INTRODUCTION

Birds are bio-indicators of environment (Koskimies, 1988) which are best example for seasonality in vertebrates. Seasonality is represented by the initiation-termination and reinitiation of physiological processes, which is an adaptation for survival in many species. Almost all bird species that have been studied so far exhibit seasonality in several functions, like food intake, body mass, body fattening, plumage and bill colors, sleep-wake cycle, hibernation, reproduction, gonadal recrudescence and regression, photo refractoriness, nest building, parental care, molt, hormonal levels, song production, immune system, migration etc (Wingfield and Farner, 1993; Jain and Kumar, 1995; Kumar, 1997). In seasonality regulation two mechanisms appear to be involved. One is the photoperiodism, in which environmental photoperiodic times, the component events of seasonality. The other is the circannual rhythm generation, in which a self-sustained endogenous rhythmicity of approximately one year duration. Seasonal functions occur synchronized with the geophysical periodic environment such that they occur at the time of the year when the possibility of survival of young ones is greatest. At any latitude, the annual variation in the availability of daily light is predictable since day length is the consequence of relatively stable positions of sun, earth and moon over the years.

Seasonality is emanating from the earth's spinning, tilt with 23.58^0 on its axis, revolution around the sun and moon is rotating periphery of the earth. This planetary and sub planetary movements illuminate the cycle of changes at the earth's surface. These environmental changes give rise to daily (Aschoff, 1981; De Coursey, 1990; Pittendrigh, 1993), tidal (De Coursey, 1983; Morgan and Christy, 1995), lunar

(Neumann, 1989) and annual (Gwinner, 1981) rhythms. These physiological processes of rhythms may have a period of 24 h, 29 days and 365 day periods. The biological rhythmic processes manifest of physiology and behavior (Dunlap *et al.*, 2003), some may be mimic of environmental cycle, and many more are expressions of endogenous mechanisms, believed to be an outcome of millions of years of interaction between the biological and geophysical world (Pittendrigh, 1993; Hastings *et al.*, 1991; Sharma, 2003). Also, day length influences temperature and light that varies in duration, intensity and spectral distribution over seasons; and light intensity and light spectrum also vary from morning to evening. Hence, day length is a reliable 'calendar' in many birds in timing their physiological and behavioral functions such that they do not occur at 'wrong time' of the year.

The role of long day length in causing fat deposition and gonadal growth has been established in several species of temperate (Kumar *et al.*, 1993; Kumar, 1997; Gwinner and Hau, 2000) and tropical birds (Tewary and Dixit, 1986; Kumar and Kumar, 1991, 1993). However, relatively less attention is paid on photoperiod-induced effects on fat deposition (Kumar and Tewary, 1983; Kumar, 1986, 1988, 1997). Most of the birds breed during a narrow window of the year (in late spring and summer), breeding season among mid- and low-latitude species can be scattered. In tropics, breeding seasons can be found spread out over the entire year although individual species or different populations of the same species are essentially seasonal (Chandola *et al.*, 1983). Many tropical birds breed during spring and summer exhibiting cyclicity in reproduction, similar to temperate species (Epple *et al.*, 1972; Lewis *et al.*, 1974; Thapliyal, 1981; Gwinner and Dittami, 1984; Dittami and Gwinner, 1985; Tewary and Dixit, 1986). Examples of Indian seasonal breeders including those migratory species that overwinter in India are: Indian owls, *Anthena brama,* Bubo bubo, *Ketupa zeylonesis* and *Tyto alba* (Thapliyal, 1954) Doves, *Streptopelia tranquebarica*, *Streptopelia senegalensis* (Singh, 1958); crows, *Corvus macrorhynchos, Corvus splendens* (Prasad, 1965); pigeon, *Columba livia* (Dominic, 1960); Indian weaver bird, *Ploceus philippinus* (Saxena, 1964); lal munia, *Estrilda amandava* (Tewary and Thapliyal, 1962); mynas: blackheaded myna, *Temenchus pagodarum*, bank myna, *Acridotheres ginginianus,* common Indian myna, *Acridotheres tristis,* pied myna, *Sturnopastor contra* (Tewary, 1967); spotted munia, *Lonchura punctulata* (Chandola *et al.*, 1983; Bhatt and Chandola, 1985); blackheaded bunting, *Emberiza melanocephala* (Kumar and Tewary, 1982a; Jain and Kumar, 1995); common Indian rosefinch, *Carpodacus erythrinus* (Kumar and Tewary, 1985); redheaded bunting, *Emberiza bruniceps* (Tripathi, 1985); brahminy myna, *Sturnus pagodarum* (Kumar and Kumar, 1991) and blossom headed parakeet, *Psittacula cynocephala* (Maitra, 1986).

Birds undergo a series of molt during their life span. At least four different molts occur from hatching to the end of the first year, beginning from natal down, juvenile, alternate to appearance of basic plumage (Lucas and Stettenheim, 1972). During rest of the life, many birds display two molts in a year. One of these is prenuptial or pre alternate molt that prepares birds to the approaching breeding. The other is the postnuptial or pre-basic molt that signals the end of the breeding season. In European starling (*Sturnus vulgaris*), molt starts in June and complete by August, which is starling’s post-reproductive phase (Dawson, 2003). In many species, the prenuptial molt is less distinct as compared to the postnuptial molt. Postnuptially, birds exhibit a more complete molt involving on many occasions the loss of rectrices, remiges and body feathers. Furthermore, the postnuptial molt is indicative of not just the feather replacement but of several significant physiological changes. For example, postnuptially molting individuals show increased vascularization of the dermis underneath feather follicles and papillae (Stettenheim, 1972), osteoporosis (Meister, 1951; Murphy, 1996), increased metabolic rate (Perek and Sulman, 1945; Lindström *et al.,* 1993), decreased fat (Kuenzel and Helms, 1974), and changes in blood cell profiles (Davis *et al.*, 2000). In the white crowned sparrow (*Zonotrichia leucophrys gambelii*) cholesterol, phospholipid and glyceride levels, which are high in the pre-migratory and migratory periods and low in the breeding period, are further reduced during the period of body molt.

Several physiological changes coincide with the period of postnuptial molt. In one study that induced a forced molt in hens by restricting food and water found thyroxin (T_4) to be an important hormone responsible for initiating the molt process (Brake *et al.*, 1979). Experimentally, a single intramuscular injection of progesterone at a dose of 20 µg terminates egg production and subsequently induces complete molt in hens (Shaffner, 1954; Adams, 1955; Tanabe *et al.*, 1957; Harris and Shaffner, 1957). In general, high prolactin levels during late breeding season are implicated in the development of reproductive refractoriness and postnuptial molt in birds (Dawson and Goldsmith, 1982). Also, immune system of birds undergoes changes in the molt period. In both young and old willow tits (*Parus montanus*), for example, spleen is found enlarged during the molt period (i.e. late summer and early autumn) compared to the preparatory phase of late autumn and winter (Silverin *et al.*, 1999).

Day length (Light length phase = Photoperiod)

Photoperiod is an important environmental variables in determining the adaptations to the environment and providing cues from the environment to control biological functions. Photoperiodism was discovered and named in second decade of this century by W.W. Garner and H.A. Allard of the U.S. Department of Agriculture, working on the understanding of the mechanisms of timing of flowering in plants. 'Photoperiodism is the control of some aspect of life cycle by the timing of light and darkness' (Hillman, 1979). It has therefore, two important components -

(1) it influences development of long lasting behavioural patterns, often related to reproduction, not transient events of minutes or hours, and

(2) influence of photoperiod is through the timing of the light, and thus of darkness, received and not the total amount.

Birds are the first vertebrates in which the role of day length (= photoperiod) was demonstrated in the control of seasonal functions. That the photoperiod could act as a temporal information dates back to eighteenth century when Dutch netters realized that the song associated with breeding activity could be induced in males of several species of passerine birds by keeping them first in darkness from May to August and then returning to natural day lengths (Hoos, 1937).

William Rowan (1925) experimentally demonstrated the role of day length in gonadal development of a passerine bird species, the slate-colored junco (*Junco hyemalis*). In series of investigations, he established that the vernal migration and gonadal recrudescence could be induced out of season by exposure of birds in laboratory to increasing day lengths (Rowan, 1926, 1928, 1929, 1932). Since then the role of day length in control of seasonal pre-migratory fattening, maturation and reproduction has been confirmed in many high-, mid- and low-latitude species (Murton and Westwood, 1977; Farner *et al.,* 1983; Follett, 1984; Wingfield and Farner, 1993; Kumar, 1997; Dawson *et al.,* 2001; Hau, 2001; Deviche and Small, 2001; Kumar *et al.,* 2004; Rani *et al.,* 2005; Kumar and Arvind, 2006). It is also recognized that other factors in the environment, such as food availability also influence gonadal growth and development in several species (Wingfield and Farner, 1993; Kumar *et al.,* 2001; Kumar and Anushi, 2004; Trivedi *et al.*, 2006a, b). Temperature (Hoffman, 1968; Wingfield *et al.,* 2003), food (Hau and Gwinner, 1996; Berkvens *et al.,* 2008; Fuller *et al.*, 2008; Budki *et al.,* 2009; Rani *et al.*, 2009), sound and song (Menaker and Eskin, 1966; Meitzen *et al.,* 2009), stress (Bokonv *et al.*, 2009), social cues (Viswanathan and Chandrashekaran, 1985; Mrosovsky *et al.,* 1989; Stevenson *et al.*, 2008) and endocrine secretions (Turek and Gwinner, 1982) play role in the synchronization of circadian functions in many vertebrates including birds.

The role of photoperiod in control of seasonal cycles has been demonstrated from both low and high latitudes in about six dozen species belonging to 15 different families. Seasonality in Indian birds is however more fascinating (Thapliyal, 1981; Thapliyal and Gupta, 1989; Kumar, 1997).

Reproductive cycle and histology

Studies on reproductive cycles of Indian birds at Banaras Hindu University, Varanasi (25^0N, 83^0E) were done more than five decades ago (Misra, 1948). Since then a number of birds have been studied and their breeding seasons are summarized by Thapliyal (1978) and Chandola *et al.* (1983, 1985). Here, we decide to re-investigate seasonal cycles of blackheaded munia (*Lonchura malacca malacca*), a most interesting species with oriental region distribution, for the reasons enumerated in the general introduction. The effects of environment are reflected at histological level. The gonadal activity increases and decreases with the onset and termination of reproductive phase respectively. From standpoint of the histological changes occurring in the gonads, the annual reproductive cycle of Indian birds can be divided into four distinct phases i.e., (i) Preparatory or regenerative phase, (ii) progressive phase, (iii) breeding phase, and (iv) regressive phase, each of which have a specific duration. The duration of each phase varies from species to species (Saxena, 1964; Pandha, 1966; Tewary, 1967; Garg, 1968; Chaturvedi, 1976; Kumar, 1981; Lal, 1982; Singh, 1982; Dixit, 1987; Tripathi, 1987).

Aim of the thesis

The present work was undertaken to address the role of photoperiod in regulation of circadian (daily activity pattern) and seasonal rhythm associated with the reproduction in the blackheaded munia.

Studies centre around two objectives:

i. To study the involvement of photoperiodism on endogenous rhythm in regulation of daily activity rest pattern (circadian rhythm) with food intake and seasonal responses in terms of body mass, testis growth-regression and molt cycle, and

ii. to investigate the responsiveness to changing photoperiods under long days compared with the control, under short days and bioassay of bio-molecules (Protein, lipid and carbohydrate) in blood samples under certain experiments.