India					1	
Turdoides caudatus	S.India	1					
Turdoides striatus	N.India				1		1
Garrulax striatus	N.India					1	
Garrulax jerdoni	S.India		1			1	
Garrulax albogularis	N.India						2

Fig 5.1 Monthly data of the number of *Acridotheres fuscus* moulting primary feathers in North Indian region during the study period

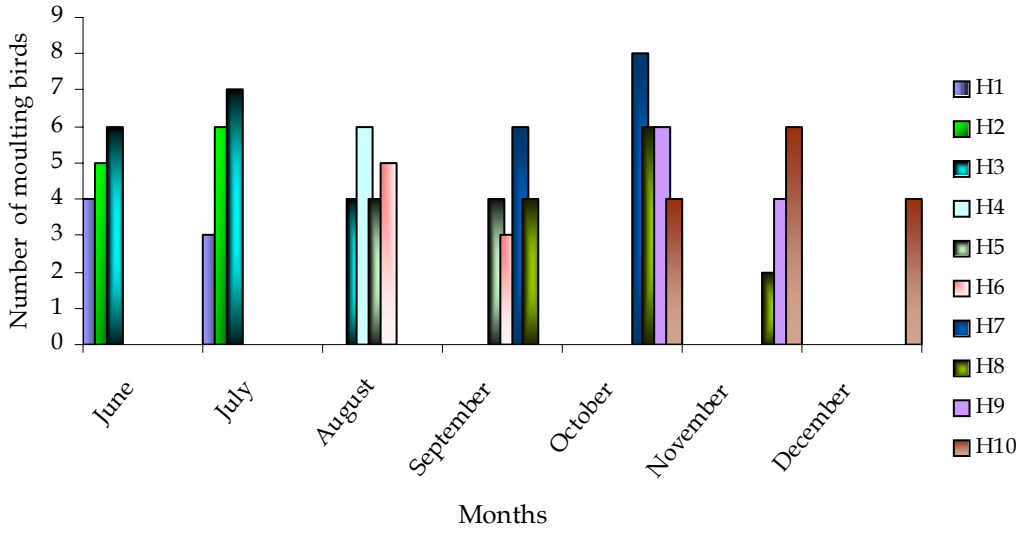


Fig 5.2 Monthly data of the number of *Acridotheres tristis* moulting primary feathers in North & South Indian regions during the study period

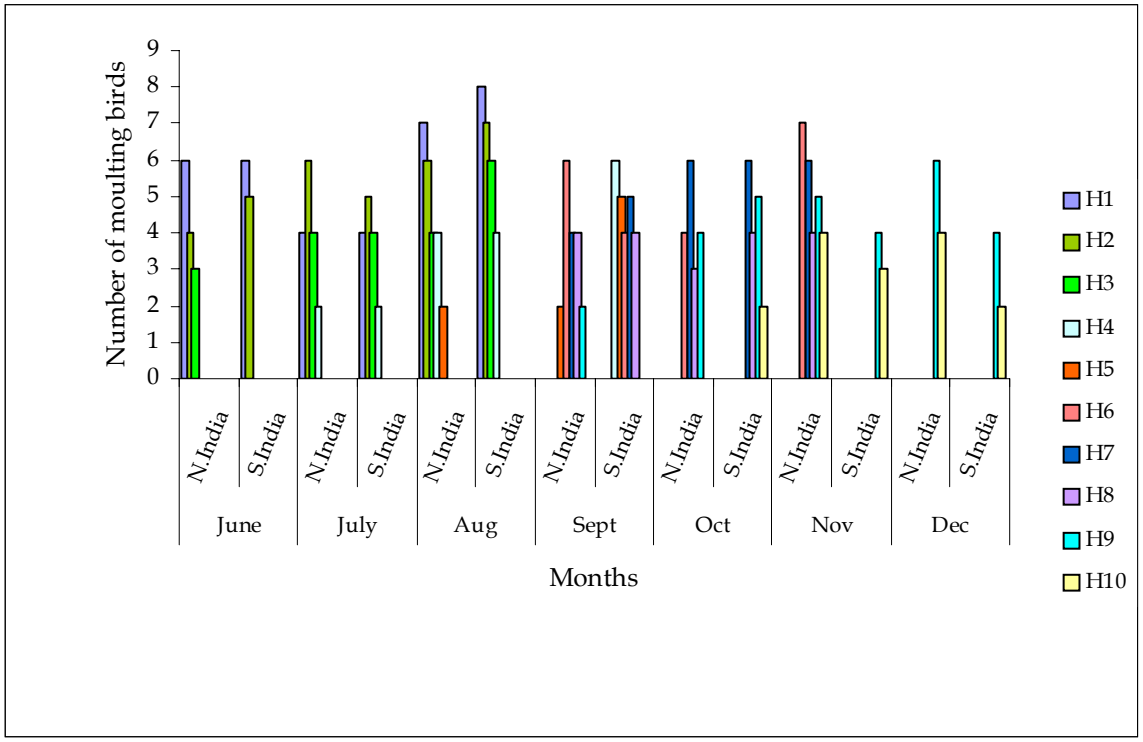


Fig 5.3 Monthly data of the number of *Sturnus malabaricus* moulting primary feathers in North & South Indian regions during the study period

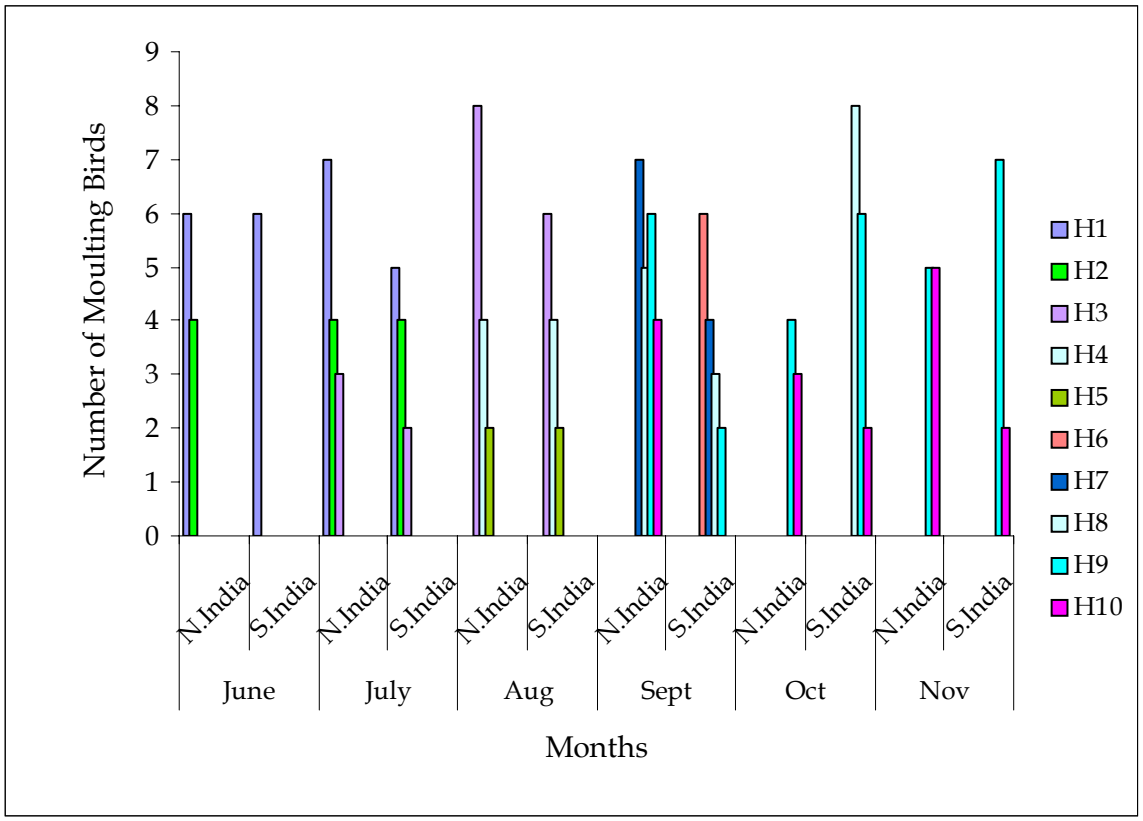


Fig 5.4 Monthly data of the number of *Sturnus contra* moulting primary feathers in North Indian region during the study period

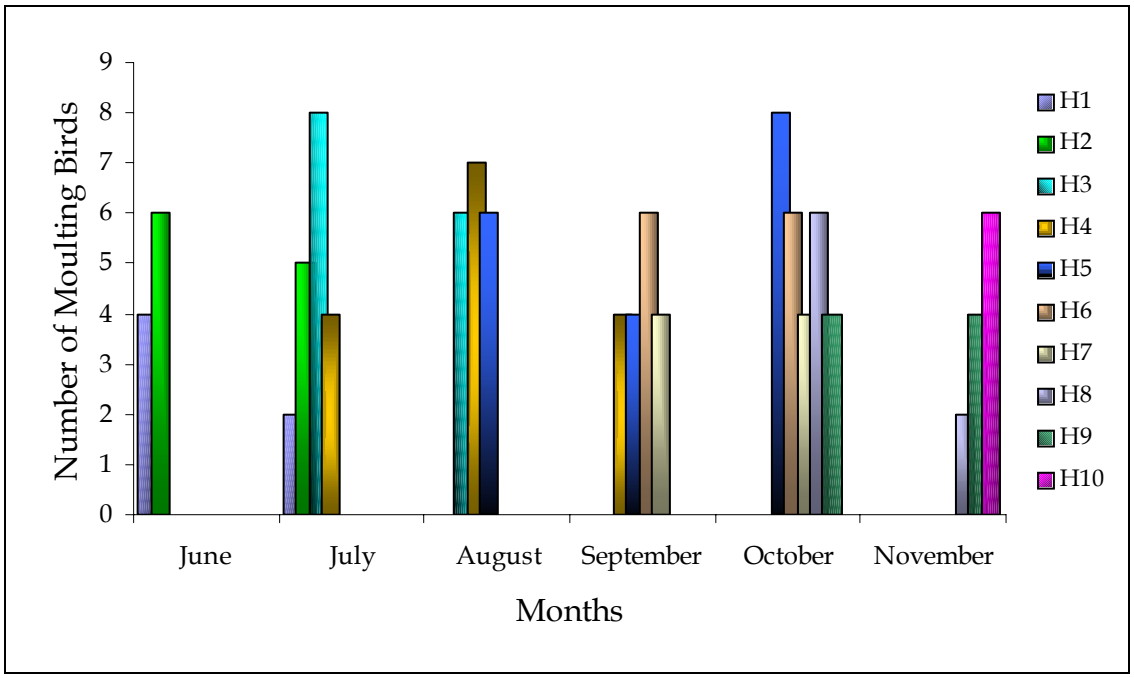


Fig 5.5 Monthly data of the number of *Corvus splendens* moulting primary feathers in North & South Indian regions during the study period

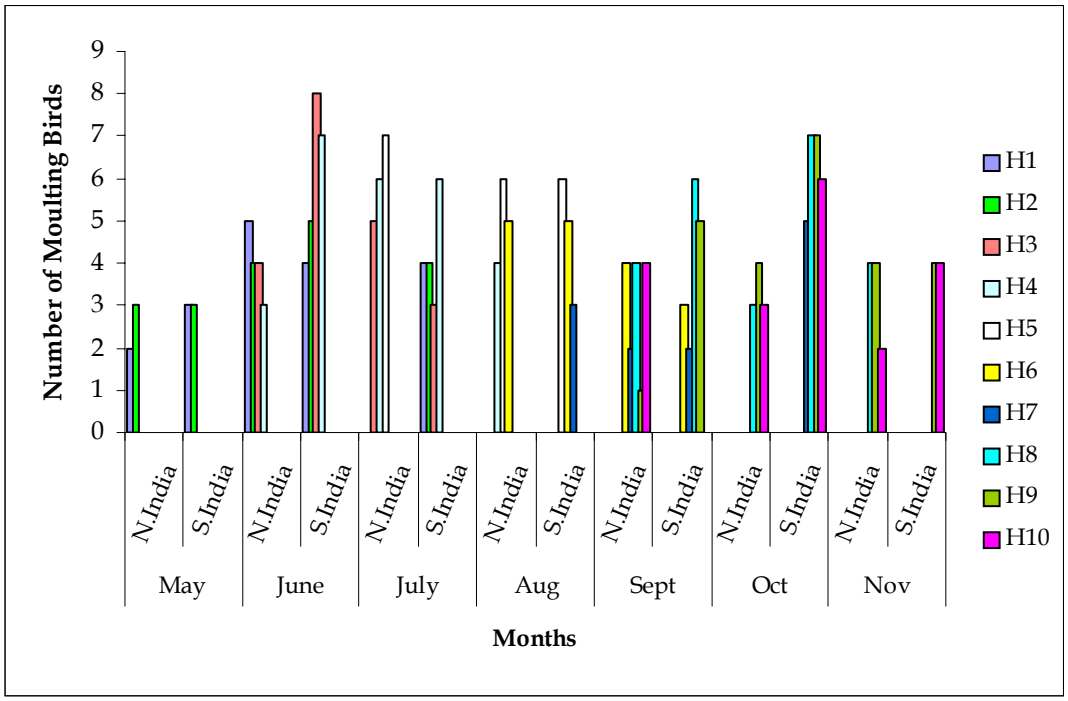


Fig 5.6 Monthly data of the number of *Corvus macrorhynchos* moulting primary feathers in North & South Indian regions during the study period

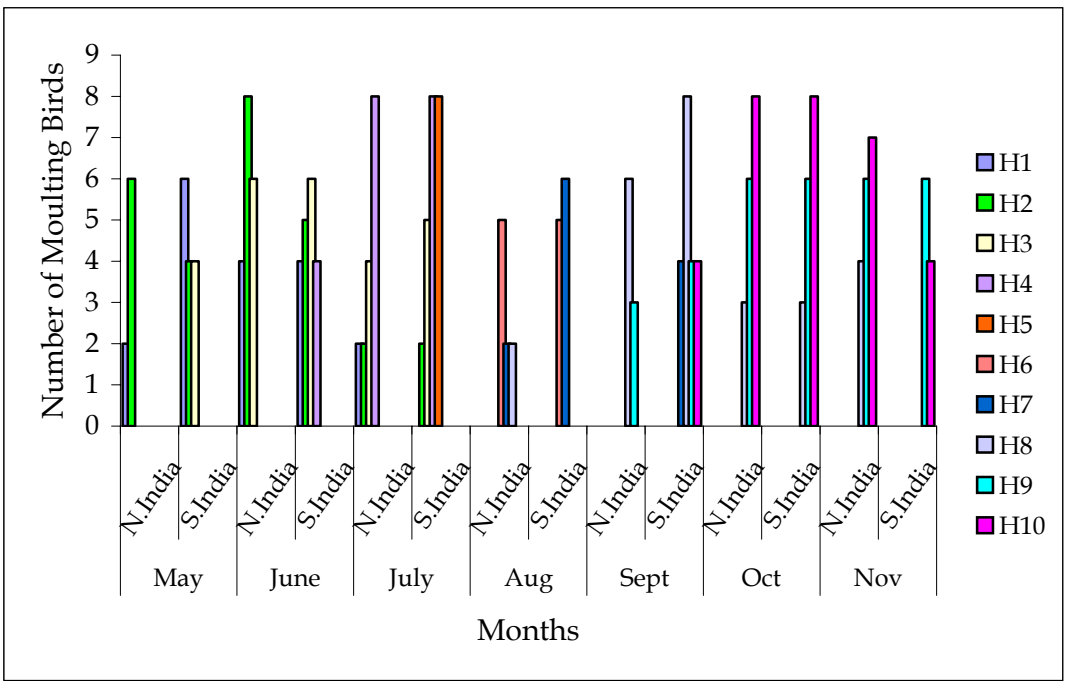


Fig 5.7 Monthly data of the number of *Dendrocitta vagabunda* moulting primary feathers in North & South Indian regions during the study period

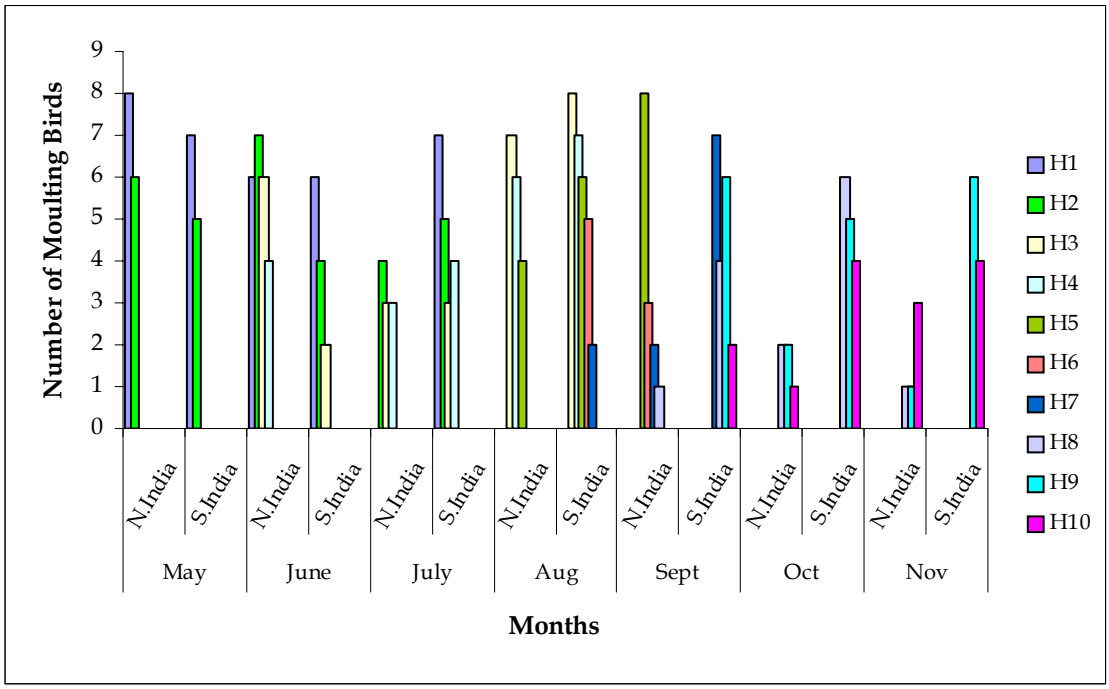


Fig 5.8 Monthly data of the number of *Dicrurus adsimilis* moulting primary feathers in North & South Indian regions during the study period

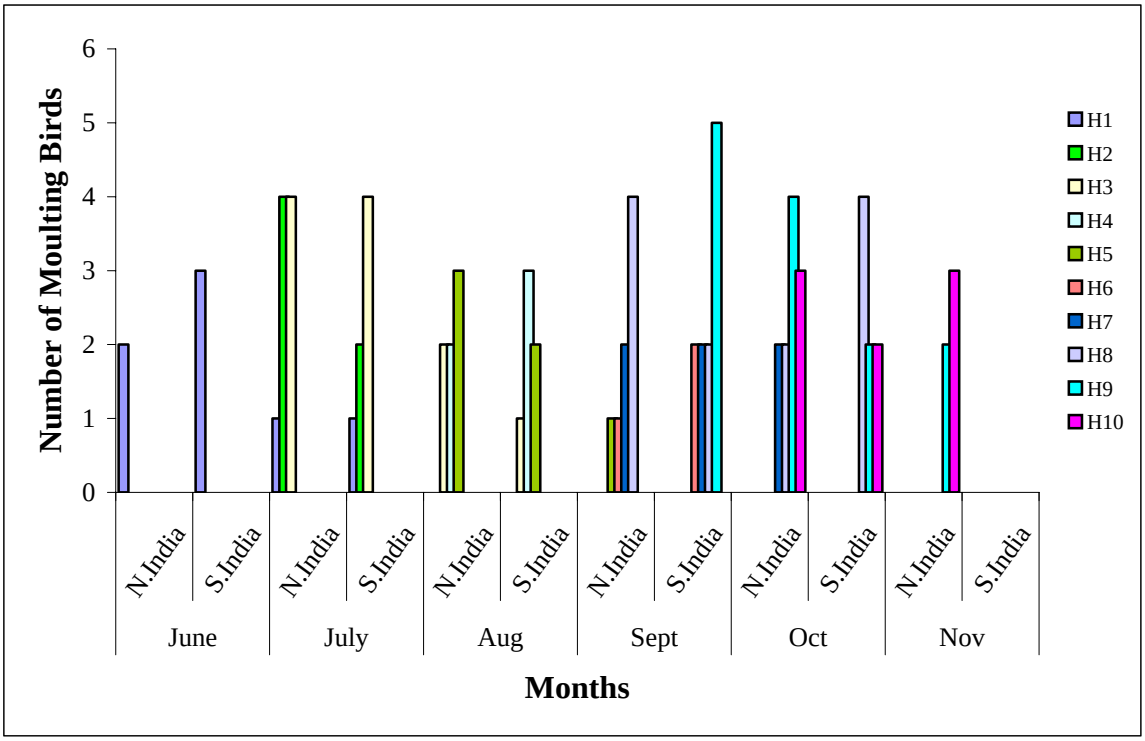


Fig 5. 9 Monthly data of the number of *Dicrurus paradiseus* moulting primary feathers in North Indian region during the study period

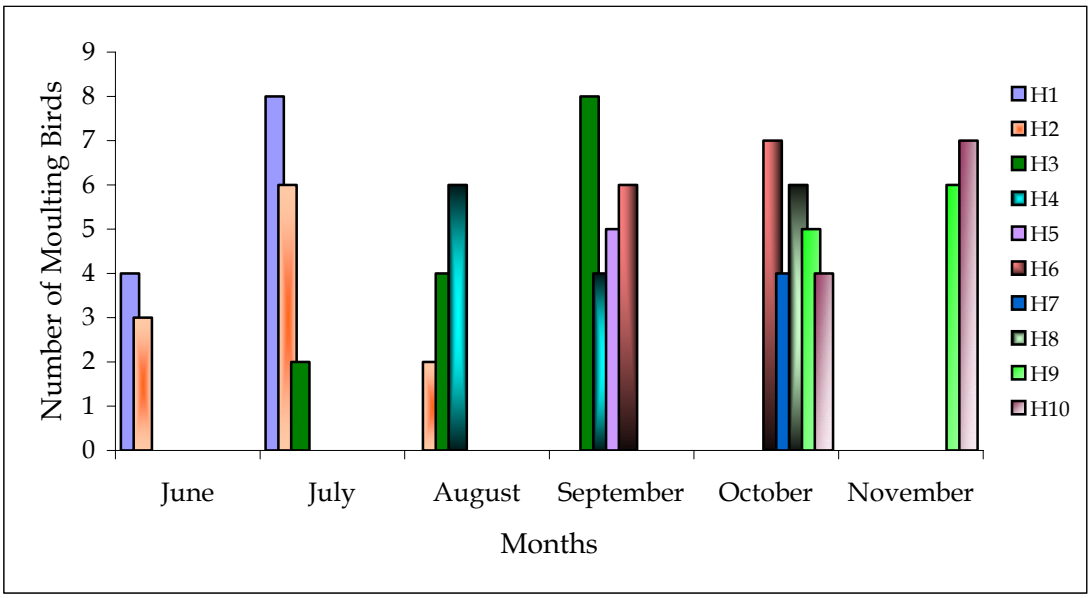


Fig 5.10 Monthly data of the number of *Dicrurus caerulescens* moulting primary feathers in North Indian region during the study period

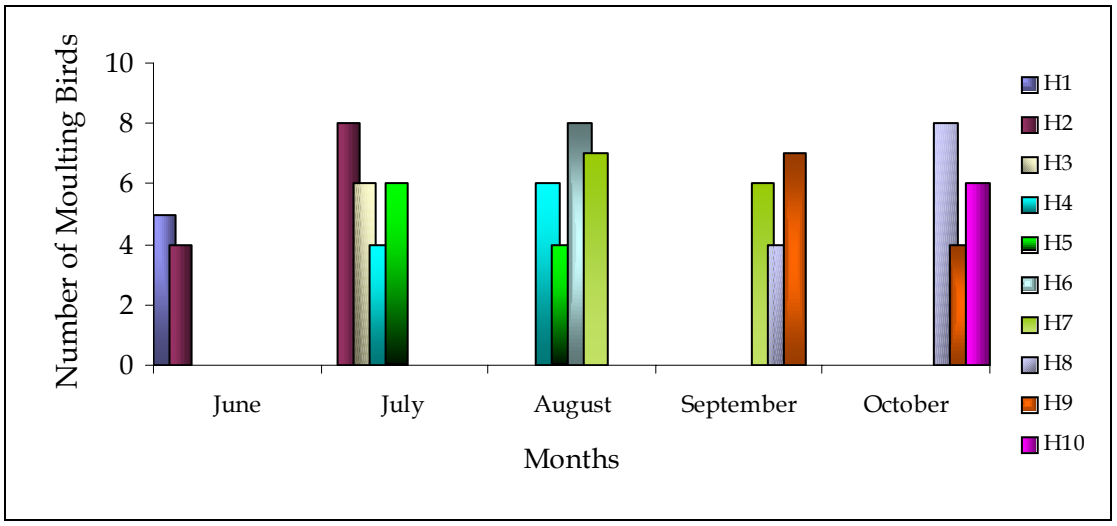


Fig 5.11 Monthly data of the number of *Oriolus xanthorns* moulting primary feathers in North Indian regions during the study period

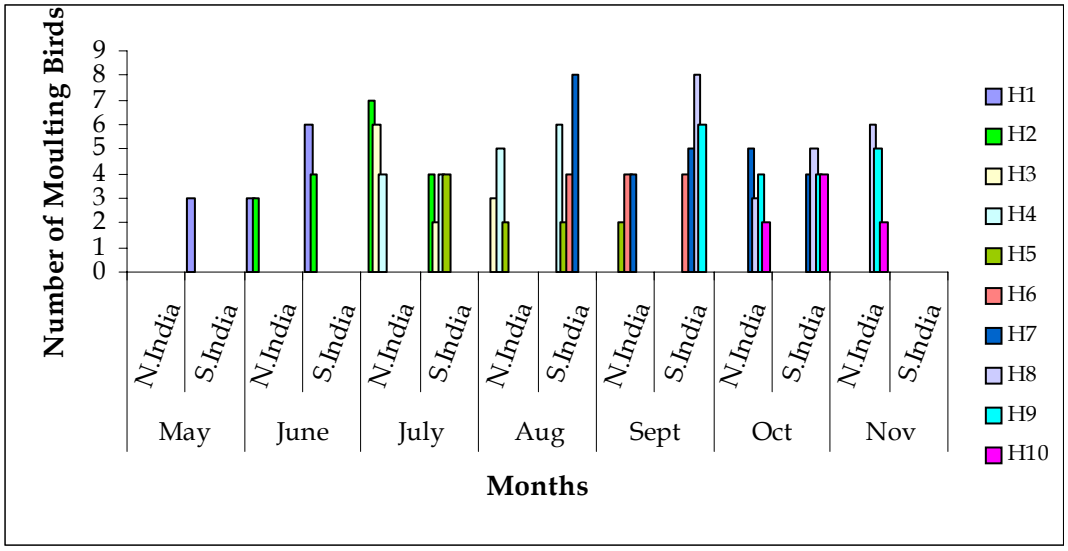


Fig 5.12 Monthly data of the number of *Oriolus oriolus* moulting primary feathers in North Indian region during the study period

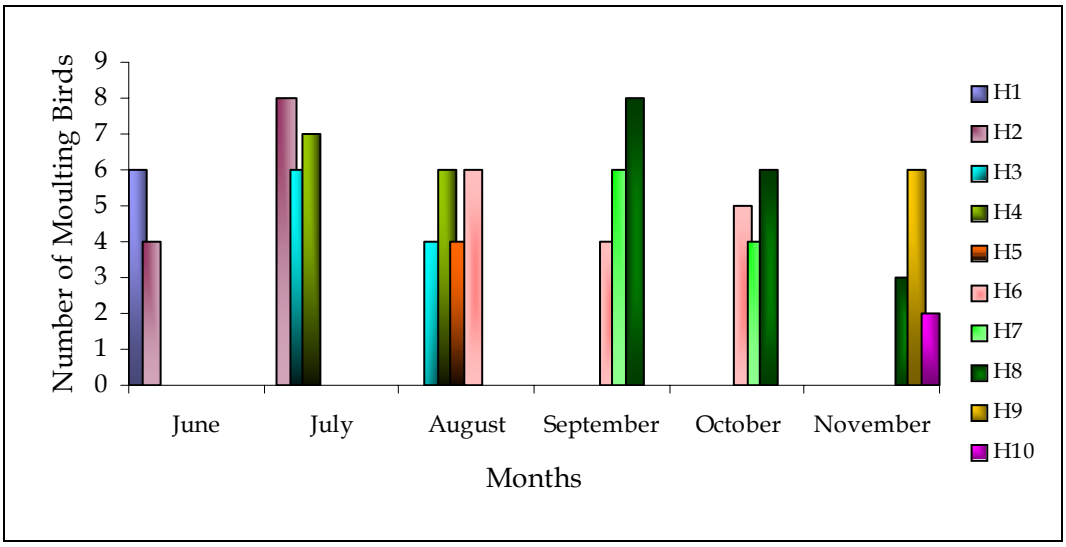


Fig 5.13 Monthly data of the number of *Lanius excubitor* moulting primary feathers in North Indian region during the study period

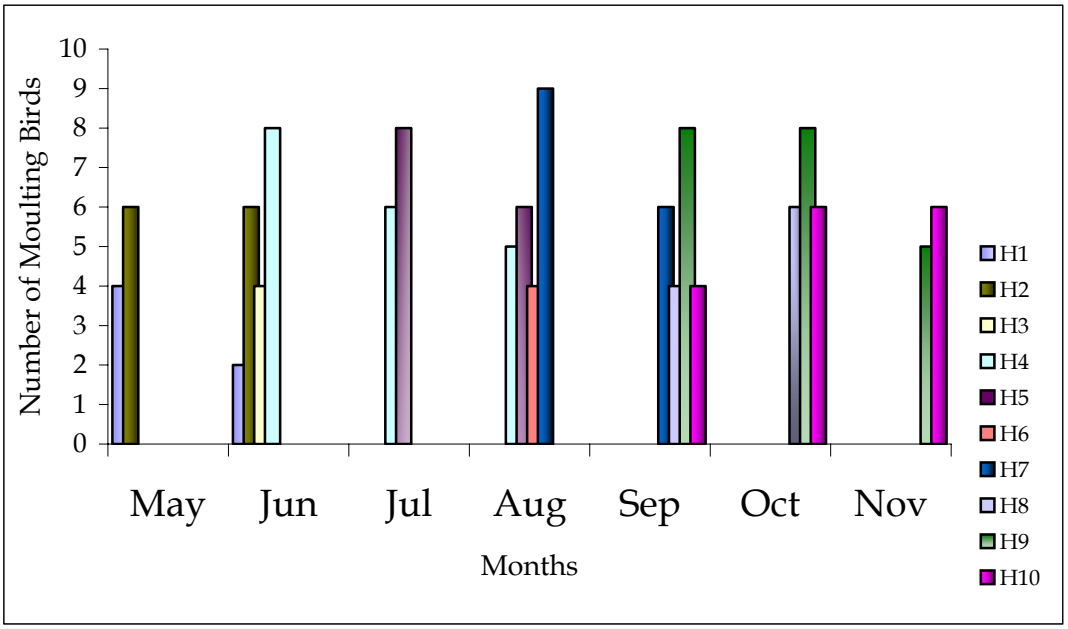


Fig 5.14 Monthly data of the number of *Lanius schach* moulting primary feathers in North & South Indian regions during the study period

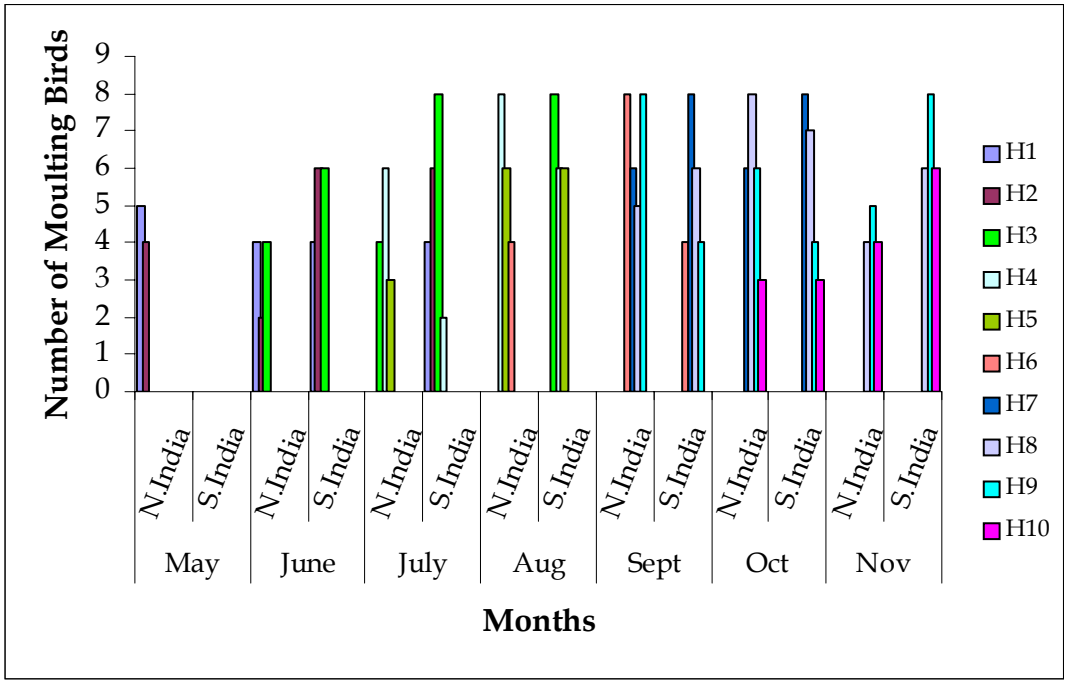


Fig 5.15 Monthly data of the number of *Lanius tepronotus* moulting primary feathers in North Indian region during the study period

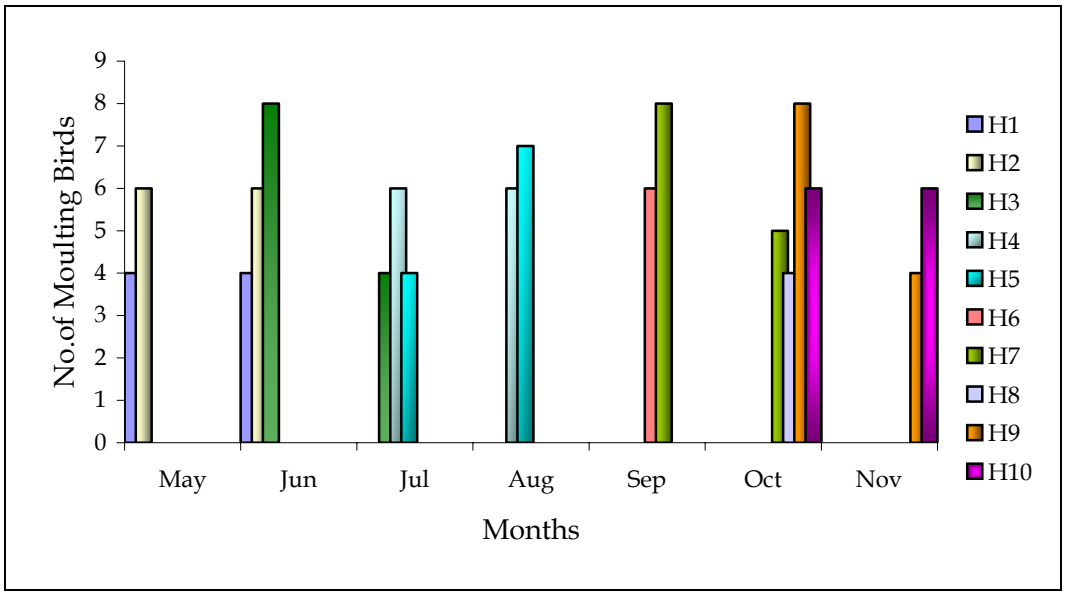


Fig 5.16 Monthly data of the number of *Pycnonotus cafer* moulting primary feathers in North & South Indian regions during the study period

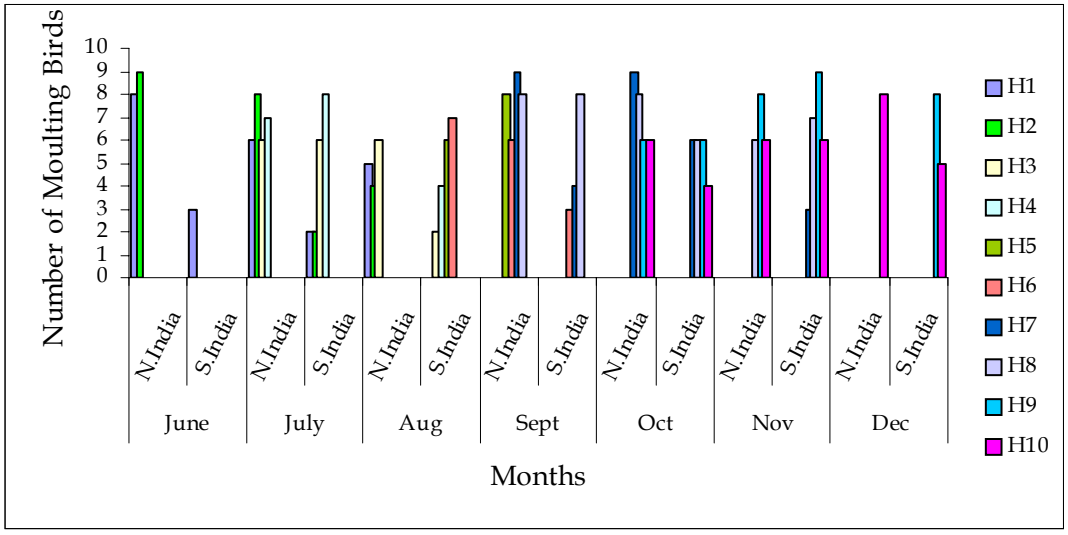


Fig 5.17 Monthly data of the number of *Pycnonotus jocosus* moulting primary feathers in North Indian region during the study period

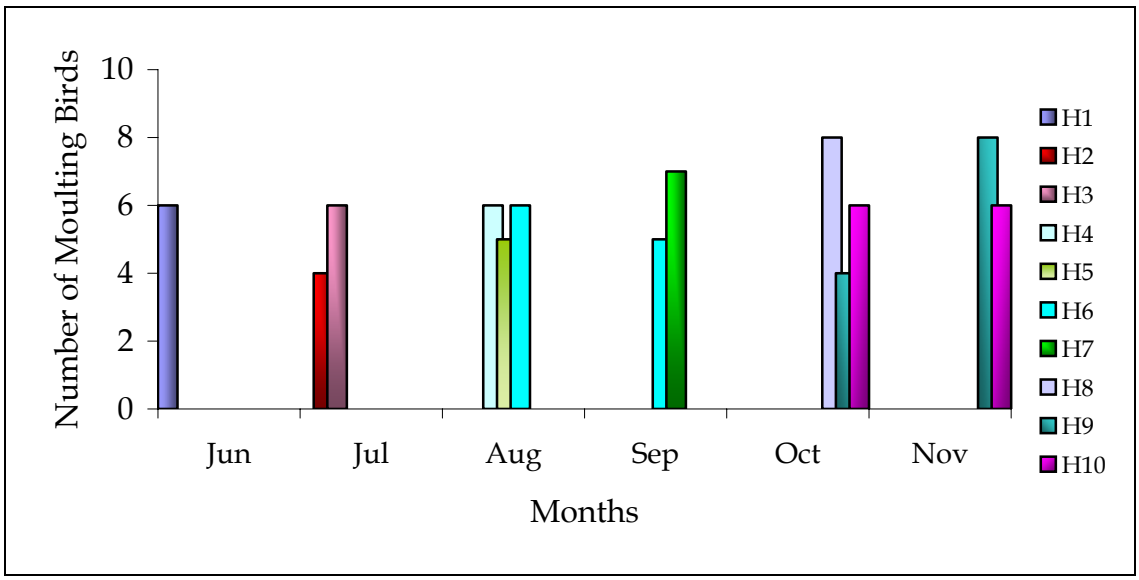


Fig 5.18 Monthly data of the number of *Turdoides caudatus* moulting primary feathers in North & South Indian regions during the study period

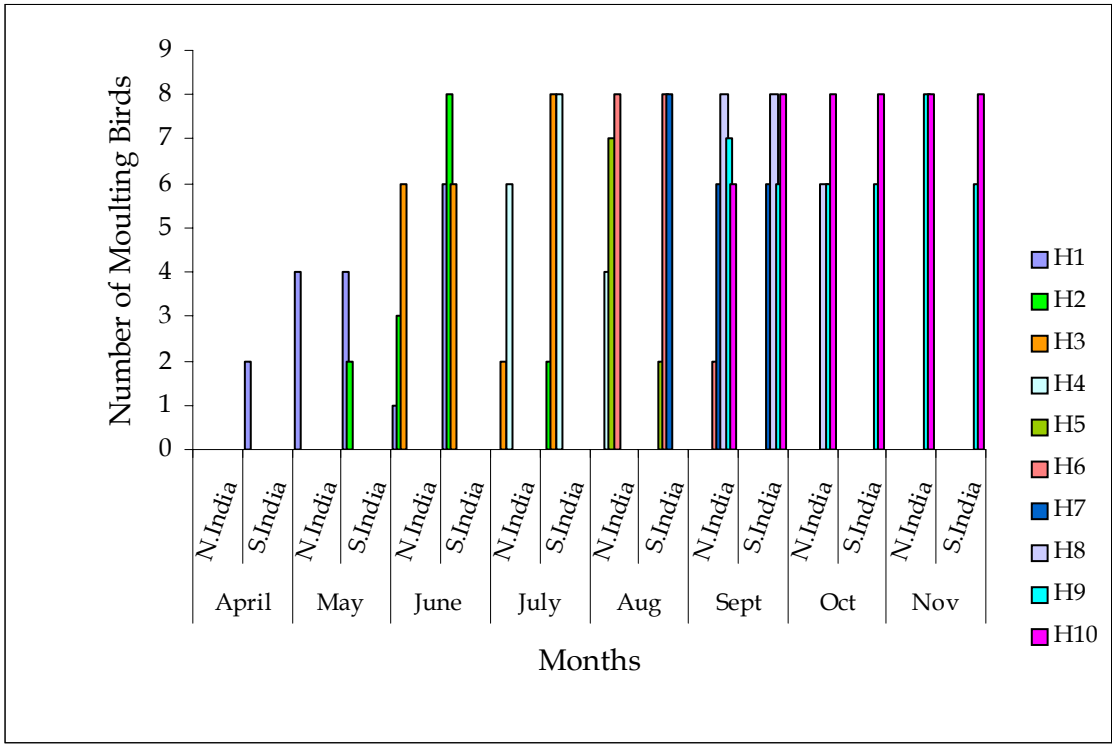


Fig 4.19 Monthly data of the number of *Turdoides malcolmi* moulting primary feathers in North Indian region during the study period

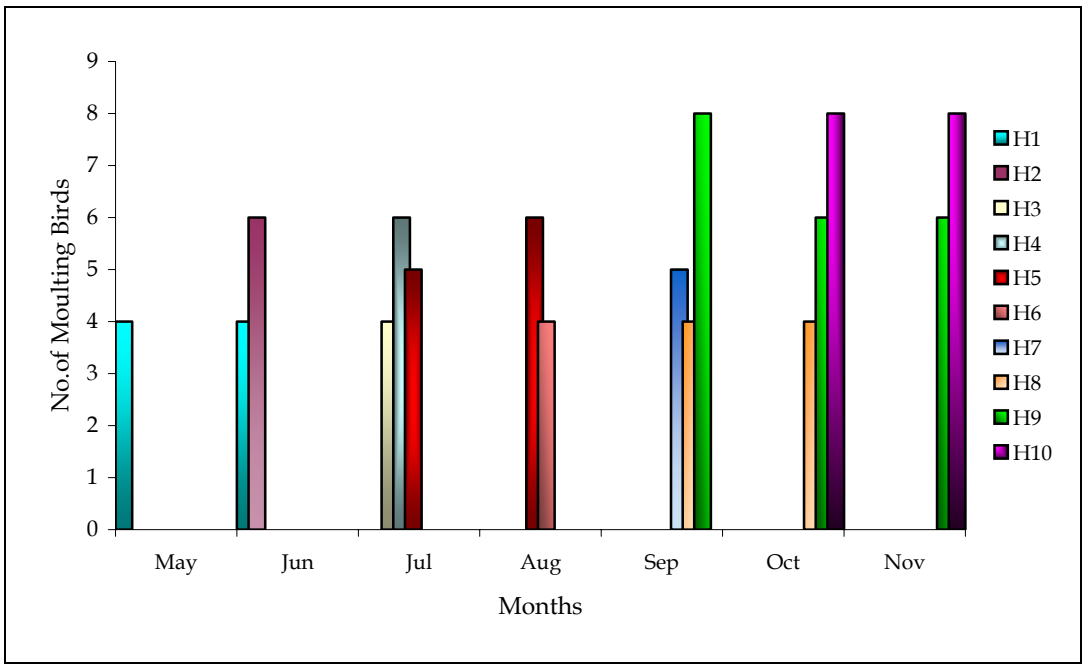


Fig 5. 20 Monthly data of the number of *Turdoides striatus* moulting primary feathers in North & South Indian regions during the study period

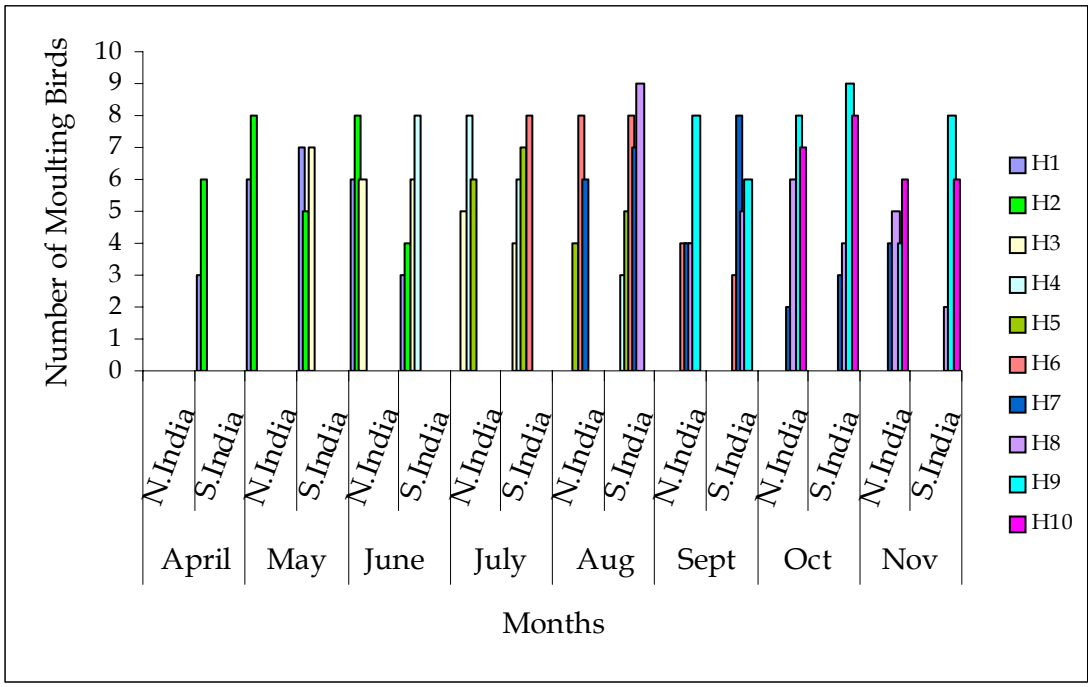


Fig 5.21 Monthly data of the number of *Pomatorhinus schisticeps* moulting primary feathers in North Indian region during the study period

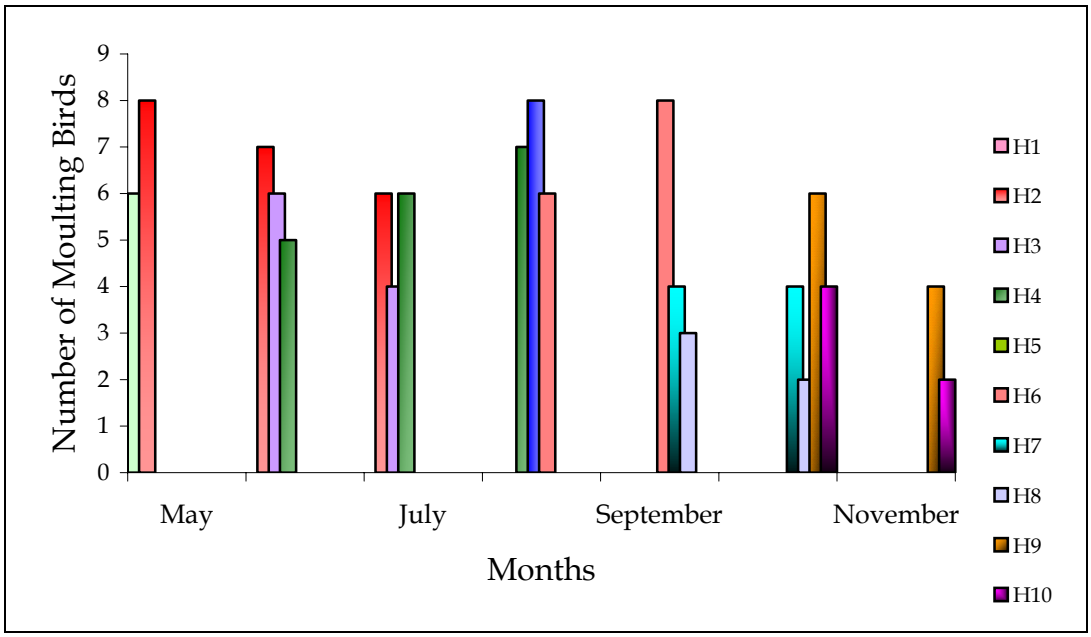


Fig 5.22 Monthly data of the number of *Garrulax jerdoni* moulting primary feathersin Western Ghats during the study period

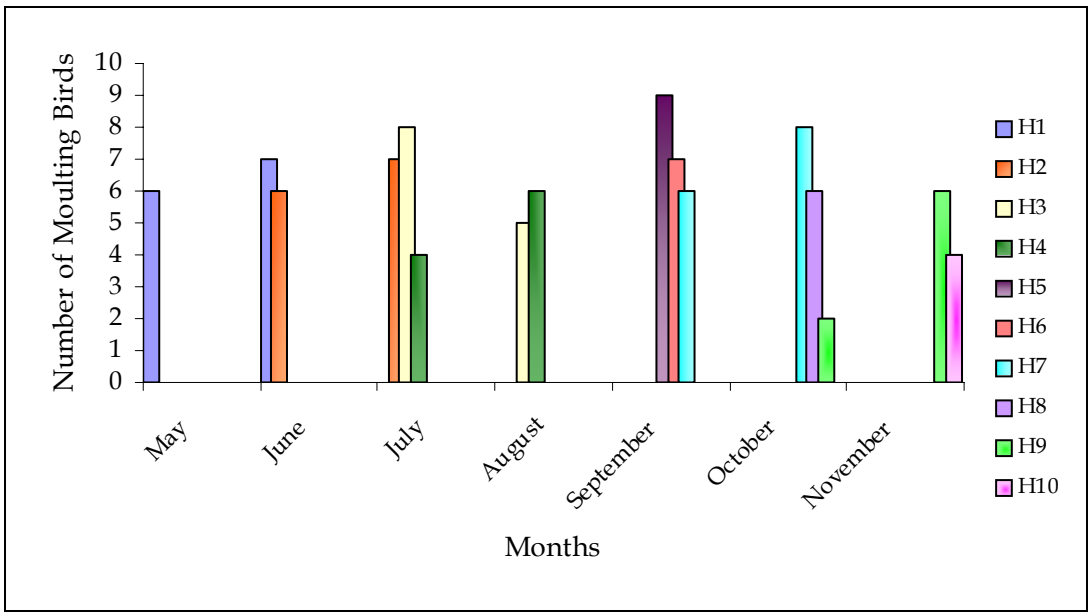


Fig 5. 23 Monthly data of the number of *Garrulax pectoralis* moulting primary feathers in North Indian region during the study period

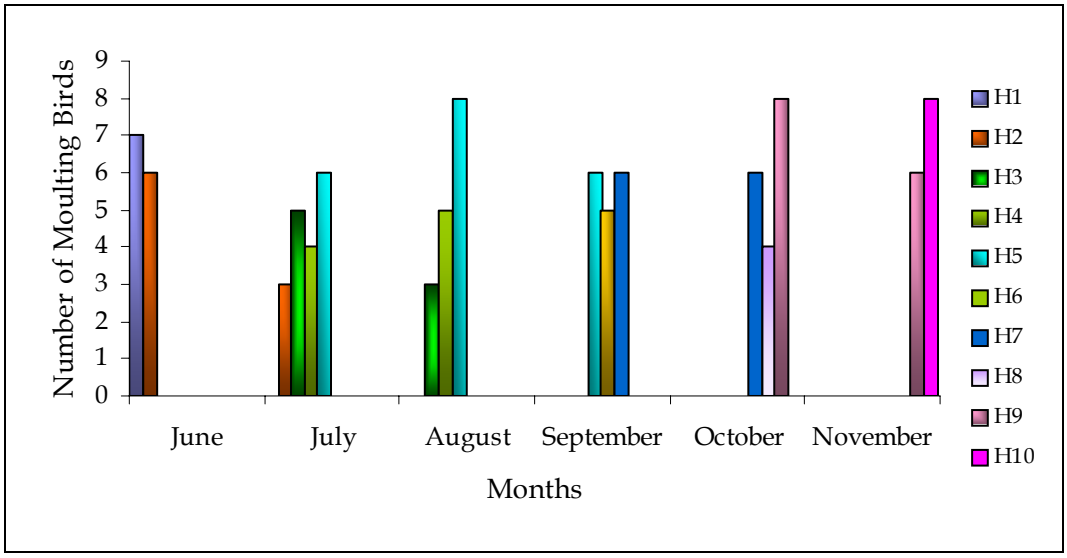


Fig 5.24 Monthly data of the number of *Garrulax striatus* moulting primary feathers in North Indian region during the study period

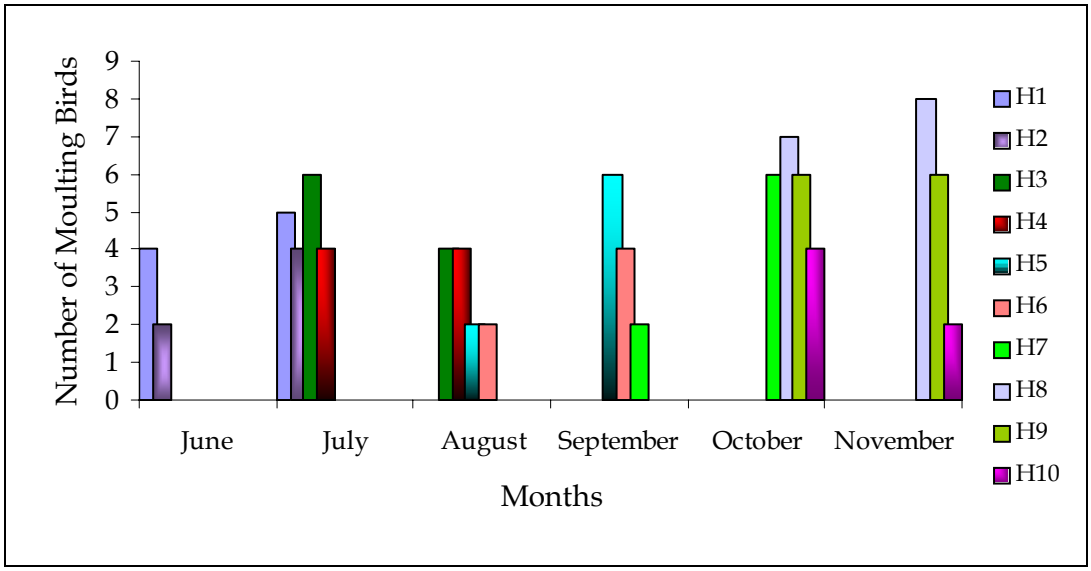


Fig 5.25 Monthly data of the number of *Garrulax albogularis* moulting primary feathers in North Indian region during the study period

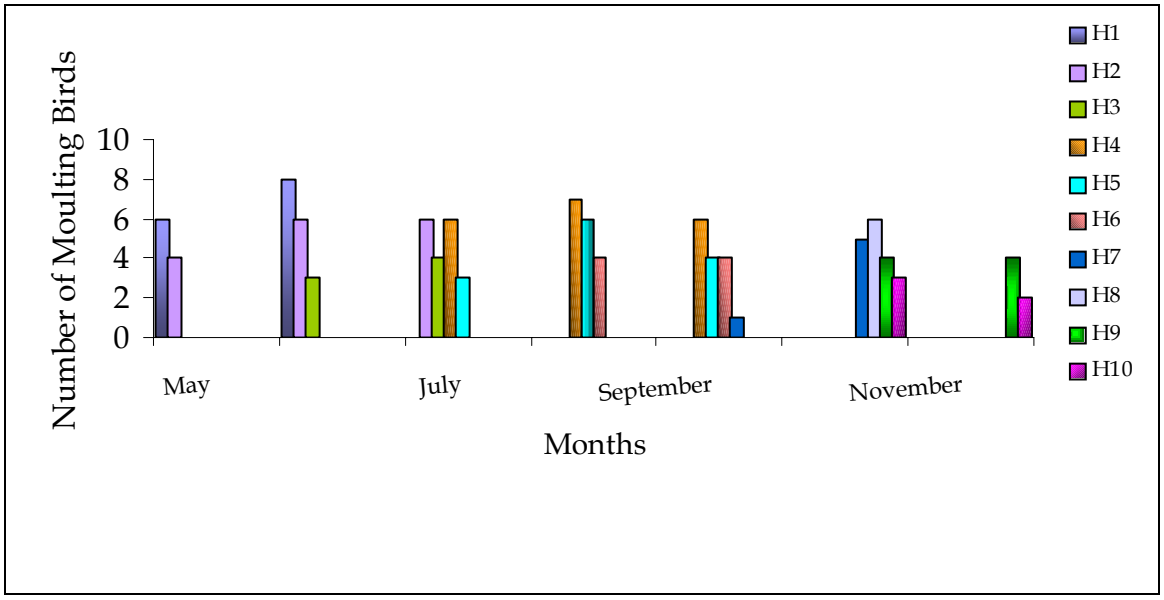


Plate 1 *Acridotheres tristis*

Plate 2 *Corvus splendens*

Plate 3 *Corvus macrorhynchos*

Plate 4 *Dendrocitta vagabunda*

Plate 5 *Dicrurus paradiseus*

Plate 6 *Pycnonotus cafer*

Plate 7 *Pycnonotus jocosus*

Plate 8 *Oriolus xanthornus*

CHAPTER 6

BREED-MOULT INTERRELATIONSHIP

INTRODUCTION

Breeding and moult are two important seasonal activities demanding major energy expenditure in the annual cycle of birds (Hunter, 1984; Dawson, 1994). The study of the temporal relationship between these two activities may give an insight into the ecological pressures acting on the population. The vast majority of birds and in particular the passerines replace their entire plumage at least once in a year (Netto and Gosler, 2006). Simultaneous breeding and moult is not possible in many species of birds because of energy constraints (Swaddle and Witter,1997) but in many others these two activities go together (Hemborg,1999). Majority of birds in the tropics and in higher latitudes have moulting schedule that do not overlap breeding (Snow and Snow, 1964; Dittami,1987). In the resident birds, moult immediately follows breeding (Dawson,2004; Netto and Gosler,2006). But in habitats where availability of food is ensured throughout the year and no seasonal variation in abundance, the moult is often prolonged and overlaps breeding (Snow,1966).

Moult-breeding overlap and moult interruption occurs quite often in tropical birds (Mathew and Padmavati, 1985). Increased level of reproductive hormones may be the reason for moult interruption. Some birds interrupt their moult when they breed in response to rain whereas others

continue to moult while they breed (Snow, 1966; Keast, 1968). If significant rain falls very late during the open breeding period, autumn moult and breeding may overlap, resulting in development of a new breeding plumage (Herremans, 1999).

If breeding is extended, the time available for moult may not always be enough for a normal complete moult. In this case moult may start before breeding is over (Gwinner, 1996). Birds that breed two or three times in the same season often delay moult initiation till breeding is over (Mathew and Naik, 1986) and when it overlaps breeding in the population, it will be at a slow rate (Naik and Andrews, 1966).

METHODS OF STUDY

Breeding and primary moult seasons of individual species were analysed to find out how these two are inter-related in the annual cycle of the species. Duration of breeding and moult as well as extend of overlap and arrest of moult were studied. Comparisons were made between members of the same species distributed in Northern and Southern India as well as between members of a genus or family.

Duration of primary moult of individual birds were calculated using Pimm's method (Pimm,1976). In this method primary moult data of individual birds were consolidated to get the time of moult initiation and termination for the population. Twentyfive species of passerines were analysed, twentyfour of these were collected from North India and thirteen from South India (Table 5.1).

RESULTS

Acridotheres fuscus of Northern India were moulting primary feather 'H1' in June. Primarie 'H10' were moulting from October to December (Fig 5.1). Breeding occurred between March and August.

Acridotheres tristis of Northern India were moulting primaries 'H1' from June to August and 'H10' in November and December. Breeding season was from March to November. In Southern India they moulted primaries 'H1' from June to August and 'H10' from October to December (Fig 5.2). Breeding season was long, from January to November.

Sturnus malabaricus of Northern India were moulting primaries 'H1' in June and July, and 'H10' in September, October and November. Breeding season was between March and August. In Southern India primary moult was from June-July to October-November (Fig 5.3). Breeding was between March and June.

Sturnus contra of Northern India were moulting primaries 'H1' in June and July and 'H10' in November (Fig 5.4). Breeding occurred from March to October.

Corvus splendens, in N.India began moulting in May-June by renewing 'H1' primaries. Primaries 'H10' were moulting from September to November. Breeding was from February to October. In S. India primaries 'H1' were moulting in May, June and July and 'H10'in October and November (Fig 5.5). They were breeding throughout the year.

Corvus macrorhynchos, in N.India were moulting primaries 'H1' from May to July and 'H10' in October and November. Breeding was from February to December. In S. India primaries H1 were moulting in both May and June and 'H10' were moulting from September to November (Fig 5. 6). Breeding was from January to December.

Dendrocitta vagabunda in North India were moulting primaries 'H1' in May and June and 'H10' in October and November. Breeding was from February to September. In South India primaries 'H1' were moulting from May to July and 'H10' from September to November (Fig 5. 7). Breeding season was between February and August.

Dicrurus adsimilis in North India were moulting primaries 'H1' in June-July and 'H10' in October-November. Breeding was from February to October. In South India primaries 'H1' were moulting in June-July and 'H10'in October (Fig 5. 8). Breeding was between January and October.

Dicrurus paradiseus, in North India, were moulting primaries 'H1' in June-July and 'H10' in October and November (Fig 5. 9). Breeding was between March and June. *Dicrurus caerulescens* in North India were moulting primaries 'H1' in June and 'H10' in October (Fig 5. 10).

Oriolus xanthornus from North India were moulting primaries 'H1' in June and 'H10' in October and November. Breeding was between March and August. In South India, primaries 'H1' were moulting in May and 'H10'in October (Fig 5.11). Breeding was between March and August.

Oriolus oriolus a migrant in N.India were moulting primaries ‘H1’ in June and H10 in October (Fig 5.12). Breeding season was between March and August.

Lanius excubitor a summer visitor to N. India were moulting primaries ‘H1’ in May and ‘H10’from September to November (Fig 5.13).Breeding was from February to July.

Lanius schach in North India, were moulting primaries ‘H1’ in May and H10 in November and December. Breeding season was from March to September. In South India primaries ‘H1’ were moulting in June and ‘H10’in November. Breeding took place from February to August (Fig 5.14)

Lanius tepronotus, an altitudinal migrant in N.India were moulting primaries ‘H1’ in May,‘H10’in October and November (Fig 5.15).Breeding was from March to August.

Pycnonotus cafer in N.India was moulting primaries ‘H1’ from June to August and ‘H10’from October to December. Breeding was from February to October. In South India primaries ‘H1’ were moulting in June and July and H10 from October to December (Fig 5.16). Breeding season was from January to December.

All moulting *Pycnonotus jocosus* specimens obtained were from North India were moulting primaries ‘H1’ in June and ‘H10’in October and November (Fig 5.17). Breeding occurred between February and August,

Turdoides caudatus in North India were moulting their primaries ‘H1’ in May and June. Primaries ‘H10’ were moulting from September to November. Breeding season was from February to October. In South India primaries ‘H1’ were moulting from April to June and ‘H10’ from September to November (Fig 5.18). They were breeding from January to December.

In North India, *Turdoides malcolmi* were moulting primaries ‘H1’ in May and June, ‘H10’ in October and November (Fig 5.19). Breeding was from January to December.

The North Indian *Turdoides striatus* was moulting primaries ‘H1’ in May and June and H10 from September to November. Breeding occurred from February to October. In South India primaries ‘H1’ were moulting from April to June and ‘H10’ from September to November (Fig 5.20). In South India they were breeding from February to October.

Pomatorhinus schisticeps in South India were moulting primaries ‘H1’ in May and June and ‘H10’in October and November (Fig 5.21). Breeding was from January to September.

Garrulax jerdoni endemic to Southern Western Ghats were moulting primaries ‘H1’ in May and June and ‘H10’in October and November (Fig 5.22). Breeding was from April to June.

Garrulax pectoralis in North India were moulting primaries ‘H1’ in June and ‘H10’ in December (Fig 5.23).Breeding was from March to August.

Garrulax striatus in N.India were moulting primaries ‘H1’ in July and ‘H10’in October and November (Fig 5.24). Breeding was from April to August.

Garrulax albogularis in N.India were moulting primaries ‘H1’ in May and June and ‘H10’ in October and November (Fig 5.25). Breeding was between April and June.

DISCUSSION

Seasons of breeding and moulting

Breeding commenced between January and April in all the species where both breeding and moult were studied. It continued in majority of the species to September-October and a few species were found breeding till December. Moult initiated in most of the species in May or June while in *Turdoides caudatus* and *T. striatus* of South India it began in April itself. In several groups of birds moult appear to begin each year on a definite seasonal schedule independent of breeding activity (Payne,1969).

The twelve species of which moult data were collected from North and South Indian regions belonged to seven families of passerines (Table 3.2). Breeding in these species initiated simultaneously in both Northern and Southern India or it initiated earlier in Southern India. In *Acridotheres tristis, Corvus splendens Corvus macrorhynchos, Lanius schach* and *Pycnonotus cafer* breeding initiated earlier in Southern India.

Season of moult is much more constant than breeding season from year to year (Keast,1968). In the present study, primary moult initiated at the

same time in both Northern and Southern Indian varieties of *Acridotheres tristis* (Fig 5.2), *Sturnus malabaricus* (Fig 5.3), *Corvus splendens* (Fig 5.5), *Corvus macrorhynchos* (Fig 5.6), *Dendrocitta vagabunda* (Fig 5.7), *Dicrurus adsimilis (*Fig 5.8) and *Pycnonotus cafer* (Fig 5.16). South African Pied Starling also showed no regional variations in moult season though it is expressed in the timing of breeding (Craig, 1983). In the present study slight regional variations in time of moult initiation were exhibited by *Oriolus xanthornus* (Fig 5.11), *Lanius schach* (Fig 5.14), *Turdoides caudatus* (Fig 5.18) and Turdoides *striatus* (Fig 5.20). When *Lanius schach* and *Turdoides striatus* moulted earlier in North India, *Oriolus xanthornus* and *Turdoides striatus* were moulting first in South India.

The most common schedule of moult is alternation with breeding (Michener and Michener,1940; Hulley *et al*.,2004). Most birds in temperate regions begin the main annual moult shortly after breeding, when the young ones are independent. In the present study, peak breeding for most of the species studied occurred in March–April before the initiation of moult, though breeding season prolonged and overlapped the entire moult period. Moult initiation while feeding the young one is common among songbirds though most of them usually moult after the young becomes independent (Newton,1966). In *Acridotheres fuscus*, *Pycnonotus cafer* and *Pycnonotus jocosus* peak egg laying period is April-May; in *Acridotheres tristis* and *Corvus splendens*, it is from April to June; in *Corvus macrorhynchos*, *Dicrurus paradiseus, Lanius excubitor, Garrulax pectoralis* and *Dendrocitta*

vagabunda, it is in April; in *Oriolus xanthornus* and *Dicrurus adsimilis*, May-June; in *Lanius schach*, June; in *Lanius tepronotus* and *Garrulax jerdoni*, May; in *Turdoides striatus*, March-April and in *Turdoides caudatus*, April.

Birds in the present study began moult mainly in May and June. So most of the birds in each species studied would have completed breeding quite before moult initiation. But in birds having two or three broods in a breeding season, the last brood and the late breeders of the season might overlap moult. This is reported in Redbilled Firefinches, *Laganosticta senegala* of Zambia having prolonged nesting period from February to August, some adults would begin wing moult as early as May (Payne,1980).

Initiation and duration of Primary moult

All species selected for the present study initiated breeding from January to April and terminated it in the period from August. Primary moult commenced in April, May or June and terminated in the months of September, October or November. So breed-moult overlap of varying extend is there. In Chestnutbellied Starling, *Spreo pulcher* at Kano, Nigeria, the population's moult and breeding cycles showed considerable overlap (Wilkinson,1983). However, the moult period of individual birds were shorter than that for the population and individual birds could avoid overlap. In the species studied, breeding commenced between January and April in most of the regions except the dry arid zones of Indian Desert (Table 4.1). This enables majority of birds in a region to complete egg laying and

incubation before the beginning of moult. But at population level breeding is a prolonged activity and the late breeders of the species might overlap moult.

Primary moult occurred at a slow rate taking sixteen to twenty weeks for their completion (Table 6). Since both breeding and moult of feathers are functions that demand much energy, it may be advantageous to renew feathers at a slow tempo, so that too much strain is not placed on the bird's energy budget at any particular period (Zacharias *et al*., 1994).

Moult initiated either in May or June in most of the species studied. The exceptions were *Turdoides caudatus* and *T. striatus* of S.India which began moult in April (Fig 5.18 & 5.20). Those initiated moult in May were *Corvus splendens, Corvus macrorhynchos, Dendrocitta vagabunda* of North and South India; *Lanius schach, Lanius excubitor,Lanius tepronotus, Turdoides caudatus, Turdoides malcolmi, Turdoides striatus* and *Garrulax albogularis* of Northern India; *Oriolus xanthornus, Pomatorhinus schisticeps* and *Garrulax jerdoni* of Southern India. Those initiated moulting in June were *Acridotheres tristis, Sturnnus malabaricus, Dicrurus adsimilis* and *Pycnonotus cafer* of Northern and Southern India; *Acridotheres fuscus, Sturnus contra, Dicrurus paradiseus, Dicrurus caerulescens, Oriolus xanthornus, Oriolus oriolus, Pycnonotus jocosus, Garrulax pectoralis* and Garrulax *striatus* of Northern India. In these species moult termination occurred between September and November. So duration of primary moult were sixteen to twenty weeks.

. In the present study *Turdoides caudatus* and *Turdoides striatus* from Southern India initiated moult in April. Species, which commenced moult in April, were breeding from January or February; so there would be enough time for breeding activities before moult started. Primary moult usually occur after egg laying, when the breeding pairs are feeding their nestlings (Naik and Naik, 1965).

Acridotheres tristis, Corvus splendens, Turdoides caudatus and *Turdoides striatus* were found to breed throughout the year. Since there is no clearly marked breeding season, there does not appear to be any advantage in moulting in one restricted part of the year or at a fast tempo (Mathew, 1977). In these species moulting season is a prolonged one. In *Acridotheres tristis,*it is from June to December, in *Corvus splendens*, May to November and in *Turdoides caudatus* and *T.striatus*, April/May to November.

Moult arrest

It occurs in some tropical birds with seasonal breeding or prolonged periods of moult (Miller, 1961). Moult may be temporarily arrested during the nesting period (Ashmole, 1968). Feathers that started growing complete their growth but the neighbouring feathers are not dropped until breeding has been completed. Increased levels of reproductive hormone at this time may be the cause of moult arrest (Payne, 1972). In the present study two birds each of *Acridotheres tristis* and *Dendrocitta vagabunda* of N.and S.India had fully grown ‘H1’primaries in May but ‘H2’ were not shed (Fig

5. 2 and 5.7). A *Corvus splendens* from Northern India had fully grown H2 in May while H3 were not shed (Fig 5.5)

Interruption of moult was more common among birds with a late onset and it would lead to a significant time gain and moult completion was consequently more synchronized than moult onset (Hall and Fransson, 2001). Breeders of *Turdoides caudatus*, may arrest their moult during the incubation and nesting period (Gaston, 1981).

Food: a determining factor of breeding and moult season

In Indian Deserts and parts of Semi-Arid regions insects would be abundant for only a limited span of time during and after South-West monsoon and their abundance appear to follow closely the amount of fresh vegetation (Gaston,1981). Birds would make use of this opportunity for breeding and moulting. Since both are energy demanding processes they would take place only when there is surplus food in the environment (Davis, 1971). In other regions insect food would be available earlier, coinciding with the earlier leaf flushing or flowering. This would promote earlier breeding, before the onset of monsoon (Becking, 1981). Therefore in the present study a major portion of breeding took place in pre-monsoon times (Table 4.3) and primary moult initiated mainly in May and June (Table 6).

In the present study a few Southern Indian species show long breeding season compared to their Northern Indian counterparts. This might be due to early availability of insect food due to sprouting of grass during summer showers (Ligon, 1971). No marked regional variations in time of

moult were observed between Northern and Southern Indian varieties. In all the species studied, primary feathers had a moult sequence similar to that most prevalent among the passerines and breeding took place in the normal breeding season of the species. In these small passerines breeding and moult were annual phenomena. The two important features of moult, the long duration and lack of temporal separation between breeding and moulting (Zacharias,1978) were observed in the species selected for the present study. Regional difference in time of moult was negligible though considerable differences were observd in breeding seasons. Moult breeding overlap and moult arrest of varying degrees would be there as the period of moult coincided with breeding season.

Table 6 Duration of primary moult in different species of insectivorous birds studied

Species studied	Distribution	Date of Moult initiation		Date of Moult termination		Duration of Moult
		Earliest	Latest	Earliest	Latest	
Acridotheres fuscus	North India	June,8th	July,29th	Oct,6th	Dec,12th	17 –19 weks
Acridotheres tristis	North India	June, 1st	Aug, 8th	Nov,2nd	Dec,24th	18-20 weeks
Acridotheres tristis	South India	June,2nd	Aug,10th	Octo,5th	Dece 31st	18-20 weeks
Sturnus contra	North India	June 4th	July 1st	Nov 1st	Nov 29th	17-19 weeks
Sturnus malabaricus	North India	June 2nd	July15	Sept 26th	Nov,24	16-20 weeks
Sturnus malabaricus	South India	June,2nd	July,7th	Oct,8th	Nov,20th	17-20 weeks
Dendrocitta vagabunda	North India	May,27th	June,25th	Oct,1st	Nov,10th	18-20 weeks
Dendrocitta vagabunda	South India	May,17th	July,20th	Sept,9th	Nove,25th	17-19 weeks
Dicrurus adsimilis	North India	June,18th	July,23rd	Oct,10th	Nov,26th	16-18 weeks
Dicrurus adsimilis	South India	June,10th	July,1st	Octo,4th	Oct,31st	16-18 weeks
Dicrurus paradiseus	North India	June,10th	July,8th	Octo,6th	Nov,12th	17-19 weeks
Dicrurus caerulescens	North India	June,1st	June,15th	Sept,7th	Sept,29th	16-17 weeks
Corvus splendens	North India	May,3rd	June,28th	Sept, 5th	Nov,15th	17 -20 weeks
Corvus splendens	South India	May,25th	July,5th	Octo,1st	Nov,14th	18-20 weeks
Corvus macrorhynchos	North India	May,28th	July,1st	Oct,2nd	Nov,20th	18-20 weeks
Corvus macrorhynchos	South India	May,10th	June,28th	Sept,13th	Nov,15th	18-20 weeks
Oriolus xanthornus	North India	June,14th	June,25th	Oct,11th	Nov,7th	17-19 weeks
Oriolus xanthornus	South India	May,25th	June,1st	Oct,2nd	Oct,14th	18-20 weeks
Oriolus oriolus	North India	June,4th	June,30th	Nov,1st	Nov,16th	17-20 weeks

Species studied	Distribution	Date of Moult initiation		Date of Moult termination		Duration of Moult
		Earliest	Latest	Earliest	Latest	
Lanius excubitor	North India	May,29th	June,28th	Sept,25th	Nov,17th	16-20 weeks
Lanius schach	North India	May,29th	June,27th	Oct,2nd	Nov,20th	18-20 weeks
Lanius schach	South India	June,12nd	July,13th	Oct,4th	Nov,24th	17-19 weeks
Lanius tepronotus	North India	May,26	ne,20	Oct,1st	Nov,6th	18-20 weeks
Pycnonotus cafer	North India	June,5th	Aug,2nd	Oct,4th	Dec,20th	17-20 weeks
Pycnonotus cafer	South India	June,8th	July,30th	Oct,5th	Dec,18th	17-20 weeks
Pycnonotus jocosus	North India	June,9th	June,30th	Oct,1st	Nov,6th	18-20 weeks
Turdoides caudatus	North India	May,18th	June,29th	Sept,30th	Nov,15th	17-20 weeks
Turdoides caudatus	South India	April,27th	June,30th	Sept,2nd	Nov,11th	18-20 weeks
Turdoides malcolmi	North India	May,,31st	June,28th	Oct,1st	Nov,14th	17-20 weeks
Turdoides striatus	North India	May,22nd	June,25th	Sept,27th	Nov,10th	17-20 weeks
Turdoides striatus	South India	April,30th	June,20th	Sept,1st	Nov,5th	17-20 weeks
Pomatorhinus schisticeps	South India	May,26th	June,28th	Oct,2nd	Nov,15th	19-20 weeks
Garrulax jerdoni	South India	May,30th	June,28th	Oct,1st	Nov,,15th	18-20 weeks
Garrulax pectoralis	North India	June,2nd	June,27th	Oct,2nd	Nov,21st	18-20 weeks
Garrulax striatus	North India	June,5th	July,2nd	Oct,4th	Nov,20th	17-20 weeks
Garrulax albogularis	North India	May,31st	June,21st	Oct,3rd	Nov,8th	18-20 weeks

CHAPTER 7

SUMMARY AND CONCLUSION

The first chapter '**General Introduction'** deals with the importance of the present work. It provides information on the two seasonal activities, breeding and moulting of insectivorous birds.

The second chapter '**Review of Literature'** describes the major works done in the areas of breeding and moulting.

The third chapter '**Materials and methods'** gives a description of the major Indian bio-geographic regions from where the breeding data were obtained. Climatic factors, mainly the rainfall which influences the bird's breeding activities are analysed in the different bio-geographic regions. Methodology used for analysis of breeding and moult data are discussed.

In the fourth chapter '**Breeding season of insectivorous birds of Indian Mainland'** the number of species laying eggs in each month in the eight major bio-geographic regions are compared. Out of the total 400 species recorded laying, 154 are Prevalent species distributed in four or more bio-geographic regions. For 246 species breeding is restricted to one or three bio-geographic regions. Fourty eight species are restricted to Himalayan region alone, fifteen species to Western Ghats.

Analysis of breeding data of wide spread species shows that highest number of species are laying eggs in pre-monsoon times in the major bio-

geographic regions except Indian Desert, where peak breeding season coincides with the heavy rainfall of South West monsoon, which is of short duration. In Western Ghats, Deccan Peninsula, Eastern Ghats and Northeast India highest number of egg laying species are recorded in April while in Himalayan and Semi-arid regions in June. In Indian Desert it is in July. Gangetic plain shows highest percentage of egg-laying both in April and June. In Himalayan region many species start egg-laying in April when atmospheric temperature rises up after the chilling winter.

Thus peak numbers of species are laying eggs prior to the commencement of South West monsoon in regions which get profuse summer showers and in those regions getting winter showers like Himalayan region while in arid regions like Indian Desert it is during the South West monsoon itself. Breeding data of the five common birds show that most of the birds are pre-monsoon breeders except in Indian Desert. Breeding season is of long duration in Western Ghats, Deccan Peninsula and Semi-arid region.

Breeding season is found to be related to season of insect abundance, which in turn is dependent on the time of sprouting of new leaves and flowers. When numbers of species laying eggs are related to average monthly rainfall, highest coefficient of correlation is displayed in Indian Desert. Other regions do not show any positive relationship with intensity of rainfall as these regions get pre-monsoon summer showers to promote plant growth and therefore breeding of birds.

In the fifth chapter '**Primary moult of insectivorous birds in Northern and Southern India**' primary moult activities of twentyfive species were studied. Twentyfour of these are recorded moulting in North Indian region and thirteen in South India. Moult season and duration are analysed for the North and South Indian varieties of the same species and for related species. No marked regional variations in season or duration of moult of a species are observed. Apparently no difference in season of moult occurred between species also. Moult initiated between April and June in all the species studied. Renewing a single primary feather on both wings simultaneously is the general rule, but synchronous moult of two or three primaries on each wing were are observed in all species.

In the sixth chapter '**Breed-moult inter-relationship**' time of initiation and termination of breeding and moulting of the twentyfive species of passerine birds were analysed. All species studied initiated breeding in the first four months of the year and terminate it in the period from August while moult commenced mainly in May / June though two species from Southern India started it in April. Moult was terminated in the period from September to December. So duration of moult was sixteen to twenty weeks. Though the peak breeding would be over before the moult commenced, overlap of varying degrees existed at the population level.

Regional difference in time and duration of moult was negligible though South Indian species were found to start breeding earlier.

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APPENDICES

APPENDICES

Appendix-1 Breeding season of the prevalent insectivorous species in different bio-geographic regions of Indian mainland

Name	Bio-geographic region							
	Deccan Peninsula	Indian Desert	Eastern Ghats	Gangetic Plains	Himalayan region	Northeast India	Semi-arid Region	Western Ghats
Indian Pitta	April-Dec			June	May-Aug		April-July	Mar-Aug
Ashycrowned Finch Lark	Jan-Dec	Feb-Aug	Aug	Feb-April	Feb-Sept		Feb-Nov	Jan-Dec
Bush Lark	April-Sept	July		Mar-July	Mar-July	April-Sept	Feb-June	Jan-May
Crested Lark	Feb.-Aug.,Nov				Feb-Aug		Mar-June	Jan-Dec
Singing Bush Lark	Mar-May	Mar-		April-May		April	April-Sept	April-May
Skylark	Mar-May	July-Sept		Mar-June	April-July	Dec-April	Feb-July	Mar-Oct
Small Skylark	June	June-Sept		MAy	May-July	April-Oct	Feb-May	
Sand Lark	May	May-Aug		April	Feb,April	Mar-May	April-May	
Redwinged`Bush Lark	Feb-July	Mar-Sept		Mar-Aug	Mar,April,Aug		Mar-Sept	Mar-Nov
Rufoustailed Finch-Lark	Jan-June	Feb-April					Feb	Jan-June
Swallow	June,July				Feb-Aug		July-Aug	Feb-June
Striated Swallow	May-Sept	April-Sept	Feb-Sept	Sept	Feb-Aug	April-June	Feb-Sept	Jan-Oct
Wiretailed Swallow	Jan-Sept	Feb-July		Feb-Mar	May-July	Mar-Dec	Feb-Sept	Jan-Dec
Wood Shrike	Feb-July	June-Sept	Mar-May	May	Feb-June	Jan-May	Mar-Aug	Jan-June
Rufousbacked Shrike	Dec-Sept	May-Aug		April-June	Mar-Aug	April-June	Mar-Aug	Feb-Aug
Grey Shrike	Mar-Sept	Mar-July		April-June	Feb-July		Feb-July	Jan-June
Greybacked Shrike	Mar-Aug	July-Aug		April	April-July	April-May	May-June	Feb-Aug
Pied Flycatcher Shrike	April			April	April-June	Feb-June		Jan-May
Baybacked Shrike	Mar-July	Feb-Aug	Feb-May		Jan-Aug	Mar	Feb-Oct	Mar-July
Ashy Swallow Shrike	April	April		April-May	April	Mar-June	May	Feb-Aug
Golden Oriole	April-Aug	April-Aug			April-Aug		April-Aug	April-June
Blackheaded Oriole	Mar-May		Feb-Mar	Mar-April	Mar-Aug	Mar-April	Mar-Aug	Mar-Aug
Haircrested Drongo	Mar-April				Mar-June	April-May	April-June	Feb-I5June

Continued ……

Name	Bio-geographic region							
	Deccan Peninsula	Indian esert	Eastern Ghats	Gangetic Plains	Himalayan region	Northeast India	Semi-arid Region	Western Ghats
Greater Racket-tailed Drongo	April				Mar\h-July	April-May	May-July	Mar-Sept
Grey Drongo	Mar-June	July	Mar-July		Mar-June	Mar-May	May-July	April-May
Black Drongo	April-Aug	May-Aug	April-Aug	April-July	Aprill-july	April-Oct	Mar-Sept	Jan-July
Whitebellied Drongo	Mar-Sept			April-June			Mar-June	Mar-June
Bronzed Drongo	Mar-June			April-June				
Dusky Crag Martin	Feb-Aug	July-Sept	Mar-April				Feb-Oct	Jan-Sept
Sand Martin		Feb-Mar			Nov-Mar	Nov-Feb	Feb-Mar	
Common Myna	Jan-Sept	July-Sept	April-Sept	April-Aug	April-June	Feb-Aug	Mar-Sept	Jan-Aug
Brahminy Myna	Mar-July	May-Sept	April-June		April-Aug	June-July	Feb-Aug	Feb-July;Nov
Pied Myna	April,July	April-Aug		May-June	Mar-Aug	Mar-Oct	May-Aug	June
Greyheaded Myna			April-May	May	April-July	April-May	May-June	April-May
Hill Myna	April				Feb-Mar	April-May	April-May	Feb-April
Jungle Myna	Mar -Sept		May	April-June	April-June	Mar-Aug	May	Mar-July
Bank Myna		July-Sept	Aug-Sept	May	May-July		Mar-Aug	Mar-Aug
Jungle Crow	Jan-July	Feb-April	Jan-June	Dec-Mar	Feb-July	Dec-April	Feb-May	Jan-Dec
House Crow	Jan-Sept	Mar-Aug	April	Feb-Aug	Feb-July	April-Oct	May-Sept	Jan-Dec
Indian Tree Pie	June-Aug	April-June	Feb-July	June	Feb-Dec	April-June	Mar-Aug	Feb-Sept
Small Minivet	July-Aug				June-Aug	May-Aug	Mar	June-Oct
Rosy Minivet	April		April-June		May-June	May-June	May	
Whitebellied Minivet	June-Aug	Aug-Sept			June-Aug	May-Aug	Mar-June	June-Aug
Blackheaded Cuckoo-Shrike	June-Oct		May	April	April-Oct	Feb-Mar	May-Aug	April-July
Large Cuckoo-Shrike	Mar-July,Oct	May-Oct		Mar-Aug		Mar-Aug	April-Sept	Jan-Aug
Paradise Flycatcher	Feb-Aug	May-June	April-June	April-June	April-Aug	April-July	Mar-Sept	April-Aug
Common Iora	Mar-Sept		Mar-June	Jan-June	Feb-July	Feb-Aug	April-July	Jan-Dec
Goldfronted Chloropsis	May-Aug		July	July	Mar-Aug	May-Aug	Sept	Jan-Dec
Goldmantled Chloropsis	June-Aug			Mar-Aug			Mar-June	Jan-Oct
Black Bulbul	Feb-April		June-July	April-July	April-June	April-May	June-Aug	Mar-Oct
Blackcrested Yellow Bulbul				April-Msy	Feb-June	Mar-Sept		Jan-Nov

Continued .....

Name	Bio-geographic region							
	Deccan Peninsula	Indian Desert	Eastern Ghats	Gangetic Plains	Himalayan region	Northeast India	Semi-arid Region	Western Ghats
Whitecheeked Bulbul		July-Sept			Mar-Aug	Mar-April	Mar-Aug	
Striated Green Bulbul		April-Aug		June-July	Feb-June	April-June	July	Feb-July
Whitebrowed Bulbul	Jan-July		Jan		Jan-June		June	April-Aug
Yellowthroated Bulbul	May-July	April	April-June					Mar
Redwhiskered Bulbul	Nov-May	Mar-May	Mar-Aug	Feb-June	Mar-Aug	Mar-June	Mar-Aug	Feb-Oct
Redvented Bulbul	Jan-Dec	Feb-June	Jan-Aug	Mar-Aug	Mar-Aug	April-Sept	Mar-Aug	Feb-Sept
Chestnut-bellied Nuthatch	April,July		Feb-Mar		Jan-April	April-May	Feb-April	Feb-April
Jungle Babbler	April-July,Oct		Feb-Aug	June	Mar-Oct		Feb-Oct	Mar-Dec
Slatyheaded Scimitar Babbler	May-June				Jan-June	April-June	Jan-Mar	Oct-May
Scimitat Babbler	Sept					Jan-May		Mar,April
Common Babbler	Mar-Sept	Jan-Aug	Mar-Aug	June	Jan-Sept	April-July	Feb-Sept	Jan-Dec
WhitethroatedBabbler	June-Sept		July	April-June	May	Mar-Dec	May-Aug	April-Nov
Whiteheaded Babbler	Jan-Oct		June-Oct				Jan-Feb	Nov-June
Yelloweyed Babbler	June-Oct		April	Aug-Sept	Mar-Sept	June-Oct	April-Aug	June-Octo
Spotted Babbler	Mar-June		April	April	Feb-July	April-Dec	May-Aug	Feb-Nov
Quaker Babbler	June		May-July		May	May-June	Aug-Sept	Jan-Dec
Large Scimitar Babbler	Sept		Mar		Jan-April	April-May		April-May
Large Grey Babbler	Feb-July	Jan-Dec	June-July				Mar-Oct	May-Dec
Whitebrowed Fantail Flycatcher	Mar-June	Feb-Aug	Feb-June		Mar-Aug		Mar-Oct	Mar-June
Greyheaded Flycatcher	Feb-June				April-June	Mar-June	June-July	
Dusky Blue Flycatcher			April-May		Mar-July	Mar-Aug	April-July	Mar-July
Verditer Flycatcher	Mar,May		Sept-Oct		April-July	Mar-June	Mar-June	Jan-June
Tickell's Blue Flycatcher	April-Aug		April-May	June			May-June	May-Oct
Redbreasted Flycatcher			April		May-June	May	Mar	Mar-Aug
Whitethroated Fantail Flycatcher	Mar-Aug		April		April-June	April-June		April-Aug
Blacknaped Flycatcher	Mar-Aug					June-July	April-Aug	April-Aug
Brown Flycatcher	April-Aug		Mar-June		April-July	April-May	May	Mar-July
Streaked Fantail Warbler	Feb-Dec	Aug-Sept		May-June	July	May-Sept	July	Mar-Oct

Continued ……

Name	Bio-geographic region							
	Deccan Peninsula	Indian Desert	Eastern Ghats	Gangetic Plains	Himalayan region	Northeast India	Semi-arid Region	Western Ghats
Rufousfronted Wren Warbler	July-Sept	Mar-Sept			July		Mar-Oct	Mar-Oct
Jungle Wren Warbler	July-Sept	July-Aug	June-Oct	July	June-Sept		Aug	June-Nov+I63
Streaked Wren Warbler		Mar-Aug			Mar	April	Feb-Sept	Mar-Aug
Ashy Wren Warbler	May-Dec	Mar-Sept	June - Sept	June-Sept	May-Sept	April-May	Feb-Auguat	Jan-Sept
Plain Wren Warbler	June-Oct	Mar-Aug	Sept	July-Aug	May-Sept	June	Mar-Sept	Mar-Dec
Great Reed Warbler	Mar	July-Sept		July	May-Sept	May-June	May-Sept	Mar-Aug
Fantail Warbler			May-Aug		Feb-Sept.	June-Aug	Mar-Oct	Feb-Dec
Ashy GreyWren Warbler	May-Dec	May-Sept	Jan-Mar	June	May-Sept	Feb-Sept		Jan-Sept
Brown Hill Warbler		July-Sept			May-Oct	April-June	June-July	
Bristled Grass Warbler		July-Aug		May	Aug	June-Aug	July-Sept	July
Broadtailed Grass Warbler			Mar-Sept		May-Aug	May-Aug		Mar-Sept
Eurasian Blackbird				April	April-Aug	June		Mar-Aug
Shama	May,July		May-June	June-July	April,July	Mar-May		April-July
Bluethroat	Mar-Aug	June-Aug	April-Nov		May-Aug			
Tailer Bird	Mar-Dec	April-Sept	Mar-Dec	May-June	Feb-Aug	May-Sept	Feb-Dec	Mar-Oct
Orangeheaded Ground Thrush	April-Aug				April-Sept	April-Aug	May-Aug	Mar-Sept
Whitetailed Bush Chat					Feb-May	Jan-May	Feb-June	
Stone chat	Mar-June	Mar-Aug	June-July	June-July	Feb-July	April-May	Mar-Aug	Mar-Aug
Pied Bush Chat	Feb-Aug			Mar-April	Mar-Aug	Mar-May	Feb-Auguat	Mar-July
Indian Robin	Jan-Aug	Mar-July	Mar-April	Mar-April	Jan-Aug		Mar-Aug	Jan-Aug,Dec
Magpie Robin	Feb,April-Aug	April-Sept	April-June	April-June	Mar-Aug	Feb-Oct	Mar-Aug	Feb-July
Yellowcheeked Tit	May-Oct		April-June		April-June			July-Oct
Whitecheeked Tit	Aug	May			Mar-July		April-Sept	
Blackspotted Yellow Tit	May-June		May-Sept			Mar-April	April,May	July-Dec
Grey Tit	Mar-July	June		Mar-April	Mar-July	April-May	Mar-Aug	Feb-July
Velvetfronted Nuthatch	May					April-May	April	Jan-April
Paddyfield Pipit	Jan-June			Feb		April-June	Mar-June	Mar-May

Continued ….

Name	Bio-geographic region							
	Deccan Peninsula	Indian Desert	Eastern Ghats	Gangetic Plains	Himalayan region	Northeast India	Semi-arid Region	Western Ghats
Indian Pipit	Jan-April	April-June	May	May-June	Feb-July	Feb-Aug	April-July	Jan-June
Brown Rock Pipit					April-Aug	June	Mar-Aug	April-July
White Wagtail		Mar-July		Mar	April-July		Mar	May
Yellowheaded Wagtail	Mar,April	Mar			April-July	April-July		
Large Pied Wagtail	Feb-Dec	Mar-Aug		Mar-May	April-July		Jan-June	Jan-Dec
Grey Wagtail	Mar,Aug	Mar			April-July		Mar-May	Mar,April
Tickell's Flowerpecker	Mar-June			April-June		April-June		Mar-June
Thickbilled Flowerpecker	Mar-April			Mar-April	June		April-May	Jan-May
Purplerumped Sunbird	Feb-April;July-Dec		Mar-Dec	April-May	Mar	May-Oct	Mar	Jan-Dec
Loten's Sunbird	Feb-Mar;Dec				Feb-Mar		Aug	Feb-April
Purple Sunbird	Jan-July;Oct	Mar-Oct	Feb-Nov	Feb-April	Feb-July	Mar-Oct	Feb-Auguat	Jan-Nov
White- eye	Jan-July;+B100Nov	April-July	Mar-July		April-Aug	April-May	Mar-Aug	
House Sparrow	Jan-Dec	Feb-Oct	Jan-Dec	Feb-June	Feb-Sept	Jan-Sept	Jan-Oct	Jan-Oct
Yellowthroated Sparrow	Feb-May	Mar-Sept	April-June				April-June	Mar-Nov
Blackthroated Weaver	Mar-Sept	June-Oct		June-Aug	June-Oct	June-July	May-Sept	July-Sept
Streaked Weaver Bird	May-Sept	June-Sept		July-Aug	April-June	June-Oct	May-Sept	June-Sept
Finn's Baya Weaver		May-Oct			May-Aug	June	June-Aug	
Baya weaver	Feb,June-Nov.	May-Oct	April-June	April-Aug	Feb-Aug	May-Nov	Mar-Oct	Feb-Nov
Whitethroated Munia	Jan-Dec	June-Oct		July,Aug	Feb-Dec	Jan-Dec	Jan-Nov	Jan-Dec
Red Munia	Dec-Feb.,Seot.-Oct	Oct			July-Nov	April-Nov	Mar-Oct	Jan-Oct.
Spotted Munia	May-Dec		Sept-Nov		Mar-Oct	May-Dec	July-Oct	April-Nov
Whitebacked Munia	Mar,Sept			May-Sept	May-Nov	May-Oct	Feb-Auguat	Feb-Dec
Blackheaded Munia	April-Oct		May-Oct			April-Aug	June-Sept	April-Dec
Crested Bunting	April,June	June-July			Mar-Aug	April-Dec	Mar-Aug	June-Aug
Blackbacked Woodpecker	Nov-Jan	July-Sept						Nov-Jan
Goldenbacked woodpecker	Mar-July			April	Mar-July		Mar-Aug	Feb-July
Heartspotted Woodpecker	Jan-Mar				Mar-April	April-May	Nov-Dec	Jan-Dec
Lesser Goldenbacked Woodpecker	Jan-July	April-May		April				Mar-July
Pigmy Woodpecker	Mar				Mar-July	Feb-May	Mar-May	Jan-Mar

Continued ……

Name	Bio-geographic region							
	Deccan Peninsula	Indian Desert	Eastern Ghats	Gangetic Plains	Himalayan region	Northeast India	Semi-arid Region	Western Ghats
Yellowfronted Pied Woodpecker	Jan,Mar	Jan-June			April-July		Feb-June	Jan-Mar
Yellownaped Woodpecker	Jan-June		Jan-Mar			May-June		Dec-May
Palm Swift	Jan-July	Mar-April			Feb-Aug	Mar-May	Mar-Nov	Feb-Sept
Crested Swift	Mar-June	Mar-Sept		April-July	Dec-July	Jan-Dec	Mar-June	Jan-April
House Swift	Feb-Aug	Aug-Sept	May-Aug		Jan-Aug	May-July	Feb-Sept	Feb-July
Green Bee-Eater	Mar-june	Mar-May		April-June	Mar-may	April	Feb-May	Feb-May
Bluecheeked Bee-Eater		Mar-June			June	April-Aug	May-June	May-July
Bluetailed Bee-eater	Mar-July	May-June		April-July	Mar-June	Feb-June	Mar-June	Mar-June
Chestnut -headed Bee-eater	April-May			Mar-April	Mar-Aug	Feb-April		Feb-April
Redwattled Lapwing	Mar-June	April-Sept		April-Aug	April-June	Mar-June	Mar-Sept	Mar-May
Yellow-wattled Lapwing	Mar-Sept	April-May				April-June	April-Aug	Mar-Aug
Lesser Ringed Plover	Mar-May	Mar-April			April-May		Mar-June	Dec,Jan
Franklin'sNightjar	May-July	June-July		Mar-July	July-Aug	June-July	Feb-Auguat	Mar-Aug
Jungle Nightjar	Mar-July	Mar-June	Mar-June		May-July	April-July	Feb-July	Feb-Aug
Longtailed Nightjar	Mar-June				Mar-June	Mar	June-July	Mar-May
Pied Crested Cuckoo	May-Sept			June-Aug			June-Aug	July-Sept
Jungle Fowl	Feb-June,Oct,Nov.				April-July	Jan-Sept		Feb-Dec
Indian Cuckoo	June-Aug			June	April,June	April-May		Mar,Sept
Whitebreasted Kingfisher	April-Dec	Mar-July		May-July	April-July	Mar-April	Mar-July	Jan-Aug

Appendix 2.1 Prevalent species initiating egg-laying in January in different bio-geographic regions of Indian mainland

Sl.No.	Species
1	Ashycrowned Finch Lark
2	Eurasian Blackbird
3	Black Drongo
4	Brownbacked Pied Flycatcher Shrike
5	Bush Lark
6	Chestnut-bellied Nuthatch
7	Common Babbler
8	Common Iora
9	Common Myna
10	Crested Swift
11	Dusky Crag Martin
12	Ashy GreyWren Warbler
13	Goldfronted Chloropsis
14	Indian Bee Eater
15	Heartspotted Woodpecker
16	House Crow
17	House Sparrow
18	House Swift
19	Indian Pipit
20	Indian Robin
21	Jungle Crow
22	Jungle Nightjar
23	Large Cuckoo-Shrike
24	Large Pied Wagtail
25	Lesser Goldenbacked Woodpecker
26	Paddyfield Pipit
27	Palm Swift
28	Pied Bush Chat
29	Pigmy Woodpecker
30	Purple Sunbird
31	Purplerumped Sunbird
32	Quaker Babbler
33	Red Munia
34	Redrumped / Striated Swallow
35	Redvented Bulbul
36	Rufoustailed Finch- Lark
37	Sand Martin
38	Scimitat Babbler
39	Slatyheaded Scimitar Babbler
40	Spotted Munia
41	Tailor Bird
42	Thickbilled Flower Pecker
43	Tickell's Flowerpecker
44	Verditer Flycatcher

Continued…….

Sl.No.	Species
45	White- Eye
46	Whitebrowed Bulbul
47	Whiteheaded Babbler
48	Whitethroated Munia
49	Wiretailed Swallow
50	Wood Shrike
51	Yellowfronted Pied Woodpecker
52	Yellow-wattled Lapwing
53	Yellownaped Woodpecker
54	Blackbacked Woodpecker

Appendix 2.2 Prevalent species initiating egg-laying in February in different bio-geographic regions of Indian mainland

Sl.No	Species
1	Ashy Swallow Shrike
2	Ashy Wren Warbler
3	Baya weaver
4	Baybacked Shrike
5	Black Bulbul
6	Blackcrested Yellow Bulbul
7	Blackheaded Cuckoo-Shrike
8	Bluetailed Bee-eater
9	Brahminy Myna
10	Chestnut -headed Bee-eater
11	Crested Lark
12	Fantail Warbler
13	Franklin'sNightjar
14	GoldenBacked Woodpecker
15	Grey Shrike
16	Greyheaded Flycatcher
17	Greyheaded Myna
18	Hill Myna
19	Indian Tree Pie
20	Jungle Babbler
21	Large Grey Babbler
22	Loten's Sunbird
23	Magpie Robin
24	Redwhiskered Bulbul
25	Redwinged Bush Lark
26	Rufousbacked Shrike
27	Small Minivet
28	Small Skylark
29	Spotted Babbler
30	Stone chat
31	Streaked Fantail Warbler
32	Streaked Wren Warbler
33	Striated Green Bulbul
34	Velvetfronted Nuthatch
35	Whitebacked Munia
36	Whitebreasted Kingfisher
37	Whitebrowed Fantail Flycatcher
38	Whitetailed Bush Chat
39	Yellowthroated Sparrow

Appendix 2.3 Prevalent species initiating egg-laying in March in different bio-geographic regions of Indian mainland

Sl.No.	Species
1	Bank Myna
2	Blackheaded Oriole
3	Blackthroated Weaver
4	Bronzed Drongo
5	Crested Bunting
6	Dusky Blue Flycatcher
7	Golden Oriole
8	Goldmantled Chloropsis
9	Great Reed Warbler
10	Greater Racket-tailed Drongo
11	Grey Drongo
12	Grey Tit
13	Grey Wagtail
14	Greybacked Shrike
15	Haircrested Drongo
16	Indian Cuckoo
17	Indian Pitta
18	Jungle Fowl
19	Jungle Myna
20	Large Scimitar Babbler
21	Lesser Ringed Plover
22	Longtailed Nightjar
23	Orangeheaded Ground Thrush
24	Paradise Flycatcher
25	Pied Myna
26	Plain Wren Warbler
27	Redwattled Lapwing
28	Rufousfronted Wren Warbler
29	Shama
30	Singing Bushlark
31	Skylark
32	Streaked Weaver Bird
33	Swallow
34	White Wagtail
35	Whitebellied Drongo
36	Whitebellied Minivet
37	Whitecheeked Bulbul
38	Yelloweyed Babbler
39	Yellowthroated Bulbul
40	Yellowheaded Wagtail
41	Redbreasted Flycatcher
42	Bluecheeked Bee-Eater
43	Bluethroat

Appendix 2.4 Prevalent species initiating egg-laying in April in different bio-geographic regions of Indian mainland

Sl.No	Species
1	Blackheaded Munia
2	Blackspotted Yellow Tit
3	Brown Flycatcher
4	Brown Hill Warbler
5	Brown Rock Pipit
6	Pied Crested Cuckoo
7	RufousbelliedWhitethroatedBabbler
8	Sand Lark
9	Tickell's Blue Flycatcher
10	White Bellied Treepie
11	Whitethroated Fantail Flycatcher
12	Whitecheeked Tit
13	Blacknaped Flycatcher
14	Rosy Minivet
15	Yellowcheeked Tit

Appendix 2.5 4 Prevalent species initiating egg-laying in May & June in different bio-geographic regions of Indian mainland

Sl.No	Wide spread species initiating egg-laying in May-June	Month of laying initiation
1	Bristled Grass Warbler	May
1	Jungle Wren Warbler	June
2	Finn's Baya Weaver	June

Appendix 3.1 Breeding season of species restricted to Himalayan region

Sl.No	Species	Breeding Season
1	Horned Lark	May-July
2	Shorttoed Lark	May-July
3	Maroon Oriole	March-June
4	Shortbilled Minivet	April-June
5	Carrion Crow	April-June
6	Chiffchaff	April-July
7	Nutcracker	February-July
8	Redbilled Chough	March-June
9	Rock Nuthatch	April-May
10	Orange Flanked Bush Robin	April-June
11	Robin Ascentor	April-July
12	Rufousbreasted Blue Flycatcher	May-June
13	Saphireheaded Flycatcher	April-June
14	Orangegorgetted Flycatcher	April-June
15	Missel Thrush	April-June
16	Tickell's Thrush	May-June
17	Plainbacked Mountain Thrush	May-June
18	Redstart	May-July
19	Wall Creeper	May-August
20	Isabelline Chat	April-June
21	Black And Yellow Grosbeak	June-Aug
22	Himalayan Whistling Thrush	July
23	Little Forktail	April-June
24	Redbilled Babbler	April-August
25	Variegated Laughing Thrush	April-August
26	Whitethroated Laughing Thrush	April-May
27	Largebilled Willow Warbler	May-June
28	Orangebarred Willow Warbler	April-August
29	Pale Bush Warbler	May-August
30	Largebilled Bush Warbler	May-July
31	Largebilled Willow Warbler	June-July
32	Palla's Willow Warbler	May-June
33	Firecapped Tit warbler	April-July
34	Blackfaced Flycatcher Warbler	May-June
35	Pipit	May-June
36	Upland Pipit	April-August
37	Hedge Sparrow	June-July
38	Firetailed Sunbird	January-July
39	Whitebrowed Rosefinch	May-August
40	Plaincoloured Mountain Finch	June-August
41	Redbrowed Finch	April-July
42	Goldfronted Finch	May-July
43	Rock Bunting	May-June
44	Whitecapped Bunting	May-July
45	Brownfronted Pied Woodpecker	March-June
46	Western Himalayan Pied Woodpecker	April-May

Sl.No	Species	Breeding Season
47	European Bee-Eater	April-August
48	Eastern Swift	May-July

Appendix 3.2 Breeding season of species restricted to Western Ghats

Sl.No	Species	Breeding Season
1	Nilgiri Pipit	April-June
2	Tickell'sBlue Flycatcher	April-June
3	Travancore Laughing Thrush	April-June
4	Wynad Laughing Thrush	February-August
5	Neilghery Flowerpecker	February-June
6	Blackheaded Babbler	January-August
7	Nilgiri Laughing Thrush	January-August
8	Rufousbellied Munia	January-August
9	Great Black Woodpecker	January-March
10	Black And Orange Flycatcher	March-August
11	Little Nightjar	March-August
12	Rufous Babbler	March-August
13	Nilgiri Verditer Flycatcher	March-June
14	Little Pied Flycatcher	May-June
15	Monarch Blue Flycatcher	May-June