2.1 Flea Fauna:

Lewis (1972) gave a review of the geographical distribution and host preferences amongst fleas, dividing the order into two Super families comprising 15 families, 212 genera and 2018 species and sub species, all of which are ectoparasitic.

Fleas are wingless insects with a laterally compressed body of about 1.5-4 mm length. Like other insects, body is divided into head, thorax and abdomen. Taxonomically they belong to the order Siphonaptera (Eckert et al. 2000). This family contains several species and subspecies. These species belong to the families Pulicidae, including *Pulex* spp., *Ctenocephalides* spp., *Spilopsyllus* spp. and *Archaepsyllus* spp., or the familia Ceratophyllidae with the genus *Ceratophyllus* or *Nosopsyllus* to mention only some of the most important veterinary and human representatives. Fleas represent one of the most important ectoparasites (Mehlhorn 2000; Mehlhorn et al. 2001). At the moment there are more than 2000 described species and subspecies throughout the world (Borror et al. 1981).

Fleas have a history of about 60 million years and were already found on prehistoric mammals. While becoming parasites the original exterior of the two-winged insects also designated as the order Diptera, has changed by losing the wings in the adults, whereas the larval form still has similarity with the larva of the order Diptera (Strenger 1973). About 95% of the ~2000 different flea species parasitize mammals like rabbits, rats, mice, squirrels, rodents and 5% live on birds. Flea are largely parasites of rodents about 74% of known forms being recorded from this order of mammals Other mammalian hosts occur in orders Insectivore (8%), Marsupial (5%),
Chiroptera (5%), Lagomorpha (3%), Carnivora (3%) and less than 1% each in Monotremata, Edenata, Philodota, Hyracoidea and Artiodactyla. About 6% occur on birds, mainly sea birds and passerines. Fleas are largely temperate in distribution, both latitudinally and altitudinally, because relatively few mammals in the low land tropics create conditions suitable for flea breeding (Wenzel and Tipton, 1966). Farkas, R. (1999) determined the distribution of this flea species, its biology and ecology (feeding and breeding behaviour, larval and pupal development, host seeking activities of adults and surviving ability of adults off their hosts). Information of veterinary and medical importance, including flea-bite allergic dermatitis (FAD) of dogs and cats is also discussed.

Wells, K. Beaucournu, J. C. et.al. (2012) collected a total of 1,968 fleas of two species, *Ctenocephalides orientis* and *Ctenocephalides felis felis*, from 195 dogs (prevalence, 92%). Flea density was higher on dogs residing in houses made of bamboo or corrugated metal (increase of 40% from the average) compared to timber or stone/compound houses.

Aydenizoz, M., Kose, M. (1997) observed the prevalence of ectoparasites on dogs in Konya, Turkey, was investigated between April 1994 and September 1996. Of 50 dogs (29 male) examined, 59% were found to be infested with ectoparasites. The ectoparasites were identified as: 46% *Ctenocephalides canis*, 18% *Ctenocephalides felis felis*, 10% *Pulex irritans*, 12% *Rhipicephalus sanguineus*, 2% *Sarcoptes scabiei canis* [Sarcoptes canis] and 2% *Hippobosca sp*. 16 (55.2%), 10 (34.5%) and 3 (10.3%) dogs were infested with 1, 2 and 3 different ectoparasites, respectively.

Franc, M. Choquart, P. Cadiergues, M.C. (1998) observed flea found on dogs in France. Out of 1071 fleas collected from 392 dogs, including *Ctenocephalides felis* (86.6%), *Ctenocephalides canis* (11.2%), *Pulex*
irritans (0.8%) and Archaeopsylla erinacei (1.3%). 350 dogs were infested with *Ctenocephalides felis* and only 40 by *Ctenocephalides canis*. *Ctenocephalides felis* was identified all over the country, on animals living inside or outside. 75% of dogs infected with *Ctenocephalides canis*, however, lived outside, half of them in mountain or oceanic climates. This species was more frequent at high altitude than at lower ones: 32.5% of dogs infested with *Ctenocephalides canis* lived over 400 msl against only 11.2% of dogs infected by *Ctenocephalides felis*.

Kumsa, B. E. Mekonnen, S. (2011) investigated the prevalence, risk factors and species composition of ticks, fleas and lice infesting dogs and cats in and around Hawassa in southern Ethiopia. In total, 200 dogs and 100 cats were examined from November 2008 to April 2009. Of the dogs and cats examined, 99.5% and 91.5%, respectively, were infested with one or more species of ticks, fleas or lice. The overall prevalence was higher in dogs than cats. A total of six different species of ectoparasites were collected and identified from dogs, but only three species from cats. *Ctenocephalides felis* was the predominant species amongst the animals, with a prevalence of 82.9% on dogs and 67% on cats. Other prevalent species on dogs included *Ctenocephalides canis* (73.8%), *Heterodoxus spiniger* (4%), nymphs of *Amblyomma* spp. (3.5%), *Pulex irritans* (2.5%) and *Haemaphysalis leachi* (0.5%). *C. canis* (18%) and *P. irritans* (6%) were also found on cats. The female fleas were observed more than male fleas.

Hernandez-Valdivia, E. Cruz-Vazquez et. al. (2011) observed seasonal distribution of *Ctenocephalides canis* (Curtis) and *Ctenocephalides felis* (Bouche) infestations in urban dogs of the city of Aguascalientes, Mexico, were studied. Between January and December 2007, 863 dogs in the Municipal Canine and Feline Control Center were examined. Overall
prevalence of infestation was 12% (95% CI 10-14). Seasonal distribution revealed that prevalences in spring and summer were highest, while autumn and winter had lower prevalences. Two infestation peaks were observed, i.e., in April (17.7%) and July (18.9%). A positive correlation was detected between prevalence and temperature during the winter season (P<0.05). Prevalence in relation to gender showed that males were more frequently infested, 14% (95% CI 11-17), than females, 9.4% (95% CI 7-13); hair length did not affect differences in prevalence. Six hundred twenty-nine fleas were examined; 62% were *C. canis* and 38% *C. felis*. Dogs infested with only *C. canis* were 48% (95% CI 38-58), while 18% were infested only with *C. felis* (95% CI 11-27); the remainder, 34% (95% CI 24-44), had mixed infestations.

Tavassoli, M. Ahmadi, A. *et.al.* (2010) observed flea infestation in dogs in different geographical regions of Iran. The total of 407 fleas belonging to 5 different species, were recovered from 83 domestic dogs from 3 regions. There was a distinctive pattern of species distribution and infestations with the highest infestation rates observed in a temperate climate and higher rainfall. Additionally, fleas were observed over all seasons, except February and March, with the highest infestation rate observed in August (24.7%) and the lowest rate in January (1.7%). They also parasitize dogs with a different spectrum of species. The cat flea, *Ctenocephalides felis* (67.5%), exhibited the highest prevalence among all flea species found on dogs.

Zakharov, V.V., Maiorov, A.I. (1994) observed flea infestations in mink. The mink are infested with *Ceratophyllus fasciatus, Ctenocephalides felis, Ctenocephalides canis* and *Pulex irritans*.
Imai, S., Takeda, M. (1995) studied the species distribution of fleas infesting dogs and cats in Japan. 257 dogs and 264 cats from various areas of Japan were surveyed for flea species. Of 2520 fleas collected, 328 (13.0%) were *Ctenocephalides canis* and 2192 (87.0%) were *Ctenocephalides felis*. No *Pulex irritans* was identified. 891 (75.9%) of 1174 fleas recovered from dogs and 1301 (96.7%) of 1346 fleas recovered from cats were *Ctenocephalides felis*, suggesting a slight host preference of the 2 flea species. Mixed infestation rates were 9.7% in dogs and 2.7% in cats. There was no relationship between the age, sex or housing of the cats and dogs and the species of flea recovered.

Koutinas, A.F., Papazahariadou, M.G. *et al.* (1995) observed the fleas collected from 129 dogs and 38 cats of random breed, sex and age in northern Greece.

Varghese, M.A., Jagadish, S., Bhalerao, D.P. (1994) studied during a 5-month survey of dogs with dermatitis carried out in an animal hospital in Bombay in 1991, 83 dogs with skin lesions were examined. The overall incidence of dermatitis during the period was 12.83%. Ectoparasitoses were the most common causes of dermatitis (21.69% *Ctenocephalides canis*, 19.28% *Sarcoptes scabiei var. canis*, 15.66% *Demodex canis* and 15.66% *Rhipicephalus sanguineus*). None of the other 9 conditions (including non-specific dermatitis) had an incidence above 5%.

Kutzer, E., Lowenstein, M. (1990) observed the problem of animal fleas (*Ctenocephalides canis*, *Ctenocephalides felis* and *Ceratophyllus gallinae*) with insecticides. Four cases are reported from Austria. In Central Europe, bird fleas appear to be more of a problem in spring, and mammal fleas in summer.
Kalvelage, H., Munster, M. (1991) observed biology, epidemiology, clinical features, diagnosis and treatment of canine and feline *Ctenocephalides* infestations. 5.5% of 163 dogs and 18.9% of 90 cats examined in the 1st Animal Medical Hospital of the Veterinary Faculty, Munich were infested with fleas. 0.6% of the dogs were infested with *Ctenocephalides canis*, 1.2% with *Ctenocephalides felis*, 2.5% with *Archaepsylla erinacei* while 1.2% had no determinable flea species although flea faeces were found. 11.1% of the cats were infested with *Ctenocephalides felis* and in 7.8% just the flea faeces were found. The importance of fleas as vectors of different diseases is discussed.

In a survey of infestation of flea on cats, *Ctenocephalides felis* (Bouché) (Siphonaptera: Pulicidae) was the most abundant (98.4%), followed by *Ctenocephalides canis* (Curtis) (1.1%) and *Pulex irritans* (0.5%) in Spain (Gracia MJ, Calvete C, et. al. 2013).

### 2.2 Flea Vectors of Diseases:

Arthropod vectors transmit many new and reemerging diseases. Fleas have long been associated with nuisances to man. Some of the notorious genera like *Ctenocephalides* are related to plague and murine typhus but some parasitise domestic animals like dog and cat that infect humans temporarily. Such arthropods should be considered as a possible cause of erythematous and pruritic papules and nodules of unclear origin. Not only the pets but humans are also affected by the protozoan, bacteria vectored by these fleas, like *Leptomonas ctenociphali* a protozoan that is related to the development of rectal ampullae, Molyneux, *et. al.* (1981). Thus the study of biology and control of various pests of humans and their pets becomes very necessary to help in finding a solution to control them.
Muraleedharan, K., Paramsivaiah, B.N., (1993) observed *Ctenocephalides* infestation in sheep and goats found a severe infestation with *Ctenocephalides felis orientis* [*Ctenocephalides orientis*] in a flock of 179 sheep, 52 lambs, 18 goats and 15 kids belonging to the Regional Research Station, Tiptur, Karnataka, India during April 1992.

Ghosh, R.C. Shrivastava, S.K., Das, K., (2001) observed the flea bite dermatitis in workers from the power station of the Madhya Pradesh Electricity Board (Raubandha, Bhilai, Madhya Pradesh). Fleas were collected from affected individuals and were identified as *Ctenocephalides canis*, on the basis of morphological characteristics.

Scheidt (1988) studied about the dermatitis caused by *Ctenocephalides canis* and *Ctenocephalides felis* and suggested their diagnosis and treatment. Opasina (1983) studied the infestation of *Ctenocephalides canis* in goats in Nigeria. He studied effects of fleas on hosts and their clinical reasons. Ugochukwu (1983) gave comparative account of the effects of different therapeutic formulations for treatment of flea dermatitis in dwarf goats. Bilqees and Khan (1982) described the parasites of dogs as the potential sources of humans infection in Karachi. Muller and Kutschmann (1985) recorded the prevalence of fleas in domestic animals and found that *Ctenocephalides felis* is most frequently found species followed by *Ctenocephalides canis*.

Plague, a disease of great antiquity was responsible for taking a heavy toll of life in our country in the early part of 20th century. It has been reported that during 1898 to 1930 a total of approximate 11.9 million deaths were caused by plague alone in different states of India. The disease showed a gradual decline over the next two decades and many part of the country
became free of plague by 1950 except a few foci, lingering in Karnataka, Andhra Pradesh and Tamilnadu.

The mortality caused by abiotic factors is important to fleas especially to immature ones. Extreme temperature and low humidity affect reproductive potential slowing the development rate and reducing survival of *Ctenocephalides felis*, (Silverman, *et. al.* 1981). More annual generation of fleas in warmer situations and consequently increased insecticides applications, increases the resistance rate.

Guaguere, E. (1995) provided the special issue on dermatology, Clinical and therapeutic aspects. This special issue contains 12 papers: biology of the cat flea and its control; feline pododermatoses; claw diseases in the dog and cat; crusting dermatoses of the cat; systemic cutaneous antibiotic therapy in the dog; marbofloxacin for the treatment of canine pyoderma; treatment of canine demodecosis; screening tests for canine hyperadrenocorticism; ketoconazole for the treatment of canine hyperadrenocorticism; sensitization to the cockroach in the atopic dog; calcinosis circumscripta in the dog; treatment of canine pyotraumatic dermatitis with a non-antibiocorticoid solution.

Marquez, F.J., Muniaín, M.A., Perez, J.M., Pachon, J. (2002) investigated the presence of *Rickettsia felis* in the cat flea from Southwestern Europe. *Rickettsia felis*, formerly called ELB agent, was identified by using molecular biology techniques in the cat flea (*Ctenocephalides felis felis*) from southwestern Spain. For the first time, this flea-transmitted Rickettsia has been detected within its vector in Eurasia.

Raoult, D. *et.al.* (2001) tested that rickettsia is pathogenic for humans. A rickettsia named the ELB agent, or "*Rickettsia felis,*" was identified by
molecular biology techniques in American fleas in 1990 and later in four patients from Texas and Mexico. They attempted to isolate rickettsia from infected fleas at various temperatures and conditions. A representative isolate of the ELB agent, the Marseille strain, was characterized and used to develop a microimmunofluorescence test that detected reactive antibodies in human sera. The ELB agent was isolated from 19 of 20 groups of polymerase chain reaction-proven infected fleas. The microimmunofluorescence results provided serologic evidence of infection by the ELB agent in four patients with fever and rash in France (2) and Brazil (2), supporting the pathogenic role of this rickettsia. The successful isolation of this rickettsia agent by these scientists makes it to use in serological tests to determine its clinical spectrum, its prevalence and distribution.

Chiu-Shiau Yen. et.al. (2001) determined the comparative analysis of exoparasitic fleas of three different species observed in subtropical areas. Three host-specific fleas were isolated, one specific to the human host [Pulex irritans], one to the Pursang cat [Ctenocephalides felis] and one to the cats in general. They have given their habitat, morphological characteristics, jumping ability, and how to distinguish between the eggs of each flea.

2.3 Morphological Studies:

Giangaspero, A. (1999) reviewed of flea infestations (Ctenocephalides felis, Ctenocephalides canis, Pulex irritans) of cats and dogs covering their morphology, biology, life cycle, pathogenic role, and transmission of disease. Taxonomic study of the genus Ctenocephalides was done by Stiles & Collins, 1930 (Insecta: Siphonaptera: Pulicidae) by using aedeagus characters. To define more accurately the taxonomic position of the species of Ctenocephalides, a morphological study of the aedeagus was conducted
on all 14 described taxa (13 species and 1 subspecies) of this genus. Based on some phallosome structures (hamulus, lobes, tubus interior), an identification key is constructed to complement the existing taxonomic criteria. *Ctenocephalides orientis* (from Cambodia, China, Indonesia, Nepal and Vietnam) and *Ctenocephalides damarensis* (from South Africa) are confirmed to specific rank.

Beaucournu, J.C., Menier, K., (1998) studied historical review of the genus Siphonaptera and an outline of the biogeographical and palaeontological origins of these fleas, the 14 taxa are studied (synonymy, repartition, specificity and morphology). A new dichotomic key is given on criteria selected by the authors. All the species included are: *Ctenocephalides canis, Ctenocephalides felis, Ctenocephalides felis felis, Ctenocephalides felis strongylus, Ctenocephalides rosmarus, Ctenocephalides craterus, Ctenocephalides arabicus, Ctenocephalides crataepus, Ctenocephalides connatus, Ctenocephalides orientis, Ctenocephalides paradoxuri, Ctenocephalides damarensis, Ctenocephalides brygoi, Ctenocephalides chabaudi* and *Ctenocephalides grenieri*.

Nayak, M.K., Sehgal, S.S., (1996a) observed interpopulational morphometric variability among six natural populations of the dog flea, *Ctenocephalides canis*. They observed among natural populations of *Ctenocephalides canis* collected from mammalian hosts in six different geographic regions of India (Chamoli (Uttar Pradesh), Ispur (Himachal Pradesh), Kullu (Himachal Pradesh), Dhenkanal (Orissa), Ranchi (Bihar), and Pathanamthitta (Kerala).

Nayak and Sehgal (1996b) studied the thirteen morphometric characters in adult dog flea. They evaluated these characters with high taxonomic reliability. They have discussed inter populational differences and
similarities in variability in body traits among six strains of dog fleas with respect to the role of microhabitat variations and population fitness.

Pascal et al. (2004) recorded the flea fauna on many mammals in French West Indies and found two siphonapterans out of six known species to be found there namely *Ctenocephalides felis* and *Xenopsylla cheopis*. They also studied the variations in the habitats of mainland and islands which explained the presence of some siphonapterans only and not others. Durden et al. (2005) studied the species composition and seasonal abundance of fleas parasitizing domestic dogs in Georgia, USA.

Isolates of the Cat flea *Ctenocephalides felis* (Bouche 1835) from Europe, Africa, USA and Australia were studied by means of molecular biological methods with respect to the markers ITS-1, ITS-2, mt 16 S-rDNA, human aldolase and 4 so-called random primers. The comparisons of these parameters of the different specimens showed a very high homogeneity - mostly even a 100% identity of sequences, while there were considerable differences to other species and genera. Thus, there were no indications for subspecies in specimens of the species *Ctenocephalides felis* from 4 continents - being formerly described at the base of morphological criteria. Mehlhorn et al. (2004).

Chiu-ShiauYen et al. (2001) observed microscopic views: the comparative analysis of exoparasitic fleas of three different species in subtropical areas. Siphonaptera were collected from Siamese cats and Pursang (Persian) cats in Taiwan. In addition, fleas were isolated from dust containing human epithelial tissue. Three host-specific fleas were isolated, one specific to the human host (*Pulex irritans*), one to the Pursang cat (*Ctenocephalides felis*) and one to the cats in general. Details are given of
their habitat, morphological characteristics, jumping ability, and how to distinguish between the eggs of each flea.

Chesney, C.J. (1995a) described the flea species found on cats and dogs in south west England: further evidence of their polyxenous state and implications for flea control. Fleas were collected from 60 dogs and 32 cats living in south west England. *Ctenocephalides felis felis* and *Ctenocephalides canis* were found on both dogs and cats, with a marked preponderance of *Ctenocephalides felis felis* on both species. More female fleas than male fleas were found. There was no apparent tendency for *Ctenocephalides canis* to be found more often in rural areas than in suburban areas. The survey confirmed the polyxenous nature of both species of flea. The significance of this state is discussed in relation to flea control and the author concluded that it is unlikely that all significant flea species could be completely eliminated from the environment of pet animals.

Saari, S. and Nikander, S. (1991) studied the morphological characters of flea species found on dogs in Finland. Fleas collected from dogs sent to the parasitological laboratory of the College of Veterinary Medicine, Helsinki, during the 1980s were identified using light and scanning electron microscopy. The most common species were *Ctenocephalides felis*, *Archaeopsylla erinacei*, *Ceratophyllus spp.* and *Ceratophyllus* (Monopsyllus) *sciurorum; Ctenocephalides canis* was submitted only once during the 10-year period.

Qi, Y.M. (1989) observed the fine structure of the digestive system of three flea species. The structural development of the proventriculus was followed from the 1st larval instar to the adult in *Leptopsylla segnis*, *Monopsyllus anisus* [*Ceratophyllus anisus*] and *Ctenocephalides felis felis*. The hind part of the foregut was found to be essentially the same in the 3
species, apart from differences in the number, size and morphology of the proventricular 'spines'. In the early pupa the proventriculus is formed from the stomodeal imaginal ring which first appears in the early 3rd-instar larva, and the proventricular spines are each produced by a cuticular cell ['spines' = 'spine-like epithelial cells']. In the late pupa the nucleus of each spine-forming cell migrates from the base to about 1/5th-1/4th of its length. Morphological details are shown for each species by means of line drawings and for *L. segnis* in a set of microphotographs. Comments are also made on the function of the proventriculus and on the half-digested blood which is retained in the posterior part of the oesophagus.

The genital apparatus (aedeagus and modified abdominal segments) of fleas is described in detail in a number of studies (Rothschild and Traub 1971). Mardon (1978) and Cheetham (1988) have made a comparative anatomical study of the aedeagus. Scanning electron microscopy has been used for aedeagus studying (Medvedev, 1984; Cheetham, 1988). This technique and together with light microscope were used in the comparative investigations of the aedeagus of many species of fleas (Medvedev, 1993, 1994). The aedeagus of male fleas consists of modified tergites and sternites of the 8th and 9th abdominal segments and claspers. The aedeagus and claspers derive from primary phallic lobe (Snodgrass, 1946). The modified tergites and sternites of flea's belong to abdominal segments 7-9.

Mortarino, M., Genchi, M. (2007) observed that the ticks most frequently found in Italy on dogs are *Rhipicephalus sanguineus*, *Dermacentor reticulatus* and *Ixodes ricinus*. The commonest fleas on dogs and cats are *Ctenocephalides felis felis* and *Ctenocephalides canis*. They described the biological characteristics of these ectoparasites and the pathogens they transmit.
Farkas, R. (1999) determined the distribution of this flea species, its biology and ecology (feeding and breeding behaviour, larval and pupal development, host seeking activities of adults and surviving ability of adults off their hosts).

2.4 Chaetotaxical Studies:

Nayak, M.K. and Sehgal, S.S. (1996b) distinguished meristic traits and their variability patterns among six natural populations of *Ctenocephalides canis*. Twenty-one different chaetotaxic traits in adults of the common dog flea, *Ctenocephalides canis*, were evaluated. This paper reports the variability patterns in chaetotaxy as observed among natural populations of *Ctenocephalides canis* collected from six different geographic regions of India—Chamoli (Uttar Pradesh), Ispur (Himachal Pradesh), Kullu (Himachal Pradesh), Dhenkanal (Orissa), Ranchi (Bihar), and Pathanamthitta (Kerala)). The mean C.V. values of males of *Ctenocephalides canis* revealed the following progression of variability from most stable to most variable strain in chaetotaxy: Strain-5>Strain-3. Strain-6>Strain-1>Strain-4>Strain-2. Similarly, females showed the following progression of variability in chaetotaxy: Strain-6>Strain-3>Strain-1> Strain-5>Strain-2>Strain-4. Fleas collected from buffaloes (Strain-2) had the largest number of setae on the body. Certain characters (rows of bristles above antennal fossa, chaetotaxy of abdominal terga-IV, and VII, and number of pits present on sensillum, number of cteni on the Genal comb and pronotal comb) were evaluated as key traits with high taxonomic reliability. The interpopulational differences and similarities in variability in body traits among these six strains of dog flea are discussed with respect to the role of microhabitat variation and population fitness.
Beaucournu, J.C; Alcover, J.A. and Launay, H. (1989) described the fleas (Siphonaptera) of the Canary Islands. Description of *Ctenocephalides guancha* n. sp. thirteen species of fleas are known from the Canary Islands, of which 3 are reported for the 1st time: *Nosopsyllus barbarus*, *Stenoponia tripectinata tripectinata* and *Echidnophaga murina*. *Ctenocephalides guancha* sp. nov. is described from males and females on mice (*Mus musculus*) and rats (*Rattus rattus*) on Lanzarote. It is distinguished from other members of the *Ctenocephalides conformis* group by the chaetotaxy of the 3rd tibia. Among species of economic importance on the islands are *Leptopsylla segnis*, *Ctenocephalides canis*, *Ctenocephalides felis felis*, *Pulex irritans*, *Echidnophaga gallinacea*, *Ctenocephalides brasiiliensis* and *Ctenocephalides canis*.

### 2.5 Biological studies:

The biology of fleas has been studied by a number of authors. However, there are no mathematical models simulating the dynamics of a population of *Ctenocephalides felis felis* fleas on their host (the cat) and in their close environment. Several diseases are transmitted by fleas and ticks to cats, dogs and man. The biology and control methods for different vectors are described by Caeiro, V.M.P. (2001), including *Ctenocephalides felis felis*, *C. canis*, *Pulex irritans*, *Rhipicephalus sanguineus*, *Ixodes ricinus*, *Dermacentor marginatus*, *Hyalomma spp.*, *Haemaphysalis spp.* and *Boophilus spp.* The fleas most frequently found in Italy on the dogs and cats are *Ctenocephalides canis* and *Ctenocephalides felis*. The biology of fleas is described and the importance and losses caused by their blood sucking and by allergic dermatitis in host pets are reviewed. Kelemen, F. (1993).

A general account is given by Rust, M.K. (1991), the biology and behaviour of fleas. Attention is drawn to the fact that *Ctenocephalides felis*,
*Ctenocephalides canis* and *Pulex irritans* are the intermediate hosts of *Dipylidium caninum*, a common parasite of cats and dogs, and a rodent tapeworm, *Hymenolepis nana*.

The biology of *Ctenocephalides canis* in Ireland studied by Baker, K.P. and Elharam, S. (1992). A colony of *Ctenocephalides canis* was established from fleas collected off dogs in Dublin, using dogs as hosts. Two diets (100 g ground dried Ox blood, 15 g dog food and 5 g brewer's yeast vs. 1 g ground dried Ox blood and 1 g wheat germ) were used as larval media. Fleas reared on cats did not develop beyond the first larval stages. The effects of different temperatures on egg hatching and larval development were examined. Larval survival was poor at 22 °C and 25 °C at RH 50%, but good at RH 75% at these temperatures. The development from egg to adult took 21 days.

Mai Hai *et. al.* (2006) Studied on the biological characteristics of *Ctenocephalides felis felis*. Adult and larvae of *Ctenocephalides felis felis* were reared with mouse blood and artificial diet, respectively, under constant temperature and humidity separately. At temperature of 23±1 °C and relative humidity of 85 ±5%, the metamorphic period was 24.80 (18-29) days. 778.90 eggs were laid per female, and 5.67 eggs were laid per female per day. The reproductive capacity was 2.57. The lifespan of starved larvae was 18.10 (12-24) days, and that of blood-sucking adults was 122.73 (33-255) days. It is concluded that the metamorphic period of *Ctenocephalides felis felis* is short, the lifespan of the adult is long, and the reproductive capacity is high.

Felis (Bouche, 1835) is the one most studied. This taxon includes two subspecies: Ctenocephalides felis felis, and Ctenocephalides felis strongylus (Jordan, 1925); only Ctenocephalides felis felis has been the subject of almost all the studies available. They were interested in Ctenocephalides felis strongylus which can be regarded as the species of substitution of Ctenocephalides felis felis on the African continent. The purpose of their work was to establish some biological parameters such as: hatching of eggs, cycle of development and emergence of adults. These data were compared with those available on Ctenocephalides felis felis. With temperatures ranging between 19°C and 29°C and a relative humidity (HR) of 75% ±5%, the hatching rates of eggs observed from the two subspecies of Ctenocephalides felis, are higher than 88%. The optimal temperature of eggs hatching for Ctenocephalides felis is 29°C, with more than 70% of hatching obtained in 1-2 days after the laying. The larval developments of the two subspecies are almost identical. For Ctenocephalides felis strongylus, it lasts in 16-17 days at 29°C, 20-21 days at 27°C and 38 days at 19 degrees C. For Ctenocephalides felis felis, published values give report of 15 days at 27°C and 17 days at 24°C. The emergence of adults of Ctenocephalides felis strongly takes eight to ten days between 19°C and 29°C, while data published on Ctenocephalides felis felis are about 26 days at 19°C and 15 days at 27°C.

Farkas, R. (1999) reviewed the distribution of the cat flea (Ctenocephalides felis Bouche), its biology and ecology (feeding and breeding behaviour, larval and pupal development, host seeking activities of adults and surviving ability of adults off their hosts). Information of veterinary and medical importance, including flea-bite allergic dermatitis (FAD) of dogs and cats was also discussed.
Rust, M.K. and Dryden, M.W. (1997) described the biology, ecology, and management of the cat flea. He considered the *Ctenocephalides felis felis* as one of the most important ectoparasite of domestic cats and dogs worldwide. In addition to its annoyance to pets and humans, *C. felis felis* is responsible for flea bite allergy dermatitis and the transmission of dog tapeworm. The abiotic and biotic factors which affect the development of immature stages are reviewed with special emphasis to the aspects directly affecting control. Factors influencing host selection and feeding by adults have also been summarized. Recent studies concerning mating and oviposition, especially as they impact the likelihood of survival by immatures, are discussed. There has been an increase in the number of reports of insecticide resistance in the past 10 years. Greater attention has been paid on disrupting larval development in modern IPM programs. The immature stages of the cat flea are extremely susceptible to environmental factors such as temperature and relative humidity and insect growth regulators (IGRs). In recent years, the control of cat fleas has increasingly relied on the use of IGRs applied to the host or to the indoor environment. Finally, advances in pesticide chemistry that provide tools for better control of adult fleas on the host are discussed.

Campos Pereira, M.de and Santos, A.P. dos (1998 a) reviewed the biology and ecology of cat fleas *Ctenocephalides felis felis*, with emphasis on factors that need to be considered in the development of effective control methods. Detailed information of the environmental parameters affecting survival of all flea developmental stages are presented.

Hinaidy, H.K. (1991) collected a total of 134 fleas from 198 cats and 182 dogs in Austria. *Ctenocephalides felis* was the most common flea found on the cats (98.5%) and dogs (77.5%). Demonstration of cysticercoids of
Dipylidium caninum through bleaching of fleas failed. Dissection of fleas however, gave positive results. Infection intensity rates were 2.3% for Ctenocephalides felis (cats), 1.2% for Ctenocephalides felis (dogs), and 3.1% for Ctenocephalides canis (dogs). Male fleas were more extensively, but less intensively infected than female fleas. Cysticercoids from fleas of feline origin were more infective to cats than those from fleas found on dogs. The longest patency in cats was 3 years.

Baker and Elharam (1992) studied the biology of Ctenocephalides canis collected from dogs in Dublin and found poor larval survival rate at 22ºC and 25ºC and 50% RH and recorded time of development from egg to adult as 21 days. Koutinas et al (1995) surveyed the fleas on domestic animals and found Ctenocephalides canis as most abundant flea on dogs as 71.3 % and conversely lower on cats as 5.3 %, while Ctenocephalides felis was 97.4 % on cats and 40.3 % on dogs.

Lipman, N.S., Erdman, S.E. (1990) identified the larvae of Ctenocephalides felis during the physical examination of a domestic cat. Larval morphology and development are described in general terms, and the treatment of flea infestations in cats is discussed.

Moser, B.A., Koehler, P.G., Patterson, R.S. (1991) introduced the two methods to verify whether head width measurements for the separation of instars of Ctenocephalides felis. Individual rearing was a reliable method of determining larval instar but was labour-intensive. The mean observed head widths were significantly different for each instar (1st-instar, 0.164 mm; 2nd-instar, 0.201 mm; 3rd-instar, 0.260 mm) and showed no sexual dimorphism. Head capsule width increased roughly 25% from instar to instar, with geometrically progressing growth in accordance with Dyar’s rule. However, head capsule width cannot be used to determine the instar of
randomly selected larvae because the measurements overlap broadly between instars.

2.6 Control strategy:

The various types of control measures can be programmed so that their impact over time can be studied. The model confirms the key role played by adult fleas, or emerged fleas contained in the cocoon. Only regular applications of persistent insecticides to the host animal will enable control of the parasite population. A combination of these insecticides with an IGR (insect growth regulator) will accelerate decontamination of the home environment and see the disappearance of the parasites altogether if they are not reintroduced. The association of additional measures such as vacuum cleaning will accelerate the process of decontamination but will have no impact if carried out in isolation. One-off treatment with insecticide will not enable a reduction in the parasite population, even if carried out frequently. Use of insecticides on the home environment premises alone does not appear to be an adequate means of control. The model presented by Beugnet, F. et. al. (2004) can be used to test various integrated control measures which take into account different factors such as the number of host animals, the frequency of movement outdoors, and the impact of the seasons.

A novel approach to flea control: systemic use of lufenuron are described by Schenker, R. (1992/1993) from experiments with the insect growth regulator lufenuron (benzoyl phenyl urea) for flea (Ctenocephalides felis and Ctenocephalide canis) control are summarized under the headings: mode of action, flea biology, pharmacokinetics, dose titration in cats and dogs, treatment schemes, clinical studies, safety and tolerability. He concluded that, lufenuron administered to dogs orally as tablets and cats orally by suspension at a minimum of 10 and 30 mg active ingredient per kg
body weight, respectively, once a month with food, is well tolerated and effectively controls reproduction in fleas by disrupting the flea life cycle.

Regarding the control Minar (1977) studied the effects of trichlorophan (hypocid) against leydig application on cattle, sheep, dogs and poultry. Rust (1993) noted for the cat fleas, the effectiveness and practical ability of resistance management tactics available such as decrease dose, increased action threshold, rotation of insecticide with different mode of actions. Kalvelage and Munster (1991) reviewed the biology, epidemiology, clinical features, diagnosis and treatment of canine and feline Ctenocephalides infestations. They also discussed the importance of fleas as vectors of different diseases. Schenker (1992,1993) experimented with the insect growth regulator lufenuron for Ctenocephalides canis and Ctenocephalides felis control. He studied the mode of action, flea biology, pharmacokinetics, and dose titration in cats and dogs treatment schemes, clinical studies, safety and tolerability. Chesney (1995b) surveyed the abundance of Ctenocephalides felis and Ctenocephalides canis in England and established the polyxenous nature of both the species of fleas. He also correlated the study with the flea control.

Insecticide tolerance and resistance often blamed for failure to control cat fleas (Fox, et. al. 1968). Even low resistance ratios may be enough to affect control (Rust 1993).

As the susceptibility is concerned, most of the populations either have developed the resistance to some insecticides or are in the stage of development. New and new bacterial parasites, the rapid movements of population toward cities and poor health infrastructure again augment the miss happening of any epidemic.
These fleas are important pests of man and domestic animals due to discomfort caused by their bites. In North America the most frequent grievance is caused by the cat flea, *Ctenocephalides felis* and the dog flea, *Ctenocephalides canis*. In California, *Pulex irritans*, the so-called human flea, was long considered to be the most important flea biting man, but in recent years at least, the cat flea has been much more frequently encountered. Domestic fleas, particularly the human flea, have been considered important vectors of plague by some authors in various parts of the world (e.g. Baltazard, 1960). Burton, G.; Shipstone, M. and Burrows, M. (2003) provided the veterinary guidelines for the control of fleas in dogs and cats in Australia. Their article discusses flea biology, particularly with respect to the difficulties involved in control, and the diseases caused by fleas in dogs and cats. It describes practical and effective flea control strategies and discusses ways of troubleshooting when pet owners are having difficulty with flea control. Yathiraj, S., Rao, P.M., *et.al.* (1992) suggests the control of ticks and fleas in canines with amitraz. The treatment took effect within 24 h and no adverse effects were seen.

Campos Pereira, M.de and Santos, A.P. dos (1998 b) described the integrated control of *Ctenocephalides felis felis*. A review of common parasiticides used for flea control in Brazil is briefly presented, listing active ingredients and their classification. Concepts of developing an integrated flea control are presented; including aspects of indoor and outdoor flea control as well products and methods used to treat the pet. Newer parasiticides used in flea control are reviewed including insect growth regulators such as methoprene and lufenuron and topically applied residual adulticides such as fipronil and imidacloprid.
Dryden, M.W. and Rust, M.K. (1994) described the control of cat flea *Ctenocephalides felis felis*. Control failures and recurrences of infestation of dogs, cats and their home environment with *Ctenocephalides felis felis* are common. Attempts to control these infestations are often impaired by an inadequate understanding of the interaction of the cat flea with its hosts and environment. This review presents information on the medical and veterinary importance of the cat flea and discusses recent information on the environmental and host factors that affect its development and survival. Additionally, information is presented on the use and effectiveness of various insecticides and insect growth regulators against the four life stages.

Blagburn, B.L. and Dryden, M.W. *et. al.* (2006) described the new methods and strategies for monitoring susceptibility of fleas to current flea control products. A flea larval bioassay was developed by an international team of scientists to monitor the susceptibility of fleas (*Ctenocephalides felis*) to imidacloprid (Advantage, Bayer Animal Health). The assay was validated using laboratory and field isolates of *Ctenocephalides felis*. Flea eggs representing different field isolates of *Ctenocephalides felis* were collected by veterinarians in the United States, United Kingdom, and Germany. Of the 972 flea isolates obtained during the 5-year study, 768 contained sufficient numbers of eggs to conduct the larval bioassay. Greater than 5% survival occurred for only six of the field isolates evaluated. Further evaluation and analysis of these isolates demonstrated that they did not differ significantly in their susceptibility to imidacloprid from the reference strains used to develop the assay.

Rust, M. K. and Waggoner, M. *et. al.* (2002) described the development of a larval bioassay for susceptibility of cat fleas (Siphonaptera: Pulicidae) to imidacloprid. Strategies for controlling cat fleas,
Ctenocephalides felis felis, have undergone dramatic changes in the past several years. With the advent of on-animal treatments with residual activity the potential for the development of insecticide resistance increases. Insect growth regulators and other novel insecticides can also be evaluated. Using a discriminating dose, the detection of reduced susceptibility in field strains can be determined with as few as 40 eggs.

Sembo, S. (2002) observed a mass-rearing method for the cat flea, Ctenocephalides felis (Siphonaptera: Pulicidae) on mice. Survival, fecundity and insecticide susceptibility of the cat flea, Ctenocephalides felis fed on mice were evaluated. Duration from egg to cocoon formation of Ctenocephalides felis fed on mice was about 8 days, that from egg to adult emergence was about 18 days, and the accumulated emergence rate was 89.2%. The average number of eggs deposited was 10.3 eggs/day per [female], maximum egg deposition was 21.6 eggs/day per female at 4 days after infestation, and total number of egg deposition was 402 eggs/female. Longevity of Ctenocephalides felis reared on mice was more than 40 days. Insecticide susceptibility of mouse strain Ctenocephalides felis was the same as that of the cat strain. This rearing method is very simple and useful for producing a large number of cat fleas in a small space.

Franc, M. and Cadiergues, M.C. (1997) has also described the susceptibility of the cat flea, Ctenocephalides felis (Siphonaptera: Pulicidae) to four pyrethroids. The amounts of bioallethrin, deltamethrin, esbiothrin [[1R-[1a(S*),3b]]-isomer of allethrin] and permethrin required to kill adult C. felis on insecticide-impregnated filter papers were determined. The LD50 and LD90 against C. felis were 121 and 770 mg/msuperscript 2, respectively, for bioallethrin, and 161 and 671 mg/msuperscript 2, respectively, for esbiothrin. For deltamethrin and permethrin, the LD50s were 0.38 and 23
mg/m$^{2}$, respectively, and the LD90s were 15 and 60 mg/m$^{2}$, respectively.

Elston, D.M. (1998) provided brief descriptions of *Ctenocephalides felis* and *Ctenocephalides canis* are given to aid identification, together with a very brief description of the pathology of human flea bites and flea control.

Logas, D.B. (1995) have written an article on the cat, the flea, and pesticides. The purpose of this article is to explain new concepts in flea biology and flea control strategies, discuss the use and toxicity of common pesticides as they relate to cats, and to introduce several new less toxic forms of flea control.

Scant information is available concerning the biology of *Ctenocephalides felis* in Taiwan. The flea's life history; the effects of temperature, humidity, food, light and other environmental factors on development, survival, fecundity and normal activities; seasonal abundance and control are reviewed. Wu-Wen Jer *et. al.* (1991).

Kobayashi,-Y; Ono,-Y; Okano,-T; Buei,-K (1994) have tested insecticide susceptibility of the cat flea, *Ctenocephalides felis* (Bouche). Insecticide susceptibility of a Sakai (Osaka, Japan) strain of adults of *Ctenocephalides felis* was evaluated using 26 chemicals after colonization for 6 months. Fleas were reared on domestic cats. In the experiments on the influence of elapsed time after adult emergence, insecticide susceptibility remained almost unchanged in the individuals up to 3 days old, and then it rose rapidly 7 to 8 days after emergence. The effects of 6 insecticides on the flea were compared by exposing adults to insecticide residues of different dosage for limited times. The higher mortalities tended to occur with longer contact times. Generally, the ratios (LC50 for 1 h contact:LC50 for 24 h
contact) based on the LC50s of pyrethroids between the 1 h and 24 h contact were greater than those of organophosphates. Toxicity (micro g/cmsuperscript 2) based on the LC50s were determined by the successive contact method. Dichlorvos and fenthion were most toxic against the flea. Other insecticides tested, in descending order of toxicity, were chlorpyrifos, fenitrothion, diazinon, propoxur, fenobucarb, carbaryl, metoxadiazone, cyfluthrin, empenthrin, trichlorfon, resmethrin and prallethrin. The Sakai strain was more susceptible to pyrethroids and carbamates, while more tolerant to organophosphates, as compared with a susceptible US (California) strain.

Palma, K.G; Meola, S.M. and Meola, R.W. (1993) have studied the mode of action of pyriproxyfen and methoprene on eggs of *Ctenocephalides felis* (Siphonaptera: Pulicidae). Adult cat fleas were exposed to residues of pyriproxyfen and methoprene in glass vials, and then fed on a cat 24 h later to investigate the mode of action of juvenoid growth regulators on embryonic development in flea eggs. Eggs laid by pyriproxyfen-treated fleas within 70 h after exposure to this juvenoid were often devoid of yolk and frequently collapsed after oviposition. Minimal amounts of yolk were deposited in eggs laid after 70 h, and no blastoderm was formed. These results are significant because both modes of action were different than those observed earlier by investigators studying ovicidal effects in adult insects treated with juvenile hormone. In contrast to the pyriproxyfen results, eggs laid by methoprene-treated fleas showed no gross morphological effects, and these eggs remained turgid during embryogenesis. However, the eggs either did not hatch or the larvae died within hours after hatching. Histological examination of the eggs revealed that most of the eggs contained segmented embryos which had apparently died during blastokinesis. Although eggs of some insects exposed to juvenile hormone during oogenesis fail to undergo
germ band formation, there was no evidence of this effect in methoprene-treated fleas.

Lemke, L.A.; Koehler, P.G. and Patterson, R.S. (1989) Studied the susceptibility of the cat flea (Siphonaptera: Pulicidae) to pyrethroids. Adult cat fleas, *Ctenocephalides felis* felis, from 2 laboratory colonies (one originating in California and one from Florida) were exposed to residues of 8 pyrethroids to compare their susceptibilities. The Florida strain was more tolerant than the Californian strain, with 6.8-, 5.2- and 4.8-fold tolerance to cyfluthrin, cypermethrin and fluvalinate, respectively. The Florida strain showed less than 3-fold tolerance to the other 5 insecticides (permethrin, tralomethrin, d-phenothrin [the (1R)-cis-trans-isomer of phenothrin], resmethrin and fenvalerate). Over-all, the pyrethroids were ineffective against the Florida strain.

Kilonzo, B.S. and Gisakanyi, N.D. (1988) observed the susceptibility of *Ctenocephalides felis* (Siphonaptera: Pulicidae) to malathion and permethrin in Tanzania. Laboratory-reared adults of *C. felis* were exposed to 0.5% malathion and 0.5% permethrin w.p. using standard WHO methods in order to determine which was the most effective at controlling this flea in Tanzania. After 24 h exposure to malathion (3.6 mg/cmsuperscript 2), 92% of the fleas died. The LT50 was about 8 h. Permethrin (0.45 mg/cmsuperscript 2) produced 100% mortality in exposed fleas after 24 h; at 0.9 mg/cmsuperscript 2 all the fleas died after 8 h. The LT50s for the 2 doses of permethrin were 7.7 and 1.05 h, respectively. The failure of malathion to kill 100% of the assay population was attributed to resistance.

El-Gazzar *et. al.* (1988a) studied the activity of chitin synthesis inhibitors on the cat flea, *Ctenocephalides felis* (Bouche). Three chitin synthesis inhibitors, Alsystin [triflumuron], diflubenzuron and cyromazine
were tested against larvae of *C. felis*. The chemicals were incorporated into the larval rearing media of 1.5-, 2.5- and 3.5-day-old larvae. The LC50s of 0.36, 0.09 and 0.94 p.p.m. for triflumuron, diflubenzuron and cyromazine, respectively, were determined by probit analysis. As larval age increased, susceptibility to these chemicals decreased, with diflubenzuron and cyromazine having effect only when applied to the younger larvae.

El-Gazzar, L.M.; Koehler, P.G. and Patterson, R.S. (1988b) have studied the factors affecting the susceptibility of the cat flea, *Ctenocephalides felis* Bouche, to chlorpyrifos. Anaesthetizing adults of *C. felis* with carbon dioxide or by cooling (at 2-9 °C) for periods ranging between 5 to 90 min did not cause significant mortality within the first 24 h after exposure. However, when similarly exposed fleas were exposed to chlorpyrifos there was a direct correlation with the length of exposure to the anaesthetizing agents and the susceptibility of the fleas to this insecticide. The age of the adult flea also affected its susceptibility to the chemical, especially those >48 h old. Handling and transporting of pupae did not affect their susceptibility to chlorpyrifos in the adult stage.

El-Gazzar et. al. (1988c) have described the comparisons of cat flea (Siphonaptera: Pulicidae) adult and larval insecticide susceptibility. The resistance levels of a Florida strain of *Ctenocephalides felis* were evaluated using 9 chemicals after colonization for approximately 1 (1984) and 2 (1985) years. It was found that the fleas had lost some of their resistance to chlorpyrifos and malathion in 1985 compared to 1984. Moreover, higher resistance was detected to the 3 carbamates, bendiocarb, propoxur and carbaryl. The increased carbamate resistance was attributed to the use of carbaryl dust to kill fleas on cats after they were taken out of flea production. The resistance levels for propetamphos, diazinon, isofenphos and
chlorfenvinphos did not change significantly. Comparing the 24 h toxicity of the 9 compounds against larvae and adults in 1985, chlorpyrifos, diazinon, chlorfenvinphos and propoxur were more toxic to adults than larvae, and propetamphos, malathion and bendiocarb were more toxic to larvae than adults. The tolerance to isofenphos was similar for larvae and adults. Both stages responded equally to carbaryl and were completely resistant. All organophosphates in 1985 exhibited delayed larval mortalities and affected cocoon formation of the larvae that survived the 24 h exposure. However, none of the organophosphates or the carbamates appeared to have any effect on adult emergence indicating that the delayed toxicity does not extend beyond the larval stage.

 Campos Pereira, M.de., Santos, A.P.dos. (1998a) introduced the common parasiticides used for flea control in Brazil, listing active ingredients and their classification. Concepts of developing an integrated flea control, including aspects of indoor and outdoor flea control as well products and methods used to treat the pet. Newer parasiticides used in flea control are reviewed including insect growth regulators such as methoprene and lufenuron and topically applied residual adulticides such as fipronil and imidacloprid.

 Campos Pereira, M.de., Santos, A.P.dos. (1998b) reviewed the biology and ecology of cat fleas, with emphasis on factors that need to be considered in the development of effective control methods. Detailed information of the environmental parameters affecting survival of all flea developmental stages also reviewed.

2.7 Significance:

Menier, K., Beaucournu, J.C., (1999) reported that *Ctenocephalides spp.* have a significant medical and veterinary importance and its
synanthropic taxa are responsible for numerous nuisances. These nuisances may be due to the bite or to the transmission of pathogenic agents (helminths, protozoan, bacteria) to man or pets. These fleas may proliferate in houses on pets, but also on large animals, sometimes causing anaemia and death. These proliferations have no serious consequences in industrialized countries, but cause economic losses in developing ones.

Resistance was reported in eight species of fleas by Georghious and Mellon (1983) including three species of notable public health importance – the cat flea *Ctenocephalides felis* (Bouche), human flea *Pulex irritans* (L) and Oriental rat flea *Xenopsylla cheopis* (Rothschild). *Cenocephalides felis* as the most common flea in Europe (Vater and Vater 1985). Rust and Dryden (1997) is resistant to more chemical categories than any other flea.