CONCISE SUMMARY

It is a known fact that a wide spectrum of biological phenomena exhibits regular recurrence of patterns of activities in cyclic manner with certain periodicities. Several environmental factors such as photoperiod, temperature, humidity, rainfall, food supply etc. have been implicated in the mechanisms that influence these cyclic occurrences (Welty and Baptista, 1990; Perrins and Birkhead, 1983). Adjustments by various living organisms to these recurring environmental variations permit adaptations to particular schedules and habitats in such a manner as to allow them to carry out various life activities at the optimal times of the life cycle. One of the fundamental phenomena of utmost importance to any species is procreation and continuation of the species. Therefore reproductive functions, naturally, exhibit meticulous regulation of initiation and development of gonadal functions, which is now known to be the out come of an intricately balanced interaction of the environmental and physiological state (Nalbandov, 1970).

Birds are the best-known relatively large and adaptively diversified group of vertebrates. Detailed information is available regarding their bionomics and constancy of reproductive patterns especially regarding seasonally breeding temperate and domesticated species. However, the information regarding continuous/almost continuous tropical/sub-tropical birds is sporadic. Hence, it was thought desirable to investigate the reproductive physiology of a subtropical bird reported to be beneficial as well as harmful to agricultural crops. Jungle babbler (*Turdoides striatus,* Order:

Passeriformes, Fam: Silvidae) has kept the originality of reproductive rhythms without undergoing the modifying influences of urbanization.

The study of birds in relation to agriculture and their application in management of agricultural crops has become an essential field as "Agricultural ornithology" in itself (Dhindsa and Saini, 1994). Predatory birds (i.e. omnivores and insectivores) play a dominant role in maintaining many pest species at innocuous level in the agricultural landscape. In an agro-ecosystem it can be said that the omnivore bird species play a dual role (Gokhale, 1992; Midha and Gupta, 1994), on one hand by feeding on the pest species and controlling its population and on the other side by damaging the crops to certain extent by feeding on them during various stages of the growth (Dhindsa, 1996; Parasharya, 1988). Jungle babbler (*Turdoides straitus*), falls in this category having a binal role. These authors have considered that these omnivore species of birds along with several other species protect the crops like Chickpea and Pigeon pea which are known to get heavily infested with the notorious pest, the gram pod borer, *Helicoverpa armigera*. Jungle babbler feed on the larvae and the pupae of this pest and thus help in biological control of these insect pests to a large extent. Contrary to this, they have also been reported to feed on the cereal crops like Sorghum, Pearl millet, Bajra *etc.* with other species of birds and damaging them and causing economic losses (Parasharya, 1988; Dhindsa *et al.*, 1994). Feeding is the principal diurnal activity of the individual of a flock of Jungle. While on ground Jungle Babblers spend almost all their time in

foraging, they hop about on the ground, turning over the leaves and digging and mulching the ground vigorously in search of food.

To begin with, in the present study feeding activity of the Jungle babblers in various agricultural fields' *viz.* crops of Pigeon pea, Sorghum, Maize, Brinjal, Cabbage *etc.* along with two empty plots one being the ploughed one and the other unploughed one were observed for a comparative study. One crop studied in particular was pigeon pea (*Cajanus cajan*) which is known to be infested severely with *Helicoverpa* larvae. The sowing time of the crop is from September and is harvested in February and March which also coincides with the cropping of the Sorghum. Jungle babblers were seen spending their maximum time in the pigeon pea fields and were rarely seen visiting the sorghum field. The number of Jungle babblers was maximum in the pigeon pea fields during October and November in both the small pod stage and the large pod stage which had heavy infestation of *Helicoverpa armigera*. Least number of birds were seen during the flowering stage in September. Later in December the fields were sprayed with three applications of insecticides *viz.* Dunnate and Monocrotophos which decreased the pest population consequently resulting in decrease in the number of Jungle babblers in the pigeon pea fields. As the effect of the chemicals decreased, along with the rise in the *Helicoverpa* in January, number of Jungle babbler feeding in pigeon pea also increased. From these observations it could be said that Jungle babblers prefer insect as food than grains and hence, should be more of a beneficial bird than being

harmful. Jungle babbler totally depends on the type of the food available during different seasons.

Brinjal, Cabbage and cowpea are other important vegetables grown in and around Baroda, which are heavily infested with the pod borer, the Diamond back moth and the aphids. In brinjal, larvae are not exposed (as present within the fruit). This is reflected in less number of Jungle babblers in these fields. In Cabbage, the insect pests *viz.* aphids and Diamond back moth are not only depredated by birds but also by Lady bird beetles, hence, the presence of Jungle babblers could be low because Lady bird beetles are to a large extent responsible for keeping the pest population in control. Cowpea at the time of the study was fully ripe and harvested and collected in a mound in the centre of the field which did not attract the Jungle babblers. Among the two unsown plots, in the ploughed field, Jungle babblers were seen in adequate number because ploughing exposed many under ground larvae and insects especially White grubs (*Holotrichia* Sp. Scarabidae), damaging the root system of several crops, which attracts large number of birds. Jungle babblers were seen in large number in this ploughed field suggesting their possible involvement with other species of birds in controlling the insect population. In the unploughed field, least number of Jungle babblers were found because of least availability of food. Thus Jungle babbler shows feeding preference depending on food availability and is basically an insectivore taking to grains only in certain conditions.

Jungle babbler is a social bird which budgets its energy for its reproduction, ideally suited for an incoherent habitat in which the natural

food is relatively scarce and over dispersed (Andrews 1968). Andrews (1968), reports that, the fragmented habitat of the Jungle babblers, correlated with its sedentary habit, reduces the dispersal of the young at the end of the breeding season and favors the formation of flocks. The natural food in the Jungle babblers' habitat is over dispersed and relatively scarce where feeding condition favors the co-operative nesting as well as the co-operative defense by individuals and leads to flocking. This type of feeding condition also favors long breeding season correlated with the staggering in the nesting of individual pairs within a flock (Andrews, 1968).

During their breeding phase, the flock breaks up into a group of 3-4 birds in which apart from the breeding pair, members called "helpers" are also present. Helpers forgo their breeding in order to assist the breeding pair.

The breeding season of the Jungle babbler is irregular but with a long period of readiness of the gonads. They are known to breed from April to November in and around Baroda district Long. 73^0 15' E Lat 22^0 17' N. From December to February a fully regressed phase is observed. In the present study, Jungle babblers were procured from November 1997' to July 2000', and maximum size of testes and ovaries were obtained between April and November, during which a few non-breeding gonads were also found. In case of females a peculiar characteristic feature was noted. A few females had larger breeding ovaries with complimentary oviducts but few other females, though had larger ovaries did not have the functional oviducts. This group was separated out as "helper" which probably had under developed oviducts, not involved in egg production and egg laying but they were involved in

assisting the breeding pair in domestic duties. A comparison of the body weights of the breeding and the non-breeding males and females and the helper females, indicates no significant differences suggesting that during the breeding phase they don't show predeposition of glycogen or fats and that they rely on their daily food supply. Moreover since they are cooperative breeders, the work load is distributed and thus the energy expenditure for each bird decreases, resulting in decreased food consumption.

Most of the reproductive events are the chain of inter dependent, mutually controlling and cyclic reactions and this optimal reproductive performance is possible because of inter play of hormones. Androgens (*Viz.* Testosterone) and, progesterone and estrogens play the most significant role in the target organs under the influence of gonadotropin resulting in physiological and behavioral changes in an animal. The synchronization between these physiological and behavioral changes leads to a successful propagation of the species. In the present study, the hormonal assay of testosterone and progesterone were carried out in all the categories of Jungle babblers. No significant difference is noted in the titers of testosterone in breeding males and females along with the helper females. From this it could be suggested that the territorial defense, nest protection as well as protecting the youngones from the predation is carried out by all the members of the flock. Hence, the threshold levels are equally maintained and no significant rise is seen in the testosterone levels in the breeding birds. Testosterone is known to maintain aggressiveness in male birds and causes decreased parental care (Vleck and Brown, 1999; Trainor and Marler, 2001).

Progesterone levels were comparatively high in breeding females than breeding males. However in helper females intermediate progesterone levels were noted. Progesterone is known to initiate the brooding, nest building and incubation behavior, it is also involved in the development of the oviduct (Hutchison, 1975; Balthazart, 1983; Seiler *et al.,* 1992). Therefore from the levels of progesterone in the breeding birds it could be said that as all the members of the flock are involved in incubation of eggs and feeding the youngones, no significant difference in progesterone titers is observed in male and female Jungle babblers. Also the intermediate levels seen in the helper females suggest their significant participation in the incubation but because of less progesterone levels oviducal development is not profound which prevents them from egg formation and egg laying.

Ascorbic acid is an important co-factor in various activities of general metabolism of the body and it is also known to play a significant role in the steroidogenesis. Because of its three principal functions of, promotion of collagen synthesis, its role in hormone production and its ability to protect cells from free radicals (Chinoy and Rao, 1979; Luck *et al.,* 1995), Ascorbic acid has long been related with fertility/reproduction. Ascorbic acid has a synergistic action with testosterone by increasing the testicular germ cell maturation and enhancing the activity of a number of androgen dependent enzymes (Chinoy *et al.,* 1978). Most of the animals have developed the ability to synthesize ascorbic acid. Most of the birds and mammals are known to synthesize Ascorbic acid in their liver and/or kidney. Biosynthesis of Ascorbic acid in non-passerine birds occurs in the kidneys, whereas in higher

passerines the kidney as well as the liver possesses this capacity (Ray chaudhari and Chaterjee, 1969). The present study reports the concentration of Ascorbic acid in liver, intestine, kidney and gonads of breeding, non-breeding male and female Jungle babblers along with the helper females. A correlation between ascorbic acid and cholesterol wherein the status of ascorbic acid affects the cholesterol levels in pregnant guinea pigs (Jenkins, 1980) and gonadal cholesterol and ascorbic acid content (Ambadkar and Padate, 1993; 1995; Ambadkar and Kotak, 1976) have been reported. All the steroid hormones *viz.* estrogens, progesterone, androgens and adreno-cortical hormones are synthesised from cholesterol. A correlation between ascorbic acid levels in different tissues and cholesterol metabolism especially in steroidogenesis is considered here in these birds. The three extra-gonadal tissues selected were liver, intestine and kidney. Liver and/or kidney are known to synthesise ascorbic acid (Raychaudhari and Chaterjee, 1969). In non-passerine birds ascorbic acid synthesis is known to occur only in the kidney whereas in higher passerines both liver and kidney are known to be synthesising sites of ascorbic acid. Intestine is the site of absorption of this vitamin coming through the dietary sources.

Among the three tissues studied, kidney had lower ascorbic acid content than the liver but higher than the intestine. The Ascorbic acid content remained high in the extra gonadal tissue of both the sexes during the breeding phase. In helper females ascorbic acid content of all the three tissues studied were equivalent to that in the breeding females suggesting that they are equally involved in possible Ascorbic acid turnover for various

metabolic activities however, accumulation of the same in the ovary in helpers was equal to that of the non-breeding females indicating the non-involvement of gonads in steroidogenesis. This is reflected in the titers of testosterone and progesterone too. Both the gonads, the testis and the ovary exhibit the cycles of tissue regeneration and degeneration and of steroid secretion that can be assumed to be ascorbate dependent. The ascorbic acid content present in the breeding and the non-breeding testes suggest the utilization of ascorbic acid as a cofactor in steroidogenesis in the breeding males and its accumulation in the non-breeding males in the absence of steroidogenesis.

The increased requirement of ascorbic acid in breeding male Jungle babblers probably comes from the liver and the kidney. Comparatively low ascorbic acid and cholesterol levels in Jungle babblers in relation to Bank myna (colonial nester) and Brahminy myna (solitary nester) may be due to its social nature. In Jungle babblers, no significant difference in cholesterol content of liver, intestine and kidney of breeding and non-breeding birds as well as helpers are noted, except for a significantly lower level of cholesterol in the kidney of the non-breeding females. Non-significant differences in cholesterol levels in general in all the Jungle babblers could be due to its flocking or social nature.

Energy plays significant roles in biological system. It is a resource necessary for the propagation and maintenance of the highly ordered physiochemical system that comprise living system. Animals obtain all their

required energy from the food they eat which consists of various biological components (Hazelwood, 1986) *viz.* carbohydrates, lipids and protein, the proportion of which varies depending on the type of the food. Jungle babblers show changes in the total amount of the food consumed as well as the nature of the diet throughout the year (Gaston, 1978). As the responsibility of reproduction except egg formation and egg laying is shared equally by all the individuals in the group and the energy is spent by all the individuals of the flock, the energy spent by the individual bird decreases, hence, probably they rely on daily food supply rather than storing the food. This is reflected by no significant difference in the physiological status, with reference to carbohydrates, lipids and protein contents in liver, intestine and kidney of a pair which is in the breeding state from the other members of the group which are helpers or in the non-breeding state. Many birds start their reproductive season with large energy reserves but this is not true for all the birds (Thomas, 1982). Jungle babbler seems to be one such bird with a long breeding season when atleast some pair show breeding activities. Hence, they probably do not show significant energy reserves throughout the year which is also reflected by no variation in the body weights too (chapter 2).

The energy required by different tissues depending upon their role, show variations in metabolites (Ambadkar and Kotak, 1976). This results in quantitative fluctuations in the levels of metabolites and enzymes as the bird undergoes adaptive changes during its breeding activities. The present study also deals with the involvement of the said tissues in energy metabolism along with testes and ovaries. The energy required for breeding activities in

case of Jungle babbler mainly comes from the carbohydrate consumed as observed in the increased intestinal glycogen (carbohydrate) content resulting into increased hepatic glycogen in the breeding and the helper females compared to non-breeding birds.

The maximum number of birds found in non-breeding state was between November to February coinciding with the cultivation period of the crops like pigeon pea and chick pea grown in winter and known to be heavily infested with *Helicoverpa armigera* larvae. Jungle babblers have been reported to feed on these (Gokhale, 1992, Parasharya, 1988, personal observations chapter 1). This is reflected by highly significant increase in the intestinal proteins in the non-breeding birds. In male birds similar trend is maintained but in females opposite trend is observed. The high protein demand by the breeding females for egg production is reflected by increased protein levels in liver as well as in kidney on one hand and decreased intestinal protein probably indicating a faster uptake from the same. The helper female which do not lay eggs show lower intake of proteins compared to breeding and non-breeding females reflected in the lower hepatic and the renal protein levels.

Accumulation of lipids in testes and ovaries during the non-breeding state has been reported (Lofts and Murton, 1973; Ambadkar and Kotak 1976; Ambadkar and Padate, 1993; 1995), in testis and ovaries of pigeon (Prasad and Guraya 1983; Patel and Ramachandran, 1987), in rat ovary (Sangha and Guraya, 1989). Almost all the seasonally breeding vertebrates

depict a seasonal lipid decrease during active spermatogenesis and steroidogenesis (Johnson, 1970).

Testicular and ovarian lipids reflect accumulation in the non-breeding male and female Jungle babblers too. This suggests that there appears a change in the metabolic pattern of testes and ovaries indicating non-utilization of lipids and its subsequent accumulation during the non-breeding state. The depletion which is noted during the breeding activity is indicative of increased utilization of lipid as a precursor of steroidogenesis. The total lipid content present in liver, intestine and kidney in breeding as well as non-breeding birds along with the helper females are almost equal which accounts for the responsibility of parenting shared equally by all the members of the flock.

Along with the metabolites certain enzymes involved in carbohydrate metabolism and energy releasing processes are also studied. These include Glycogen Phosphorylase (GP), Glucose-6-phosphate (G6Pase), Succinate dehydrogenase (SDH) and Adenosine triphosphatase (ATPase). Glycogen in animals functions as a reserve of glucose for later metabolic use. Therefore the regulation of glucose synthesis, storage, mobilization and catabolism is elaborate and sensitive to the immediate and long term energy needs of the organism. The glycogen metabolism must be controlled according to the cellular needs which involve enzymic as well as hormonal control (Hazelwood, 1986). These enzymes and hormones also affect the rate of

transport and synthesis as well as the overall metabolism of carbohydrates, fats and proteins (Spannhake, 1976).

GP is the initial catalytic enzyme in glycogenolysis which catalyses glycogen to yield glucose-1-phosphate which can be used for production of ATP (Biorn and Graves, 2001, Harper, 2000). Increased activity of GP is associated with the increased glycogenolysis and it also indicates that the tissue depends upon carbohydrate as the chief fuel for activities (Cahill *et al.*, 1957). As seen in chapter 5, the hepatic as well as intestinal glycogen levels in breeding birds are high; correspondingly the GP activity is also high in these birds indicating that the enzyme activity is modulated parallel to that of metabolic load. In Jungle babbler, it seems that the carbohydrate metabolism slows down in the liver and intestine of the non-breeding birds and the activity in the kidney increases during this period as is reflected by increase in the GP activity. In helper females which share the domestic duties except for egg formation and egg laying, the energy is not utilized probably equal to that of breeding birds as they have non-significantly higher glycogen in liver and lower GP in all the three tissues studied.

G6Pase is another crucial enzyme studied that catalyses the ultimate biochemical reaction of both glycogenolysis and gluconeogenesis. G6Pase plays an important role in glucose release from the liver through mechanism involving either gene expression and / or biochemical inhibitions of its enzymatic activity (Haber *et al.*, 1995, Minassian *et al.*, 1996, Mithieux *et al.*, 1996). The extent of glycogen accumulation is inversely related to G6Pase

which is a rate limiting glycogenolytic enzyme and the progressive increase in the liver glycogen concentration is associated with a concomitant decrease in the hepatic G6Pase activity (Raheja *et al.*, 1980). This is reflected in Jungle babbler by non-significantly lower G6Pase levels in the liver of breeding and helper females and accumulation of glycogen.

The other enzymes quantified are Succinate dehydrogenase (SDH), a key enzyme of the Kreb's cycle and Adenosine triphosphatase (ATPase) important enzyme in energy metabolism. SDH usually functions as an index of oxidative metabolism. An active synthesis of ATP and its enzymic hydrolysis is the characteristic feature of the metabolically active tissue where ATPase is actively involved in high energy phosphate metabolism. According to the energy needs of the body, the increase or decrease rate of Kreb's cycle and the oxidative phosphorylation could be inferred from the activities of the enzyme such as SDH and ATPase respectively.

The high levels of hepatic and intestinal SDH and ATPase activities observed in the breeding Jungle babblers compared to the non-breeding birds are suggestive of an active synthesis as well as hydrolysis of ATP to provide energy in order to fulfil tremendous energy demand to carry out several metabolic processes during the breeding state. Both the enzymes are active in breeding male and female Jungle babblers. The energy released during the process is for the synthesis of different metabolites as well as for all the physical activities carried out during reproduction. In case of Jungle babblers which are social birds, all the energy demanding breeding activities

are performed by the whole flock which consists of a breeding pair and assistants called helpers, the energy expenditure is distributed amongst the flock members and hence, storage of energy in the form of glycogen or lipids is lowest. They rely on the daily supply of food which is reflected in their foraging behaviour, wherein they spend their maximum time in search of food. The degree of maintenance of the enzyme activity reflects the physiological role of these enzymes *i.e.* the physiological need for keeping an animal active. The enzymes involved in the energy production are preferentially maintained during different physiological states of the animal (Szepsi, 1976). It is evident from the present work that the biochemical changes that take place in the body depend on the physiological requirement of the organism to obtain energy for maintaining vital functions of the body as well as for the different activities during reproduction.

Along with the metabolite studies, histology and histometric studies were also carried out for the above said tissues. Testis show a cyclicity in spermatogenesis wherein it could be roughly divided into seven stages depending on the type of the germ cell present. Histometric variations were also noted for the diameter of seminiferous tubule, thickness of germ layer and diameter of interstitium. It was seen that the germ cell thickness and seminiferous tubule diameter increases in the breeding state. Observations were carried out for the breeding, non-breeding and helper ovaries. In breeding ovaries cells at various stages of follicular maturation were seen. Maximum number of large follicles which also attained the maximum diameter. The non-breeding ovaries had maximum number of small follicles

in the cortical region. The ovaries of the helper females showed both large and small follicles. Maximum atretic follicles were observed in helper ovaries wherein granulosa cells migrate towards the cavity of the follicle becomes a connective tissue scar and regresses.

In the extra-gonadal tissues studied (viz. liver, intestine and kidney) no seasonal or sex related variations were observed. Liver shows a basic vertebrate plan wherein hepatocytes arise from the central vein surrounded by sinusoids. But as in case with primitive birds, two cords of hepatocytes are seen (Hickey and Elias, 1954). Kidney also shows a typical avian pattern with lobules with cortex and medullary region. In intestine at the base of the villi, Brunner's glands are seen. Within the corium of the villi dilated lacteals are seen which complements with the feeding habit of Jungle babblers.

This study is expected to help in understanding physiological adaptations of Jungle babblers during breeding and non-breeding state and to assess the impact of Jungle babbler on agricultural practices. Though it is known to feed on some of agricultural crops, it is more of a beneficial bird.

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