CHAPTER FOUR

DISCUSSION AND CONCLUSIONS

Mammalian skin or cutaneous glands of the general body surface have been studied from the point of view of their histology, histochemistry and bioassy studies and comparatively less attension has been paid to the specialized skin glands. A critical analysis of the existing literature shows that some of the specialized skin glands have been studied for histology, sex dimorphism, seasonal variations in histology, histochemical and biochemical analysis of various metabolites and seasonal variations therein. In some cases scent marking components or pheromones have been isolated and purified and tested for their behavioural responess. Comparatively less work has been carried out on the frontal sac gland of the leaf-nosed bats. Today, histology of the frontal sac gland is known in three species of the African leaf-nosed bats and two species of Indian leaf-nosed bats. Further, histology, seasonal histological variations, sex dimorphism, seasonal histochemical and biochemical alteration in various metabolites have been studied in Indian leaf-nosed bat, H. Speoris. In another Indian leaf-nosed bat, H. fulvus fulvus only histology has been reported.

In the present investigation adult male and female bats, H. fulvus fulvus were used since they

possess frontal sac gland which is well developed in male and available in sufficient number in this locality. It was decided to investigate histology, histological alterations and histochemical variations in mucosubstances according to various phases of their annual breeding cycle involving naturally occuring variation in the milieu of hormones of pituitary and gonadal origin. In light of the observations made (Chapter III) it is proposed to discuss some of the points in brief and to compare the present observations with other skin glands in general and frontal sac gland in particular.

The bat, H. fulvus fulvus selected for present investigation is a seasonal breeder and the following stages of sex cycle can be identified in a year.

1) The period of sexual quiescenee or inactivity from March to July when the testes were very small with minimal weight and there is no spermatogenesis.

2) The prebreeding or preparatory period during August to September, when the size of the testis gradually increased together with increase in weight. Preparatory changes towards spermatogenesis were seen during this period.

3) The active breeding period from October to December. The testes reached maximum size and weight with its peak in late November to early December.

During this period active spermatogenesis and liberation of sperms were observed.

4) The post breeding period occured during January and February, witnessed gradual reduction in size and weight of the testes. The seminiferous tubules underwent regression leading to the atrophy of the testes.

These observations confirm a single sex cycle in H. fulvus fulvus which was earlier reported by vibhute (1981).

In H. fulvus fulvus, the frontal sac gland was found rudimentary in the form of a papilla throughout the year in the female bats, therefore its observation are considered only from the histological point of view. The frontal sac gland in male bat was studied in detail from histological, histochemical points of view as it is prominent and undergoes seasonal variations during the sex cycle.

(I) Seasonal variations in size and Weight of the Frontal Sac Gland :

The testicular weights of adult bat show a very definite variations in the annual reproductive cycle. It is evident from the Table No. 1 and Graph that similar cyclic variations are observed in the size and weight of the frontal sac gland

in adult males.

During the sexual quiescence the frontal sac gland in each male was minimal in size with average weight 35 ± 3.7 mg in July. There was gradual increase in size and weight from 43±2.5 mg during early prebreeding period in August to 50 ± 2.0 mg in late prebreeding period in September. The active breeding period witnessed progressive increase in size and weight of the gland reaching the peak 72 ± 4.8 mg in early December during maximum breeding activities. At this time the size and weight of the gland were approximately twice than during the sexual quiescence. The size and weight of the gland reduced during the postbreeding period due to glandular regression. The average weight is reduced to 59 ± 3.00 mg in January and 48 ± 2.5 mg in February. This depletion in weight is continued further with the approach of sexual quiescence. Thus the frontal sac gland in male bat undergoes a definite cyclic variations in size and weight of the gland. Such variations are in good correlation with the cyclic variations in size and weight of the testes. Such cyclic variations in size and weight were not evident in the frontal gland papilla in the

female bat. Similar seasonal variations are evident in size and weight of the frontal sac gland in H. speoris (Chandak, 1981)

(II) Histology of the Frontal Sac Gland :

The histological observations revealed that the frontal sac gland is well developed and functional in males of H. fulvus fulvus. It consists of sebaceous glands in the invaginated skin; tubular coiled sudoriferous apcrine glands partitioned by numerous connective tissue septa and peripheral clumped gland cells without any tubular lumen. The sebaceous glands in dermis are associated with hair follicles. The apocrine tubules which lie in the depper zone are lined by cuboidal to columner cells with basal nuclei. The apocrine glands open in to the sac by ducts lined by cuboidal cells. The sac wall is lined by haired skin.

Mainoya and Howell (1977) studied the histology of the frontal sac gland in three species of African Hipposiderid bats viz. H. commersoni, H. ruber and T. Persicus. In H. commersoni the gland is more prominant in males and contains trilobed sebaceous glands associated with hair follicles and modestly enlarged simple saccular apocrine gland. The complex gland in T. Persicus consisted of a superficial haired layer of sebaceous glands and

saccular apocrine glands and deeper-lying peculiar type of apocrine gland. This gland in H. rubber is entirely of a coiled-lobule type of apocrine gland. In the Indian leaf-nosed bat, H. speoris Chandak (1981) reported that the gland consists of both sebaceous and apocrine components. Futher, Chandak and Nalavade (1980) reported on the histological architecture of the frontal sac gland in H. fulvus fulvus and showed that it resembles to that in H. commersoni. The present investigation confirms this observations earlier reported by Chandak and Nalavade (1980).

Mammalian skin glands are of two basic types, sebaceous and apocrine (Quay, 1970 a, 1972; Strauss and Ebling, 1970). The specialized sking glands may be sebaceous or apocrine or may contain both the components. Purely sebaceous glands occuring in the bats are facial glands (Dalguest and Werner, 1954), Gular glands (Horst, 1966; Gutierrez and Aokiy 1973), Lip glands (Dalguest and werner, 1954), Anal glands (Allen et al. 1917 stubbe, 1969; Quay, 1970 b) and Neck glandular skin patch (Mainoya and Howell, 1979). Purely sebaceous glands in other mammals are preorbital gland (Mainoya, 1976), Chin glands (Holt and Jones, 1973), Flank glands (Quay, 1968), Dorsal glands (Quay, 1953), Caudal gland (Quay, 1968), Tarsal glands (Muller-Schwarze, 1977 b), Midventral gland (Saroj et al., 1981). The specialized skin glands

of purely apocrine nature are poll glands (Singh and Bharadwaj, 1978), Temporal glands (Adams et al., 1978), Interdigital glands (Quay and Muller-Schwarze, 1970, 1971), Metatarsal glands (Quay and Muller-Schwarze, 1970), Ventral gland field (Starch and Poduschka, 1982) integumentary gland in lower neck and upper chest (Hood and Smith, 1984). Some specialized skin glands posses both sebaceous and apocrine components as infraorbital glands (Cohen and Gerneke, 1976), Preorbital glands (Mainoya, 1978), Supracaudal gland (Albone and Flood, 1976), Dorsal gland (Quay, 1955, 1959, Mainoya, 1976), Tarsal glands (Muller-Schwarze, 1971), Sternal gland (Mainoya and Urasa 1982). Certain gland amongst bats also possess both sebaceous and apocrine components such as skin glands in face (Kulzer et al., 1985), Gular glands (Dapson et al., 1977), Pararhinal glands (Dapson, 1977). The frontal sac gland in males of H. fulvus fulvus also contain both sebaceous and apocrine components along with clumped apocrine glands in the peripheral region.

(III) Sexual Dimorphism :

The present investigation on frontal sac glands in adults of H. fulvus fulvus shows a clear sexual dimorphism since the gland is well developed and functionally active in males as compared to rudimentary and non-functional frontal papilla in females. These observations confirm the sexual dimorphisem in

this bat which was earlier reported by Chandak and Nalavade (1980). Similar sex dimorphism has already been reported in three Hipposiderid bats (Mainoya and Howell, 1977) and in Indian Hipposiderid bat H. Speoris (Chandak, 1981).

Amongst Chiroptera sexual dimorphism is reported in other specialized skin glands in morphology, histology and functional activity. Stubbe (1969) observed odour gland at throat region in male bat, M. ater. Yellow bellied bat T. flaviventris possesses throat-pouch in males and that there was no indication of throat pouch in females (Hall and Gordon, 1982). Quay (1970 b) observed larger para-anal glandular area in male than in female bats, E. splea. Mainoya and Howell (1979) studied neck glandular skin patch in three Pteropodid bats and reported that the patch is better developed and more active in male than in females of all three species. A sexually dimorphic integumentary gland in lower neck and upper chest is restricted to males in Pteropoid bat., M. lagochilus (Hood and Smith, 1984).

Sexual dimorphism is also evident in the specialized skin glands of other mammals studied so far. Holt and Jones (1973) showed that the sebaceous acini in chin gland of cuis, G. musteloides were larger in males than in females. Paired poll

glands are present in male camel right from the birth, while no visible glands were observed in she camel at any age (Singh and Bharadwaj, 1978). Rumpler and Andriamiandra (1971) described sexual dimorphism in scent marking in neck glands of lemurs, V. variegata and Iwase (1976) reported that musk glands in M. meles exhibit sexual dimprphism. Richmond and Roslund (1952) observed larger mid-ventral sebadeous glands in males than in females of prairie deermouse. Moy (1970) reported that the subauricular gland are found only in male prong-horns. Mainoya (1980) examined inguinal glands in Thompson's gazelle, the gland is well developed and more active in males than in females. Starch and Poduschka (1982) reported that the ventral gland field forms extended unpaired ventral gland in male S. Paradoxus whereas females have a small gland. Atkeson and Marchinton (1982) studied forehead gland in white tailed deer. The gland showed moderate glandular activity in female and very high in males during rut which is consistent with the annual testosterone cycle. Thus, some of the specialized skin glands including frontal sac gland, exhibit sexual dimorphism and probable androgenic control over them.

(IV) Seasonal Variations in the Frontal Sac Gland :

In the present investigation monthly histolo-

gical observations of the frontal sac gland of male bats revealed alterations according to the sexual status of the males. During the sexual quiescence the frontal sac gland in male bats is minimal in weight and smaller in size. The regressed gland shows dermis containing sebaceous glands in collapsed condition. The sebaceous zone is smaller and sebum is very little. Few apocrine tubules are seen during the sexual quiescence and blebbing is not seen. Sometimes residual secretion is evident in the lumina of the apocrine tubules. Peripheral clumped apocrine glands are few, compact without lumina.

During the prebreeding period the frontal glands in male bats show progressive increase in size and weight. The sebaceous zone increase in thickness. The size of cells and lobes of the glands also increase. Very little sebum is evident during this period. The apocrine gland tubules also increase in diameter and thickness of the region. Occasionally the blebbing can be observed during late prebreeding period. The cells lining the apocrine tubules gradually change their shape from cuboidal to columner. Comparatively less amount of secretion is evident during this period. There is also increase in the size of the clumped apocrine glands.

The gland develops to the maximum size and

gains highest weight during the hightened sexual activities during the active breeding period. The sebaceous and apocrine glands increase in size. The sebaceous glands appear typically tri-lobed, the ducts of which open at the base of the hair follicles. The cells become larger and sebum secretion is maximum during this period. The apocrine region also incfeases in thickness and the tubules increase in diameter. Blebbing is very common during the active breeding period hence the tubular lumina appear to be filled with secretion. The glands become highly vascular. The peripheral clumped apocrine glands also increase in size.

After cessation of the breeding activities the overall size of the gland starts decreasing together with reduction in size and depletion in weight of the frontal gland during the postbreeding period. The sebaceous region shows considerable decrease in size of the glands and reduction in secretion. The apocrine gland tubules also show considerable decrease in tubule diameter and size of the cells. Along with these changes the blebbing of cells also decreases with residual amount of secretion. The peripheral clumped apocrine glands also become reduced in size.

Thus, these histological observation reveal

that the frontal sac gland in male bat undergoes cyclic alterations in accordance with the sex cycle. The frontal gland papilla of the female bats exhibits no histological variations, change in size, weight and activity throughout the sex cycle.

Recently Mainoya (1979) reported that the activity of the frontal sac gland in T. Persicus is lowest around December - January. This is the period when no spermatogenesis takes place in testes and sperms are not seen in the epididymis. The frontal sac gland activity remains low until April - May. By early July apocrine gland tubule diameters increase significantly. The testes during June show high spermatogenic activity. By october spermatogensis declines when diameter of the apocrine tubules in frontal sac gland also start to decline. These observations on frontal sac gland in T. Persicus indicate that the diameter of the apocrine tubules can be correlated with spermatogenic activity in the testes. Chandak (1981) reported on the seasonal variations in the frontal sac gland of H. speoris in histology. The various components such as sebaceous glands, apocrine gland tubules and light and dark cells in the clumped apocrine glands are few, compact and smaller. There

is no secretory activity in apocrine tubules during sexually quiescent period. During prebreeding period the size of sebaceous cells and lobes of glands increase. The apocrine gland tubules are increased in diameter with occassional blebbing and comparatively less secretion is evident in this period. There is slight increase in clumped apocrine gland. With the onset of breeding activities all the components show increase in thickness, tubule diameter and cellular activity. The sebaceous gland cells become larger with maximum sebum secretion. The apocrine tubules increase in diameter with high blebbing and hence tubular lumina appear to be filled with secretion and clumped apocrine glands also increase in size. In the postbreeding period sebaceous region shows decrease in size and amount of secretion. The apocrine tubules show considerable decrease in size of the cells and in tubule diameter containing cell debris in the lumina. The peripheral clumped apocrine glands also become reduced in size. Further, Chandak (1981) showed that seasonal variations occur in histochemical and biochemical quantities of lipids, enzymes, mucosubstances in accordance to the annual breeding cycle. Thus, histologically cyclic variations have been reported in the frontal sac gland of T. Persicus and H. speoris which are in good agreement with the present

observations on H. fulvus fulvus.

These are few reports on seasonal changes in specialized skin glands. The roe deer has several specialized skin regions with enlarged sebaceous and apocrine glands which undergo seasonal changes (Schumacher, ,1936). In January the sebaceous and apocrine glands in forehead region of roe deer are only slightly larger than winter glands of the general body skin. By May the glands of this region enlarge considerably and remain large throughout the summer. The increase in size of the forhead gland exactly parallels the increase in size of the testes and regression of gland occurs at the same time as the regression of the testes (Johnson, 1977). The enlargement of the forehead glands in roe buck during the breeding season and regression after rut has also confirmed by Johnson and Leask (1977). Andersson (1979) observed seasonal variations in secretions of the preorbital glands of reindeer.

Gutierrez and Aoki (1973) reported that the tubuloacinar units of gular glands in male bats, T. brasiliensis undergo seasonal cyclic variations. The number of tubuloacinar units change seasonally. Each acinus was found to be composed of densely packed sebaceous cells at various stages of differentiation. Stoddart (1972) reported lateral scent organs in males of A. terrestris undergoing cyclic activity with a peak in the secretory activity shortly following the peak of testicular

weight. Moy (1970) studied subauricular gland and observed that annual proliferation and regression of the subauricular glands followed similar activities of the testes.

It has already been reported in the testicular study (Singh and Bharadwaj, 1977) that the Leyding cells in the camels were hypertrophied during the winter months of December to March and reduced in size and distorted in the summer months of April to November. Singh and Bharadwaj (1978) reported that poll glands in male camel during the winter months produce a pungent and coffee coloured secretion and glands are most active. During summer months glands remain in quieseent stage with scanty secretion. In similar studies cyclic histological variations and amount of secretion have been reported in anal glands of rabbit (Hesterman and Mykytozycz, 1968), anal glands of rodents (Harbe, 1973), dorsal gland of pronghon (May, 1971), glands on the hindquarters of volve (Clarke and Frearson, 1972) and perineal glands of G. genetta (Souloumiac and Canivenc, 1976).

Atkeson and Marchinton (1982) performed skin biopsies from forehead gland of adult white-tailed deer, O. Virginianus during sexually quiscent season and again in rut. The apocrine sudoriferous gland in summer exhibited little activity. In the rut, glandular activity was moderate in females and very high in males. Such seasonal changes indicate the glands may be controlled by testicular hormones.

(V) Localization of Mucosubstances in the frontal Sac Gland:

The mucosubstances have been studied histo chemically in the frontal sac gland of the male bats. The histochemical results indicated the absence of glycogen and acid mucosubstances but presence of only PAS reactive neutral mucosubstances in the various histological sites in the frontal gland of male bats.

Miraglia and Santos (1971) reported on absence of glycogen in the sebaceous gland cells in the lips of marmoset. Sorensen and Prased (1973) studied sweat glands from different areas of horse by light and electron microscopy. Glands were found well developed and contained PAS positive granules in columnar cells. Horst (1966) showed PAS positive material in sebaceous cells of gular glands in bats. Dapson (1977) reported that the apocrine secretion from gular gland of Molossid bat, M. bondae exhibited PAS positive reaction indicating presence of carbohydrates.

Quay (1962) demonstrated glycogen in sudoriferous apocrine glands in angulus oris of microtine rodents. Quay (1955) demonstrated histochemically presence of glycogen in the apocrine tubules in interdigital in tarsal glands and preorbital glands of a caribou, R. tarandus Estes and Buss (1976) reported presence of acid mucopolysaccharides in the apocrine tubules of the

temporal gland in African elephants. Singh and Bharadwaj (1978) showed the presence of acidic mucopolysaccharides in the blebs as secretary cells of poll gland in camel. Chandak (1981) indicated the absence of glycogen and acidic mucosubstances but presence on only PAS reactive netural mucosubstances in the various histological sites in frontal sac gland of male bat, H. Speoris.

(VI) Seasonal Alterations in Mucosubstances in Frontal Sac Gland of Male Bats.

The histochemical results in the present investigation indicated the presence of only diastase resistant PAS reactive neutral mucosubstance in the various histological sites in the frontal sac gland of the male bats. From their staining intensities it is evident that mainly the variations occur in the apocrine gland tubules. During the sexual quiescence the neutral mucosubstances are in traces in the sebaceous cells and dark and light cells of the clumped apocrine glands. The mucosubstances are in weak to moderate quantities in epidermis and apocrine gland cells. In remaining periods no significant alterations occur in epidermis, sebaseous glands and clumped apocrine glands. The neutral mucosubstances slightly increase in the apocrine gland tubules during the prebreeding period and appear to be maximum during the active breeding period followed by depletion from postbreeding period onwards. Similar histochemical

variations were observed in the PAS reactive neutral mucopolysaccharides in the frontal sac gland of the bat, H. speoris by Chandak (1981).

(VII) Role of Hormones in the Control of Skin Glands :

At present more information is available on the hormonal control for sebaceous gland than for the apocrine glands. The existing literature on gonadal hormone dependency of the specilized skin glands is substantiated by castration and hormone replacement experiments which in most of the cases prove that the glands are controlled by gonadal hormones. The seasonal alterations occuring may be influenced by varying amounts of gonadal hormones.

There is general agreement that androgens increase the size and functional capacity of the sebaceous glands in all species. Castriation results in a decrease in gland volume in the rat (Ebling, 1957,1963). The specilized sebaceous glands show a similar response to castration and androgen treatments. Castration was found to reduce the poll glands in male camel (singhand Bharadwaj, 1978). Dryden and conaway (1967) reported that bilateral castration caused atrophy of sweat glands and cessation of musk production. The administration of testosterone or estradiol resulted in sweat gland recovery and resumption of odour production in castrates of both seyes.

The androgen dependency of the flank glands in male musk shrews is reported by Balkrishnan and Alexander (1977). Castration effected considerable atrophy of the secretory epithelium of flank, oral lip and perineal glands with marked regression in their secretory output. Progesterone administration reactivated all these glands (Balkrishnan et al. 1984). Steriod hormone sensitive sebaceous glands in the pubis region are reported in Bat, Cynopterus sphinx sphix by Mote and Kumbhar (1986). Dixon (1976) demonstrated androgen dependent sebaceous complex in sternal glands of male galago.

Blum et al. (1971) reported on disappearance of ventral glands in male deermouse following castration and the gland in male was found to be androgen dependent. The androgen dependency of the ventral gland and control of scent marking has also been reported in Mongolian gerbils by several investigators (Glenn and Gray, 1965; Mitchell, 1965; Lindzey et al. 1968; Thiessen and Yohr, 1970; Thiessen, et al., 1971 a, 1973; Blum, 1970; Blum and Thiessen, 1971; Whitsett, 1970; Sales and Bargerot - Blondel, 1975) and P. maniculatus (Doty and Kard, 1972). Indian gerbil, T. indica shows significant monthly variations in the ventral scent marking gland, peaks in gland size occur in maximum breeding activities (Saroj and Prakash, 1983).

Castration reduces the scent marking in gerbil and the response to testosterone propionate therapy was gradual attaining peak after 8 weeks of hormone administration (Idris and Prakas, 1985). Yahr and Ulibarry (1987) reported that testosterone stimulates sexual behaviour and scent marking in male gerbil. Bilateral castration in A. terrestris also causes involution of lateral scent organs which are reconstituted following testosterone treatment (Stoddart, 1972). Moy (1970) demonstrated that the cyclic activity of subauricular glands in male pronghorns is controlled by gonadal hormones. These glands in castrates are smaller and inactive as compared to the normal glands. Souloumiac and canvenc (1976) reported that perineal glands in G. genetta are hormonally controlled; their involution is induced by castration and hypophysectomy, whereas male hormone injections reverse this effect. Balkrishnan and Alexander (1976) showed that musk shrews marked objects by secretions of skin glands, urination and defecation. Castration reduced scent marking and methyltestosterone and ethinylestradiol reactivated scent marking in castrated male shrews. The fact that the fore head gland of the male white-tailed deer enlarges during rut and regresses during nonbreeding period sugests that they are androgen dependent (Atkeson and Marchinton, 1982). The androgen dependence of the sebaceous glands in man and laboratory rodents is well established (Strauss

and Ebling, 1970). Evidence that apocrine glands are androgen dependent has been obtained for the chin, inguinal and anal gland of wild rabbits, which are larger in males than females, reduced in castrates and restored by treatment with testosterone (Wales and Ebling, 1971; Mykytowycz and Goodrich, 1974).

There are few reports on control of skin glands by hormones of other endocrine glands. Thody and Shuster (1970) reported that rate of sebum secretion was less in castrated male rats and was progressively less in adrenalectomized castrated and thyrodectomized castrated rats. After ACTH treatment there was an increase in sebum secretion. Further increase was observed when TSH was given with ACTH. Maximum secretion was evident when ACTH, TSH and testosterone were given in castrated rats. Thody and Shuster (1972) showed that thyroidectomy of intact and castrated rats reduced the rate of sebum formation, whereas thyroxine treatment increased the rate of sebum production in castrated thyroidectomized rats. These studies are indicative of the pituitary control over skin glands through thyroids, adrenals and gonads.

In the present investigation the seasonal alterations were observed in the histology and the histochemical alterations in mucosubstances of the frontal sac gland in male bats. These alterations are also

indicative of their androgen dependency. Since, during the sexual quiescence the frontal sac gland in males undergo regression, by this time the androgen level goes down. With the onset of prebreeding period the androgen titer gradually rises and attains a peak during the active breeding period. Corresponding enhancement is observed in histology, histochemistry results. After the breeding activities when the postbreeding period begins, the androgen level is depleted which reflected in reduction of some of the metabolites. This is only suggestion and this relationship should be confirmed by studies involving castration and androgen administration. Mainoya (1979) showed that the secretory activity of the frontal sac gland of T. Persicus shows a definite variations with seasons. Fluctuations in gland secretory activity are cuncurrent with the changes in spermatogenic activity and indicated possibility of androgenic control. Frontal sac gland of Indian leaf-nosed bat, H. speoris was investigated by Chandak (1981) and reported seasonal variations in size and weight, in histology, in enzymes and lipids histochemically and biochemically and localication of mucosubstances in accordance to the annual breeding cycle. These observations suggest androgenic control over the frontal sac gland in male bats.

(VIII) Probable Functional Significance of Specilized Skin Glands :

Although the occurence of integumentary scent glands in mammals has been reported in at least 15 orders, their functions have been discussed in some (Ewer, 1968, Ralls, 1971). The specilized skin glands may have some functions in individual recognition, recognition of sex and age and terrestorial marking. Since the frontal sac gland is a modified and specialized skin gland in Hipposiderid bats, it is worth to consider the functions of other specialized skin glands and to comment on the possibilities of functions of frontal sac gland in these bats.

The preorbital glands have been considered to play a role in individual recognition and territorial marking in G. gazella (Estes, 1967) and wildbeests (Mainoya, 1976). In another study Volkman et al. (1978) showed that forehead rubbing in backtailed deer plays a role in age and class recognition. Cohen and Gerneke (1976) demonstrated that the secretions of intermandibular glands in steenbock are used in territorial marking and marking the females during mating. Holt (1973) attributed a communicative role to sebum secreted by chin glands in cuis.

Eisenberg et al. (1971) have considered the importance of chemical signals which may possibly

function as identifiers, and indicators of sex and age in male elephants. Buss et al. (1976) opined on chemical individuality in cholesterol level in temporal glands of elephants which may serve as a pheromone for group identification.

The secretions have been shown to be used in marking the territories from flank glands in musk shrews (Balkrishnan and Alexander, 1977) and hamsters (Johnson, 1975). Scent marking for intraspecific communication has been reported in D. byrnei (Aslin, 1974). The role of ventral gland in territorial marking has been established by Pearson (1946) and Thiessen et al. (1970, 1971 a, b, 1973). The ventral gland field indicated the involvement in contact and communication behaviour in S. Paradoxus (Starch and Poduschka, 1982). August (1978) described that ventral gland odour cues are likely used in sex recognition during the breeding season in wood rats. Yohro and Kamia (1973) considered the role of lateral glands in big clawed shrews in animal communication.

The interdigital glands have been showed to be important for interspecific communication in deer (Quay, 1959) and pronghorn (Moy, 1971). Muller-Schwarze (1971) studied tarsal and metatarsal glands of black tailed deer, the former were found to be involved in the identification of sex, age and individual recognition, whereas the latter were found to be important as a means

of warning and repelling (Broom and Johnson, 1982). Muller-Schwarze (1975) suggested a role of species identification for tarsal glands in black-tailed and white-tailed deers.

The secretion from the subauricular glands in pronghorn may serve in sex identification, stimulation and territorial marking (Moy, 1970; Muller-Schwarze et al. 1954). Similar functional significance has been attributed for the secretions of auricular and inguinal glands in roe bucks (Claussen and Junguis, 1973). The secretion from anal pockets in H. auropunctatus also serve for individual recognition and social communication (Gorman, 1976; Gormam et al. 1974). Steiner (1974) reported that sqiurrels rub anogenital area against substrate. A liquid trail is left behind possibly an indicator of sex and/or reproductive state. Mother offspring recognition may be the function of secretions from apocrine glands at mouth corner in squirrels (Steiner, 1974). Wallace et al. (1973) also supported this functions. According to Gisela (1970) pheromones in marmoset are important in sexual, territorial marking and social behaviour.

Sexual display are not well known in bats although some information is available for microchiroptera. Plecotus townsendii males twitter and rub

head glands over females before copulation (Pearson et al., 1952). Many of the glands in bats probably play a sexual role. Among Megachiropterans, scapular or shoulder glands are common in males (Anderrsen, 1912). Many of these species, for example E. helvum (Allen et al. 1917), P. giganteus (Neuweiler, 1969) and P. Poliocephalus (Nelson, 1965) exhibit seasonal variations in these glands. Many Vespertilionids have glands on head and muzzle. In Chalinolobus dwyeri these become active in both sexes at breeding (Dwyer, 1966). New world molossid bats tend to have sexually dimorphic chest glands (Goodwin and Greenhall, 1961) and in Eumops Perotis (Howell, 1920) and M. rufus (Horst, 1966), the amount of secretion is maximum at breeding. Many African Molossid bats exhibit sexual dimorphism and seasonal variations in size and development (Allen et al., 1917; Breastrup, 1933), Individuals of both sexes in T. flaviventris use the throat pouch area during territorial marking (Hall and Gordon, 1982).

Hipposiderid bats possess a median frontal sac gland behind the leaf-nose (Rosevear, 1965; Quay, 1970 a, Kingdom, 1974). Recently Mainoya and Howell (1977) and Mainoya (1977) reported on histology of the frontal sac gland in three species of bats. Although not much is known about the social behaviour of Hipposiderid bats.

frequent bickering observed in H. commersoni suggest that territorialism might be a common feature of their behaviour (Leen and Novick, 1969; Kingdom, 1974). Mainoya and Howell (1977) have further postulated that the median frontal gland might be a source in mediations of behavioural and physiological respones related to reproduction. Manoya (1977) suggested that the activity of the frontal sac gland in H. ruber is seasonal and is related to the breeding behaviour. Sex recognition, individual recognition and territorialsm are the functions attributed to the frontal sac gland of H. speoris (Chandak, 1981). It is seen that during breeding activities secretion of the frontal sac gland is everted and applied to all the body by male bats. The waxy secretion can be seen on leaf-nose, petagium and other parts of skin. The frontal sac gland in males of H. fulvus fulvus may be thus involved in individual recognition, sex recognition, territorialism and responses related to reproductive behaviour.

CONCLUSIONS

The following is a brief summary of the observations and conclusions drawn in the present investigation.

(1) The weight of the testes exhibited seasonal changes, maximum weight was recorded during the active breeding period.

(2) Seasonal histological variations in testes confirmed the various phases of the sex cycle such as sexually quiescent period, prebreeding period, active breeding period and postbreeding period.

(3) The weight of the frontal sac gland (in males) varied according to the sex cycle, maximum weight was recorded during the active breeding period.

(4) The glands were found to be sexually dimorphic being well developed only in the males. The female bats of this species posses nonfunctional and rudimentary frontal papilla.

(5) The frontal sac gland in male consisted of sebaceous glands in the dermis, deeper apocrine gland tubules and peripheral clumped apocrine glands.

(6) The frontal papilla in females consisted very few and small apocrine tubules surrounded by much adipose tissue and very small sebaceous glands in the dermis.

(7) The gland in male bats exhibited seasonal alterations in histology. The various components such as sebaceous glands, apocrine gland tubules and light and dark cells

in the clumped apocrine glands were very few during the sexual quiescence and progressively increased during the prebreeding and active breeding periods followed by regression during the postbreeding period.

(8) Seasonal histological alterations are not evident in the rudementary and non-functional frontal papilla in female bats.

(9) The histochemical observations revealed the presence of only diastase resistant PAS reactive neutral mucosubstances predominantly in the apocrine gland tubules. Seasonal variations were also evident in neutral mucosubstances in frontal sac gland of the male bats.

(10) The seasonal variations in frontal sac gland are discussed for their gonadal hormone dependency on the basis of circumstantial evidences in other skin glands.

(11) In the light of the existing literature, the functional significance of the frontal sac gland is discussed.

CONCLUDING REMARKS

Thus, the aims and objectives with which the present investigation was undertaken have been sucessfully fulfilled. The aims of the present investigation were to study histology, sex-dimorphism, if any and seasonal alterations

in frontal sac gland in Indian Hipposiderid bat, H. fulvus fulvus. In addition to study mucosubstances in the frontal sac gland, seasonal alterations if any, in them and probable hormone dependency based on circumstantial evidences. It is hoped that these aims and objectives have satisfactorily been completed.

While consluding the present M. Phil. dissertation on frontal sac gland of bat the auther would like to humbly state that the present work is by no means complete. He is fully aware of his shortcomings. The PAS reactive netural mucosubstances should fruther be identified. Ablation techniques have not been employed to get an insight in to hormone dependency of frontal sac gland. These results should further be confirmed by hypophysectomy, castration and subsequent hormone replacement which may give a very reliable evidence in support of hormone dependency of frontal sac gland in male bats. Here the problem was to maintain the bats in captive conditions. Some efforts have also been made to out the castration in male bats but it was observed that there was more than 90% lethality. Even with all these shortcomings, the auther feeld gratified that he had studied and reported some preliminary observations on histology, sex dimorphism and seasonal alterations in histology and mucosubstances in frontal sac gland in one of the Indian species of leaf-nosed bats, H. fulvus fulvus.