Assessing Prevalence of Parasitic Diseases at Swamp Deer *(Rucervus duvaucelii duvaucelii)* – Livestock Interface at Jhilmil Jheel Conservation Reserve and Kishanpur Wildlife Sanctuary

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in Partial Fulfillment of the Master's Degree in Wildlife Science

by

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CERTIFICATE

This is to certify that **Animesh Talukdar,** student of Wildlife Institute of India has carried out an original piece of research work entitled **"Assessing prevalence of parasitic diseases of Swamp Deer (*Rucervus duvaucelii duvaucelii*)-livestock interface at Jhilmil Jheel Conservation Reserve and Kishanpur Wildlife Sanctuary"** for the partial fulfilment of the M.Sc. Degree in Wildlife Science from the Saurashtra University, Rajkot, India. These investigations were carried out under our supervision from December 2014 to June 2015. We also certify that this research has not been submitted for any other degree to any University.

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CONTENTS

	List of Tables	i
	List of Figures	ii
	List of Plates	iii
	Acknowledgement	iv-vi
	Summary	vii-viii
1	Introduction	1-9
2	Study Animal	10-14
3	Study Area	15-19
4	Methodology	20-26
5	Results	27-38
6	Discussion	39-44
7	Management Implications	45
7	References	46-56

List of Tables

4.1	Different parasites eggs identification keys	25
5.1	Maximum Swamp deer and livestock count during the study period	27
5.2	Consistency of pellet samples of Swamp Deer	31
5.3	Attributes of parasite genera encountered in the study	33
5.4	Parasitic (EPG count per gram of Dung) for Swamp deer at Jhilmil Jheel and Jhadi Tal	34
5.5	Details of single and mixed infection at field sites for swamp deer	35
5.6	Details of single and mixed infection at field sites for livestock	36
5.7	Commonality of parasites between livestock and swamp deer at both study sites	38

List of Figures

2.1	Swamp Deer (*Rucervus duvaucelii duvaucelii)* at Jhilmil Jheel, JJCR	10
2.2	Swamp Deer (*Rucervus duvaucelii duvaucelii)* at Jhadi Tal, KWS	10
4.1	Grid Map to study space use	21
5.1	Percentage of area use by ungulate at study sites	29
5.2	Species accumulation curve for swamp deer at Jhilmil Jheel, JJCR	30
5.3	Species accumulation curve for livestock at Jhilmil Jheel, JJCR	30
5.4	Species accumulation curve for swamp deer at Jhadi Taal, KWS	30
5.5	Species accumulation curve for livestock at Jhadi Taal, KWS	30
5.6	Prevalence of parasitic ova in swamp deer at the study sites	33
5.7	Prevalence of parasitic ova in livestock at the study sites	35
5.8	Interaction of swamp deer and livestock at the study sites	38

List of Plates

2.1	Geographic range of *Rucervus duvaucelii*	12
3.1	Intensive study area : Jhilmil Jheel, JJCR	16
3.2	Intensive study area Jhadi Tal, KWS	19
5.1	Area use map by different ungulate species at Jhilmil Jheel, JJCR	28
5.2	Area use map by other ungulates at Jhilmil Jheel, JJCR	29
5.3	Swamp Deer Pellets showing different Consistency	31
5.4	Parasitic genera found during study	32
5.5	Swamp deer- livestock interaction at Jhilmil Jheel, JJCR	37
5.6	Swamp deer- livestock interaction at Jhadi tal, KWS	37

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Summary

The interaction between wildlife, livestock and other domesticated animals is existent since the domestication of species. This has seen an increase in recent past owing to increased anthropogenic dependence on natural habitats. The domesticated animals, maintained at high population densities, have the potential to act as reservoirs of disease for wild animals. Parasitic infection both micro and macro; in wildlife at the wildlife – livestock interface, can affect conservation efforts by "spillover" and "spillback". Combined with other stressors, disease in wildlife can impact reproduction, survival and fitness, thereby affecting abundance and diversity of wildlife populations. Especially vulnerable are species with limited abundance and range. Macro-parasites especially the helminths, flukes and various ectoparasites have life cycles characterized by distinct life stages and are opportunistic in nature and can infect a large number of host species.

The present study focuses on interactions between Swamp deer and livestock at two sites namely the Jhilmil Jheel (JJ) in the Jhilmil Jheel Conservation Area, Haridwar Forest Division and and Jadi Tal (JT) in the Kishanpur Wildlife Sanctuary, Dudhwa Tiger Reserve. Swamp deer is a vulnerable, flagship deer species from the Indian subcontinent, with distribution restricted to isolated localities in north and central India and parts of southwestern Nepal (Qureshi *et al.* 2004). Therefore any factor exacerbating threats for population decline of the species need careful evaluation. This work is a first structured parasitic prevalence study at Swamp deer - livestock interface, from two of the eight prime locations (Jhilmil Jheel Conservation reserve and Kishanpur Forest Division) reported for the northern population of swamp deer in India.

The study included an estimation of population size of swamp deer and livestock and their space use patterns. Coprological examination of both swamp deer pellets and livestock dung was used to assess the prevalence and load of gastro-intestinal parasites.

The result revealed that population of Swamp Deer was 153 and 435; while livestock counts were 84 and 35 respectively for Jhilmil Jheel and Jadi Tal during the study period. At Jhilmil Jheel a significant spatial overlap was observed between the two groups while the converse

was observed at Jadi Tal. The overall prevalence of parasitic ova in the dung sample of swamp deer and livestock population was higher at JJ as compared to JT (Swamp deer 15.38% and 12.69% and Livestock 95.4% aand 60% respectively). The parasitic ova reported from both the sites included *Strongyles*, *Trichostrongyle* (direct life cycle), *Amphistomes*; *Fasciola*; and *Moniezia* (mediated through intermediate host).

Difference was observed for the parasite species richness and prevalence between swamp deer and livestock at Jhilmil Jheel and Jadi Tal. Parasitic ova with simple life cycle dominated over the parasites with intermediate hosts at Jhilmil Jheel. Analysis of parasitic load based on Mc Master's technique (Soulsby , 1982) revealed significantly higher load of parasitic ova at Jhilmil Jheel in swamp deer as compared to Jhadi Tal (M-W test, $Z=-3.082$, $p=0.02$).

Our results suggest that the understanding of parasite prevalence and likelihood of disease events is poorly known for both sites. Similarities in the gastrointestinal parasites and the life histories of wild and domestic ruminants, coupled with a detailed knowledge of the ecology and life cycle of the parasites, render the host- parasitic system particularly amenable for a multi disciplinary assessment that can lead to an effective development of management interventions aimed at protection of Swamp deer in their natural ecosystems. Additionally, it would be appropriate to have systemic studies to understand drivers of disease for effective health management.

1. INTRODUCTION

Interactions between domesticated animals including livestock with wildlife have been occurring since the beginning of civilization. These interactions have increased manifold in the recent past owing to encroachment of natural habitats to meet the growing demand of space for agriculture to meet the increasing demand for food; housing and diverse array of anthropogenic activities. Competition for grazing and water resources has also risen in recent decades. In tropical regions, livestock and agriculture have recently and rapidly invaded inside and near to the protected areas as well as in between corridors, causing dramatic losses for both wildlife and their natural habitats (Dobson and Foufopoulos, 2001), causing dramatic losses for both wildlife and their natural habitats (Dobson and Foufopoulos, 2001). Although interaction between livestock and wildlife can take on many forms, the two groups most commonly interact through one of the following four modes: direct completion for food, predation (generally from wildlife on livestock), pathogen exchange and hybridization (Foufopoulos *et al.,* 2003).

Domesticated animals are usually maintained at high population densities and have a pan-global distribution, with a potential role as reservoirs of infectious disease for wild mammals (Lafferty and Gerber 2002). To elaborate, around 77% of livestock pathogens are multi-host in nature and majority of pathogens could affect wild ungulates (Cleaveland *et al.*,2001). Parasitic infection and disease in wildlife and at the livestock–wildlife interface have the potential to impede conservation efforts by restricting the ranges of host species (Dobson and Hudson, 1986) and threatening the persistence of species of conservation concern. This has led wildlife biologists to pursue studies in the ecology of diseases and parasite impacting wild population (Davidson *et al.,* 1981).

Infectious agents or pathogens; one of the causes of diseases are natural components of ecosystems, an intrinsic part of biological diversity and ecological complexity of natural, healthy ecosystems. Evaluating such causes of a disease requires an understanding of multiple features of each of the agents, the host and its environment, a combination of which has been called as the 'epidemiological triad'. However, this triad is insufficient to describe many of the diseases wherein a web of causation has to be considered having a list of predisposing factors like nutrition, stress, weather, etc. (Wobeser, 1994). Hence, ecology of wildlife disease includes study of pathogens and hosts, their behavior and biology, the

environment factors, disease transmission procedures, susceptibility of host, climate factors and impacts of diseases on wildlife populations and communities. This, relatively recent discipline works at the interface between ecology and medicine, and thus recognizes the importance of a multidisciplinary approach to understand the complexity of disease in wild animals.

Anderson and May, (1979) and Altizer *et al.,* (2001) classified pathogen into micro-parasite and macro-parasites. While micro-parasites (virus, bacteria and protozoa) usually have simple life cycles; the macro-parasite (helminths, flukes and various ectoparasites) have life cycles characterized by distinct and sometimes dramatically different stages (Foufopoulos *et al.,* 2003). Majority of these pathogens are opportunistic (Dobson and Foufopoulos, 2001) with the ability to infect an unusually large number of host species (crossing different host genera and, at times, families). Pathogens circulating between populations capitalize on several mechanisms for transmission including ectoparasitic vectors; however, a majority of pathogens are transmitted through either direct contact or fomites. Contact between wildlife and domesticated animals are facilitated more in areas where humans have expanded into native wildlife habitat. Another crucial factor promoting epizootics is the presence of feral/stray animals in an area that typically harbors a diverse community of serious pathogens (McKenzie and Davidson, 1989). Further their activity patterns play a major role in contact between both wildlife and domestic animals, feral/ stray animals can efficiently shuttle pathogens between these two groups and promote the spread of epidemics.

1.1 Diseases and their impact on populations

Occurrence of disease in wildlife is a natural phenomenon. In fact, it was viewed as a limiting factor in the ecosystems along with, predators, competitors, and resources; all together keeping a population at equilibrium (Caughley and Krebs, 1983). Recently, substantial evidences have been gathered, that diseases can greatly impact local species populations by causing temporary or permanent declines in abundance (de Castro and Bolker, 2005). There is a mounting theoretical and empirical evidence that parasites play an important role in influencing host populations through impacts on survival and reproduction (Watson, 2013) and trophic equilibria (Grenfell, 1992), as illustrated by canine distemper virus in Serengeti lions (Roelke-Parker *et al.,* 1996), Ebola outbreaks in African apes (Leroy *et al.,* 2004), and multiple pathogens that affect amphibian populations (Daszak *et al.* 1999; Pounds *et al.,*

2006). Combined with other stressors on habitats and populations, particularly fragmented populations, disease in wildlife may present serious conservation and management consequences that impact reproduction, survival and fitness, thereby affecting abundance of wildlife populations and biodiversity within ecosystems besides presenting an additional threat to many populations, especially those with limited abundance (i.e. threatened and endangered species). Pathogens can also be transmitted among conspecifics, other wildlife species, domestic animals, and humans, posing risks to human and animal health and resulting in significant economic impacts. Shrivastav (2001) reported diseases as the major cause of local extirpation of a number of wild animal species in India.

1.2 Parasitic diseases and their impact on population

Although parasites and diseases caused by them are recognized as an important health issue in domestic animals and humans, wildlife parasitology in India is still in its infancy.

Parasites are ubiquitous in wildlife and livestock and are an important component of ecological communities (Dobson and Hudson, 1986). Far from being "benign symbionts living in equilibrium with their hosts", parasites have a profound effect on host survival, fecundity and behavior (Hudson and Dobson, 1995). Parasite induced extinction of various species are more likely in situations involving multi-host parasites as well as frequency-dependent transmission and when in recital with other drivers of extinction (de Castro and Bolker 2005). Parasites often infect multiple species, and high prevalence in alternative hosts coupled with cross-species transmission can lead to parasite-induced declines in species that would normally be unable to maintain the parasite (Gog *et al.*, 2002; Fenton and Pedersen 2005). As an example, in carnivores several species near extinctions have been caused by generalist parasites transmitted to threatened species populations (Woodroffe 1999; Lafferty and Gerber 2002). Again, the transmission of some other parasites like sexually transmitted and vector-borne diseases might be decoupled from host population density (Getz *et al.*, 1983). So, these parasites are capable of spreading till the host populations decline (Boots *et al.*, 2003). Furthermore, there are many threatened mammals which are prone to extinction risk as their populations are fragmented and small with low genetic variability (Woodroffe 1999; Altizer *et al.*, 2003). Though parasites alone rarely play major role in host extinction yet it is significant when in combination with other factors like habitat loss, hunting, and invasion of invasive species (Wilcove *et al.* 1998; Purvis *et al.*, 2000). There is mounting

theoretical and empirical evidence that parasites play an important role in influencing host populations through impacts on survival and reproduction (Holmes, 1995; Hudson *et al.*,1998: Tompkins and Begon, 1999: Watson, 2013) and trophic equilibria (Grenfell, 1992). Parasitic infection and disease in wildlife and at the livestock-wildlife interface, therefore, has the potential to impede conservation efforts by restricting the ranges of host species (Dobson and Hudson, 1986) and threatening the persistence of species of conservation concern (Laurenson *et al.*,1998; Morgan *et al.*,2005). Parasite can reduce the competitive strength of infected hosts along with infection to the prey without affecting predator and vice versa. Again parasites may revise prey capture rates because of their effects on activity levels as well as host's behaviour.

1.3 Parasitic diseases in cervids

There have been only sporadic reports and reviews of parasitic diseases in cervids and minimal systematic studies have been carried out to establish the cause and spread of disease (Watve and Sukumar, 1995; Dharmarajan *et al.*, 2003, 2004, 2005; Jog *et al.* 2005; Shrivastav *et al*, 2004). Majority of information is limited to ecology, behavior of cervids with few incidental case reports of infectious diseases.

Chauhan *et al.*, (1973) reported the occurrence of amphistomes by faecal examination in spotted deer (*Axis axis*) and chinkara (*Gazella gazella*) at Lucknow zoo and in Sika deer (*Cervus nippon*) at Delhi zoo. Additionally, evidence of faecal eggs of bursate worms were also demonstrated in several species of cervids at both the zoos (Chauhan *et al.* 1973). Gaur *et al.*, (1979) reported high incidence of *Fasciola gigantica*, which along with amphistomes, appeared to be a well-established parasite of wild spotted deer and barasingha (*Cervus duvaucelli*) in Uttar Pradesh, covering Jim Corbett National Park and Kanpur zoo. Among nematodes, *Haemonchus contortus* caused the predominant infection in wild deer, followed by other S*trongyles, Strongyloides papillosus, Oesophagostomum sp. and Bunostomum sp.*

Rao and Acharjyo (1984) reported high incidence with *Fasciola gigantica* in spotted deer and black buck (*Antilope cervicapra*) and *Gigantocotyle explanatum* in sambar (*Cervus unicolor*) and Hydatid cyst caused by *Echinococcus sp.* in lungs of spotted deer at Nandankanan zoo, Odisha. Padhi *et al.*, (1987) recorded occurrence of *Paramphistomum cervi, Gastrothylax*

crumenifer and *Fischoederius elongatus* in the rumen of spotted deer from Nandankanan Bio-Park, Odisha,

At Bannerghatta National Park, Bangalore, *Strongyle spp.* in chinkara and spotted deer, and ascarids in sambar, spotted deer and barking deer were recorded by Jayagopala *et al.,* (1992). Varma *et al.,* (1993) reported occurrence of *Paramphistomum epiclitum* from rumen and *Gigantocotyle explanatum* from bile duct of sambar at Delhi zoo. Chakraborty *et al.,* (1994) recorded Fasciola in spotted deer (*Axix axix*), serow (*Capricornis sumatrensis*) and mithun (*Bos frontalis*), and 6 genera of amphistomes in various deer species and related bovids were identified. Of the *amphistomes*, genus *Paramphistomum* found in all species of deer but most in spotted deer, sambar and barking deer (*Muntiacus muntjak*). They also recorded *Echinococcosis* Cysts in spotted deer, *Cysticercus* sp. in spotted deer, sambar, barking deer, black buck and nilgais from Assam. Among the nematode, *Trichuris sp.* and *Oesophagostomum* in mouse deer (*Tragulus meminna*), *Haemonchus* and *Trichostrongyle* in barking deer, Setaria in barking deer and sambar, and Onchocerca in spotted deer were recorded from the same location. Moreover, verminous pneumonia associated with *Muellerius* capillaris, *a* lungworm in a barking deer was reported from Himachal Pradesh by Sharma *et al.,* 1996.

In different sanctuaries of Tamil Nadu, Bhat and Manickam (1998) reported Strongyloides, Trichostrongyle and *Cooperia* by copro-culture in spotted deer with observations on seasonal variations in worm burdens. *Gastrothylax crumenifer* and *G. glandiformes* were reported from barasingha by Shrivastava *et al.,* (1998). Acharjyo (2000) described gross and histological pathology of hepatic amphistomiasis (*G.explanatum*) in sambar. Varadharajan and Kandasamy (2000) observed *Moniezia* faecally as part of parasite estimation study in a sambar deer at Coimbatore Mini zoo.

Six genera of strongyles viz. *Oesophagostomum, Trichostrongyle, Ostertagia, Marshallagia, Nematodirus* and *Haemonchus* as well as *Strongyloides sp.* were recorded in the gastro-intestinal tract of Hangul (*Cervus elephus hanglu*) at Dachigam National Park in Kashmir by Shahardar *et al.,* (1995). Faecal positivity found for *amphistomes* in spotted deer, sambar and black buck at Thiruvananthapuram zoo, Kerala (Varadharajan and Pythal 1999) in spotted deer, sambar and hog deer at Thrissur zoo, Kerala (Varadharajan *et al.,* 2001), in nilgais and

spotted deer in Uttarakhand (Banerjee *et al.* 2005) and in sambar at a zoological park in Punjab (Singh *et al.*, 2006).

Strongyles and spiruroids were found to be the predominant nematode infections by faecal examination in 5 deer species viz. spotted deer, sambar, hog deer, barking deer and black buck at the Thiruvananthapuram zoo in Kerala by Varadharajan and Pythal (1999). *Dicrocoelium* was recorded from spotted deer at Maharajbagh zoo, Nagpur, Maharashtra by Dhoot *et al.*, (2002). Hussain *et al.*, (2002) reported helminth parasites of axis deer at Nagpur which includes 5 genera including *Strongyloides, Trichuris, Nematodirus* and *Haemonchus*. The lungworm *Dictyocaulus sp.* morphologically similar to *D. viviparus* was found in Kashmir stag or hangul by Nashiruddullah *et al.*, (2005).

Feacal samples of eighteen spotted deer stags by Mohan and Coumarane (2007) in captivity at the Department of Forest and Wildlife, Pudducherry revealed individual and mixed infections of *Cooperia* sp., *Capillaria sp.* and *Trichostrongyle sp.* Faecal examination of axis deer maintained in forested area of Vidharba region of Maharashtra by Meshram *et al.*, (2008), revealed 89% of positive cases for parasitic eggs. *Trichuris sp., Strongyles, Strongyloides sp., Trichostrongyle* sp., *Oesophagostomum sp., Haemonchus and Bunostomum* were identified in the samples analyzed. Sahoo *et al.*, (2010) reported 11 fatalities out of 30 inmates in a deer park in Cuttak, Odisha due to an outbreak of fascioliasis in spotted deer. Additional recent record also exists of *Fasciola* in sambar deer at Periyar Wildlife Sanctuary, Kerala (Ravindran *et al.*, 2011)

Strongyles described in the rate of 98.71% as prevalence to be maximal followed by *Amphistomes* (88.65%), *Strongyloides* (32.21%), *Trichuris* (18.55%), *Monizia expansa* (11.85%), *Coccidia* (7.47%) and *Monizia benedeni* in Barasingha (4.63%) in Kanha Tiger reserve. Previously parasite prevalence was found in comparatively low rate in Kaziranga (Chakraborty *et al.*, 1996).

In Protected areas which are often situated relatively close to agricultural farmland, cervids within the area are likely to be exposed to livestock pathogens (Chow and Davis, 1964). Though pursue of literature yielded no information on mortality in swamp deer due to any infectious disease, most of the present populations occur in areas where diseases like Foot and mouth disease, Brucellosis, Hemorrhagic septicemia and Anthrax are reported (Schaller

1967, Schaff 1978, Qureshi *et al.*, 1995). Again, while domestic and wild animals live sympatricly, there is also threat of disease transmission between them as many pathogenic infectious diseases are multihost and common for sympatric wild ungulates and livestock (Daszak *et al.*, 2000; Frolich *et al.*, 2002; Gaffuri *et al.*, 2006; Giacometti *et al.*, 2002; Gortazar *et al.*, 2007; Jansen *et al.*, 2007; Morgan *et al.*, 2006).

1.4 Challenges in Studying Wildlife Diseases

Understanding transmission, patho-physiology, epidemiology, and ecology of pathogens and how they interact with wildlife hosts is essential for developing effective strategies to prevent or manage disease in wildlife. Better understanding of these concepts will enable wildlife managers and scientists to address disease challenges. Many wildlife disease events go unrecognized due to remote locations and a lack of obvious manifestation in individuals or carcasses. In most situations, management involving veterinary management is also limited due to difficulties associated with accessing free-ranging wildlife, inability to adequately monitor elusive individuals and species, inadequate funding to support large-scale treatment programs and ethical concerns related to invasive veterinary intervention. Further challenges include lack of validated diagnostic tests and laboratory capacity for the investigation of wildlife diseases, under-developed surveillance networks, difficulties in determining key parameters such as prevalence for diseases in wildlife populations, and lack of accurate ecological data on population size and density (Woolhouse and Gowtage-Sequeria, 2005, Harrus and Baneth, 2005).

Utilizing existing systems to establish a coordinated approach is an effective and efficient mechanism to overcome some of these difficulties, where they relate to reporting and data collection. This approach can be strengthened by a functional network that facilitates communication and information flow between those engaged at all levels in surveillance, diagnosis and management of wildlife disease. Surveillance information collected in this way may contribute to the early detection of new or emerging diseases (Simpson, 2002; Karesh *et. al.*, 2005].

1.5 Swamp deer and threats to conservation

Swamp deer or Barasingha is one of the most vulnerable species of deer from the Indian subcontinent as well as in the world, which is presently found only in isolated localities in

north and central India as well as in southwestern Nepal (Qureshi *et al.,* 2004). The Barasingha was broadly distributed throughout the Indo–Gangetic plain and the lowlands flanking the southern Himalaya ranging from the terai of southern Nepal to the Sundarbans and Assam in the east. The western limit was the River Indus (Pakistan), and the River Godavari area of east central India the southern limit (Schaller 1967; Groves 1982; Sankaran 1990). The species is extinct in Pakistan and Bangladesh now. Barasingha is listed as vulnerable C1 ver 3.1(Duckworth *et al.*, 2013) and its schedule 1 species as per Indian Wildlife Protection Act, as the estimated population is about 3,500 - 5,100 animals and many of them are outside the protected area. Its habitat range is highly fragmented (Qureshi *et al.*, 2004). Three subspecies of swamp deer are currently extant namely *Rucervus duvaucelii duvaucelii, Rucervus duvaucelii ranjithsinghii* and *Rucervus duvaucelii branderi.* Whereas, *Rucervus duvaucelii duvaucelii* is distributed in northern India, *Rucervus duvaucelii branderii* is distributed in Kanha National Park in central India and *Rucervus duvaucelii ranjitsinhii* is distributed in Assam (Poudel 2007, Sankaran 1990). Schaller (1967) reported 15 swamp deer localities in India and first assessed the status of subspecies of northern Barasingha, *Rucervus duvaucelii duvaucelii* and reported its presence from 11 localities in northern India. Population status is between 3,500 and 5,100 animals among which several meta-populations are found in patches in protected areas and outside where presence is not secure (Nandi *et al.* 2012). Presently *Rucervus duvaucelii duvaucelii* is constrained to Jhilmil Jheel Conservation Reserve, Banganga Wetland, Hastinapur Sanctuary, Bijnor Forest Division, Pilibhit Forest Division, Kishanpur Sanctuary, Dudhwa National Park and Katerniaghat Sanctuary in India and Sukla Phanta Wildlife Reserve and Karnali Bardia Reserve in Nepal only (Nandi *et al.*, 2012).

Swamp deer were selected as the study animal for this study as they are a flagship species representative of cervids with a persistent threat to their long term survival due to various anthropogenic activities as well as their restricted distribution, habitat preferance, etc . The species like other cervids is vulnerable to infection by gastro-intestinal parasites with a habitat preference and seasonal movement pattern that places it in close proximity to livestock.

1.6 Rationale of the study

1. Sharing of natural habitats of wild ungulates by domestic livestock has adverse effect on wild ungulates. Besides degrading suitable swamp deer habitat, these livestock can contribute negatively by sharing diseases that are common between species. Many parasite species are generalists and capable of infecting multiple host species and have detrimental effect on population. Parasitic diseases in a population suppress the health of the population.
2. The population of swamp deer has been declining over time. Infection and parasites may have a negative role over swamp deer populations.
3. Up to certain limit, parasite load does not affect health status of an animal or group, but when there are intense demands on body resources like physiological stress, nutritional stress or environmental stress, it plays an important role in the animal's survival.

Based on the above, a study was initiated on the Northern population of Swamp deer, their interaction with livestock and commonality of parasites shared between the populations. The objectives of the study include following

1.7 Objectives

1. To study the prevalence of parasitic diseases in swamp deer in select areas of Jhilmil Jheel Conservation Reserve and Kishanpur Wildlife Sanctuary.
2. To study the prevalence of parasitic diseases in livestock at the study sites
3. To demonstrate the interactions between livestock and swamp deer at the study sites

2. STUDY ANIMAL

Fig 2.1: Swamp Deer (*Rucervus duvaucelii duvaucelii)* at Jhilmil Jheel

Fig 2.2: Swamp Deer (*Rucervus duvaucelii duvaucelii)* at Jhadi Tal

2.1 Taxonomy

Phylum : Chordata

Sub-phylum : Vertebrata

Class : Mammalia

Order : Artiodactyla

Family : Cervidae

Genus : Rucervus (Hodgson 1838)

Species : *Rucervus duvaucelii* (G. Cuvier 1823)

Swamp deer (***Rucervus duvaucelii***), a Vulnerable (Duckworth *et al.*, 2013) cervid endemic to the Indian subcontinent is a flagship species inhabiting flooded tall grassland (Dunbar Brander 1927; Pocock 1943; Johnsingh *et al.*, 2004). They are predominantly grazers (Qureshi *et al.*, 2004). The species is an integral component of their habitat and crucial to the maintenance of its successional stage limiting transition to woodland by grazing. Like other cervids they form an important component of the food chain of their ecosystems with large carnivores such as the tiger as apex predators. They disperse during monsoons and congregate in large herds during the dry summers, often in response to new growth following fire and the need for drinking water (Henshaw 1991; Qureshi *et al.*, 2004). These seasonal movements take the animals out of protected areas (Qureshi *et al.*, 2004) and place them in close contact with domestic livestock.

2.2 Physical characteristics

The species has splayed spongy hooves that enable locomotion in its swampy habitat (Singh 1970, Schaaf 1978, Groves 1982). Adult stags weigh between 170-280 kg and hinds up to 130-145 kg and measure 119-135 cm at shoulder (Schaller 1967, Prater 1971). The coat is generally brown in color, with males being darker than females. The stags are chestnut colored on the back and creamy white on the inner parts of the legs, rumps and inner side of the tail (Prater 1971). Swamp Deer exhibit marked color and texture changes of the coat according to the season. During winter a thick brownish coat is developed that is shed with the onset of summer. The summer pelage is reddish brown in color. A series of dark brown bands encircled with white spots runs down the whole length of the spine (Shrestha 2004).

The antlers are reported only in males, measuring an average of 74cm (the largest measured was 104 cm) with the girth of 12 cm with twelve or more points (Schaller 1967).

2.3 Geographic distribution

The species endemic to the Indian subcontinent was once abundant across the tall wet grasslands of the north Indian Terai, the Brahmaputra flood plain and the central Indian grasslands bordering Sal forests. It has declined over the years, as a result of loss of habitat and biotic pressure over much of its former range. The species is restricted to isolated pockets at few protected areas of north and central India, and southwestern Nepal. Dudhwa Tiger Reserve supports a single large population of 1200–1400 animals while about 2000 animals occur in Suklaphanta Wildlife Reserve and Bardia National Park. (Qureshi *et al.*, 2004). A small population of 320 animals (Tewari 2009) was rediscovered in 2005 at Jhilmil Jheel of Uttarakhand state (Sinha and Chandola 2006).

Plate 2.1: Geographic range of *Rucervus duvaucelii* (Duckworth *et al.* 2013)

2.4 Habitat

Swamp deer inhabit swampy grasslands and floodplains and are highly dependent on the availability of water (Tewari and Rawat, 2013). They utilize variety of habitat types including open forest where grasses are present, with maximum abundance occurring in marshy and sandy grasslands (Schaller 1967, Martin 1977, Schaff 1978, Singh 1985, Qureshi *et al.*, 1995). They have been reported to move across to forested habitats during shifts in habitat for fulfilling seasonal needs (Martin 1977, Schaff 1978, Qureshi *et al.*, 1995). The composite home range of herds varies from 10 to 30 km^2 (Qureshi *et al.*, 1995). They travel an average distance of 2-3 km daily and 5-7 km during seasonal shifts of habitat (Martin 1977, Schaff 1978, Singh 1985, Sankaran 1990, Qureshi *et al.*, 1995) with habitat use being largely influenced by food quality.

2.5 Activity patterns

The species exhibits a polyphasic activity pattern with feeding interspersed with walking and resting with peak grazing activity during mid-day and a marked reduction in resting time during winters (Tewari 2009; Ahmed and Khan, 2014).

2.6 Feeding ecology

Swamp Deer is primarily a grazer and largely feed on grasses and aquatic plants. The diet composition varies according to season and food availability. Preferred species were *Sacharum spp, Imperata cylindrica, Narenga porphyrocoma, Phragmites karka, Oryza rufipogon, Hygroryza spp and Hydrilla spp* (Schaller 1967, Martin 1977, Schaff 1978, Singh 1985, Qureshi *et al.,* 1995). The drinking of water varies with season. The feeding time varies between seasons, during summer morning feeding ends early and evening bout starts late (Martin 1977, Schaff 1978, Singh 1985, Qureshi *et al.,*1995). They are selective feeders only in monsoon when food supply is abundant becoming opportunistic in summer with limited food availability (Tewari and Rawat, 2013).

2.7 Social organization and behaviour

They are known to exhibit inconsistent grouping (Schaller 1967); groups tending to break up and reassemble with different associations (Schaller 1967; Tewari and Rawat 2013). These changes are attributed as a response to breeding cycle and food availability (Martin 1977, Schaff 1978, Singh 1984, Sankaran 1990, Qureshi *et al.,* 1995) with small groups or solitary individuals seen during the rutting season while larger groups (mean 32, range 2-250) were found to be more common during summer, in response to new flush in burnt flood plain grasslands (Schaff 1978, Qureshi *et al.,* 1995).

2.8 Reproduction

The Barasingha is monoestrous and monotochus (Qureshi *et al.,* 2004). Females start reproducing at the age of 2–3 years and males from 4 years onwards contribute to breeding (Schaller 1967, Martin 1977, Schaff 1978, Qureshi *et al.,* 1995). The rutting starts for *duvaucelii* in (August – September) while antler shedding begins by mid (January) (Dunbar Brander 1927, Schaller 1967, Prater 1971, Martin 1977, Schaff 1978, Singh 1985, Qureshi *et al.*, 1995).

The gestation period in Swamp deer ranges from 240 to 250 days and they have a reproductive rate of 20 to 45 fawns per 100 hinds (Schaller 1967, Martin 1977, Schaff 1978, Singh 1985, Sankaran 1990, Qureshi *et al.*,1995). Hinds segregate from the herd to give birth in selected tall grass areas and fawns remain in this surrounding for approximately 7 to 15 days during which the hinds visit the hiding sites for fawns to suckle (Singh 1985, Qureshi *et al.*, 1995). Fawns are introduced to herd as soon as they are able to follow their mothers (Schaller 1967, Martin 1977, Schaff 1978, Singh 1985, Qureshi *et al.*, 1995).

3. STUDY AREAS

The northern population of swamp deer is primarily reported from 8 localities in India (Jhilmil Jheel Conservation reserve, Ban Ganga wetland, Hastinapur sanctuary, Bijnore Forest Division, Pilibhit Forest Division, Kishanpur Forest Division, Dudhwa and Katerniaghat) and 3 localities in Nepal (Shuklaphanta Wildlife Reserve, Karnali and Bardia Reserve). To study the interaction of Swamp deer and livestock, two sites were selected with differential livestock presence. The sites selected for the study were the Jhilmil Jheel (JJ) in the Jhilmil Jheel Conservation Reserve (JJCR) of Uttarakhand and the Jadi Tal (JT) located in the Kishanpur Wildlife Sanctuary (KWS) of the Dudhwa Tiger reserve.

The reported population estimates of swamp deer in the study sites are 320 swamp deer in Jhilmil Jheel Conservation Reserve (Tewari *et al.* 2013) and Kishanpur Wildlife Sanctuary has a population of 600 number of swamp deer (*Rucervus duvaucelii duvaucelii,)*which was reported in 2008 to B. Long pers. comm. 2008 (Duckworthet al, 2013). Among which, Jadi Tal is a stronghold of about 400 animals (Midha and Mathur, 2010). Moreover in Jhilmil Jheel Conservation Reserve 1300 livestock (cattle) graze everyday (Tewari and Rawat, 2013). Jadi Tal is assumed to be free from livestock pressure as in Kishanpur wildlife sanctuary the human settlement is found only in north eastern side and the western side is bounded by Kheri Branch Canal of the Sharda Canal System (Midha, 2008).

The details of the study area are provided below:

3.1 Jhilmil Jheel Conservation Reserve (JJCR):

JJCR is a wetland situated on the left bank of river Ganges between E 29^0 32' to 29^0 50' and N 78^0 to 78^0 15' covering an area of 3783.50 ha at an altitude of 200 to 250 meters ASL. This area was declared a conservation reserve on August 05, 2005 (Tewari 2009*)*. The intensive study area was restricted to the area used by the swamp deer and has been called as Jhilmil Jheel (JJ) in the document. The area is a saucer shaped wetland between E 29^0 47' to 29^0 48' and N 78^0 12' to 78^0 13' covering an area of 1.7977 km^2 with a perimeter of 5.6087 km of the Reserve Forest. The habitat is located at the junction of the Bhabhar and Terai formations representing a unique and species rich ecosystem which encompasses spectacular landscapes, tall grasslands, and tropical moist deciduous forests. Streams and swamps are the main source

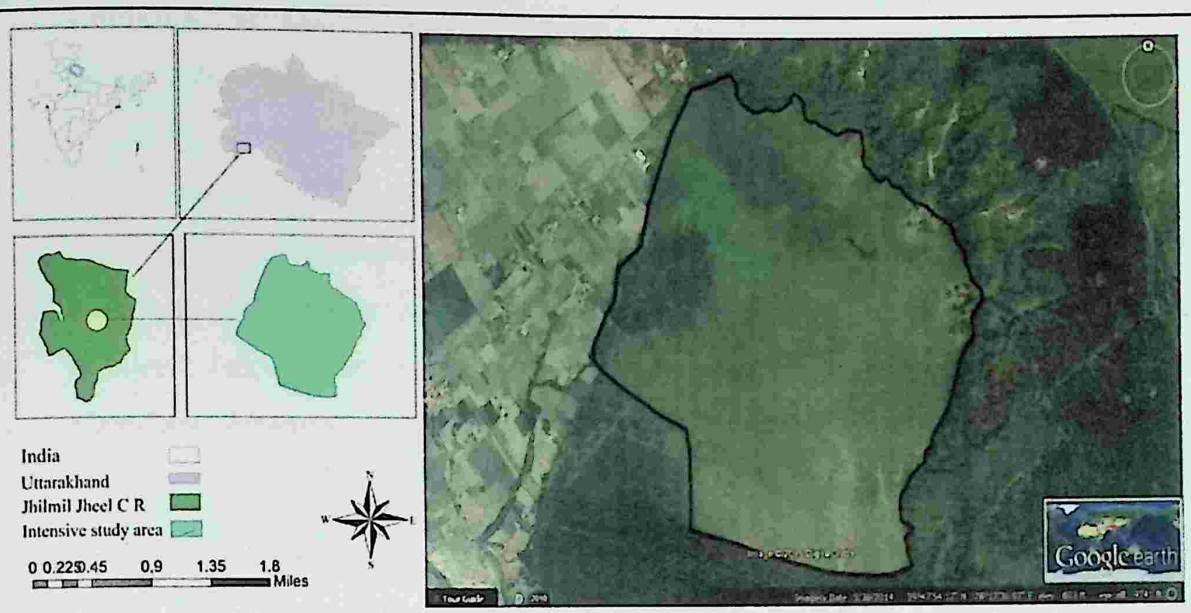


Plate 3.1: Intensive study area (Jhilmil Jheel) within the Jhilmil Jheel Conservation Reserve, Uttarakhand

of the diverse habitats of JJCR. Three small streams emerge from the woodland and discharge into the JJ, which finally drain into the Ganges. The texture of the soil of study area varies from sandy to clayey loam. Almost every year flood waters bring substantial amounts of silt, which is deposited in floodplain grasslands as well as in the adjacent forests. The area has a sub-tropical climate with the temperature ranging from minimum 2°C during winter to up to 44° C in summer. Heavy rains occur during monsoon between June to September. The mean average rainfall is 1300 mm per annum and the relative humidity ranges between 45-80% which is highest during rainy season.

The area is characteristic of *Terai* with excellent alluvium with high water table dominated by a mosaic of hygrophilous grassland and miscellaneous forests which is generally classified as Tropical Moist Deciduous Forests (Champion and Seth 1968). The vegetation of the study area is classified into four major types as Moist (mixed) deciduous forest, Riverine forest, Secondary scrub and Grassland. The intensive study area includes grasslands and secondary scrub only.

Grassland: The Grasslands in the ISA are spread over an area of more than one square kilometers and include:

1. **Common grasses:** *Coix lacrymajobi*, *Cyrtococcum accrescens*, *Eragrostis stenophylla*, *Phragmites karka*, *Cynodon dactylon*, *Imperata cylindrica*, *Pennisetum glaucum*, *Vetiveria zizanioides*, *Echinochloa colonum*, *Eleusine indica*, *Paspalum conjugatum* and *Polypogon fugax*
2. **Sedges:** *Carex myosurus*, *Cyperus bervifolius*, *C. compressus*, *C. cyperoides*, *C. kyllingia*, *Elaeocharis tetraquetra*, *Eriocaulon* sps., *Fimbristylis dichotoma*, *F. miliacea*, *Juncus bufonius* and *Scirpus lateriflorus* and *Typha spp*
3. **Climbers:** *Momordica dioica*, *Vicia sativa* and *Vigna vexillata*.

Within the grassland, small pools of water are present that provides optimum habitat for the swamp deer. Main hydrophytes include *Ceratophyllum demersum*, *Hydrilla verticillata*, *Hygrophila polysperma*, *Ludwigia adscendens*, *Monochoria* sps., *Najas graminea*, *Nymphoides cristata*, *Potamogeton crispus*, *P. nodosus*, *Sagittaria trifolia*, *Typha angustifolia*, *T. elephantina*, and *Utricularia* sps. The pteridophyte reported is *Equisetum ramosissimum*.

Scondary scrub: These are present at the edge of swamp and being wet most of the time are unsuitable for the bigger trees to grow. Common shrubs include *Lantana camara* and *Rubus ellipticus* and the major grasses include *Apluda mutica*, *Chrysopogon fulvus*, *Cymbopogon* sps., and *Cynoglossum* sps.. The herbs in the area include *Cannabis sativa*, *Desmodium gangeticum*, *Medicago lupulina*, *Solanum viarum*, *Uraria rufescens*, *Urena lobata*, and *Viola betonicifolia* that are found along with climbers such as *Coccinia grandis* and pteridophytes. The tree species found in the area are *Acacia nilotica*, *Broussonetia papyrifera*, *Psidium guajava*, and *Zizyphus mauritiana*.

Fauna

Jhilmil Jheel area represents a typical *Terai* habitat and supports a rich array of faunal diversity that include tiger (*Panthera tigris*), common leopard (*Panthera pardus*) and sloth bear (*Melursus ursinus*) along with smaller carnivores like Jackal (*Canis aureus*), Jungle cat (*Felis chaus*), Small Indian Civet (*Viverricula indica*) and Grey Mongoose (*Herpestes edwardsii*), etc. Herbivore species found are Swamp deer (*Rucervus duvaucelii duvauceli*), Sambar (*Cervus unicolor*), spotted deer (*Axis axis*), Nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*) and Asian elephant (*Elephas maximus*). Rhesus macaque (*Macaca mulatta*)

and common langur (*Semnopithecus entellus*) are also present. Amongst reptiles Indian Python (*Python molurus*), Common krait (*Bungarus caeruleus*), Indian cobra (*Naja naja*), checkered keel back (*Xenochrophis piscator*), and the Monitor lizard (*Varanus bengalensis*) have been reported along with while six species of tortoises and two species of turtles and more than 260 species of recorded birds in the area.

3.2 Kishanpur Wildlife Sanctuary

Another area selected for the study was the Jadi Tal (JT) located in the Kishanpur Wildlife Sanctuary (KWS) (28 27' N and 80 22' E) (227 km^2) of the Dudhwa Tiger reserve as it holds a considerable population of Swamp deer. The area (JT) is typical of the woodland-grassland-wetland complex with characteristic of the Terai ecosystem and is located on the floodplain of the Sharda River, which forms the northern border of KWS is characterized by tall grasslands that provide an excellent habitat for swamp deer.

The intensive study area II (JT) is a saucer shaped wetland situated on the left bank of River Sharda between E 28^0 23' to 28^0 24' and N 80^0 25' to 80^0 27' covering an area of 2.1 Sq Kilometers and with a perimeter of 5.416 Kilometers and elevation of 165 meters above mean sea level. The lake present in the JT is the main source of the diverse habitats of Kishanpur Wildlife Sanctuary. The study area comprises open grassland along with light woody trees of riverine habitat. The lake emerges from inundation of flood water received from Sharda River every year. Geologically, the area falls under Gangetic plains. Almost every year flood waters bring substantial amounts of silt, which is deposited in floodplain grasslands as well as in the adjacent forests. The area has a climate similar to that of JJCR. The faunal and floral diversity in the area is also similar to that of JJCR.

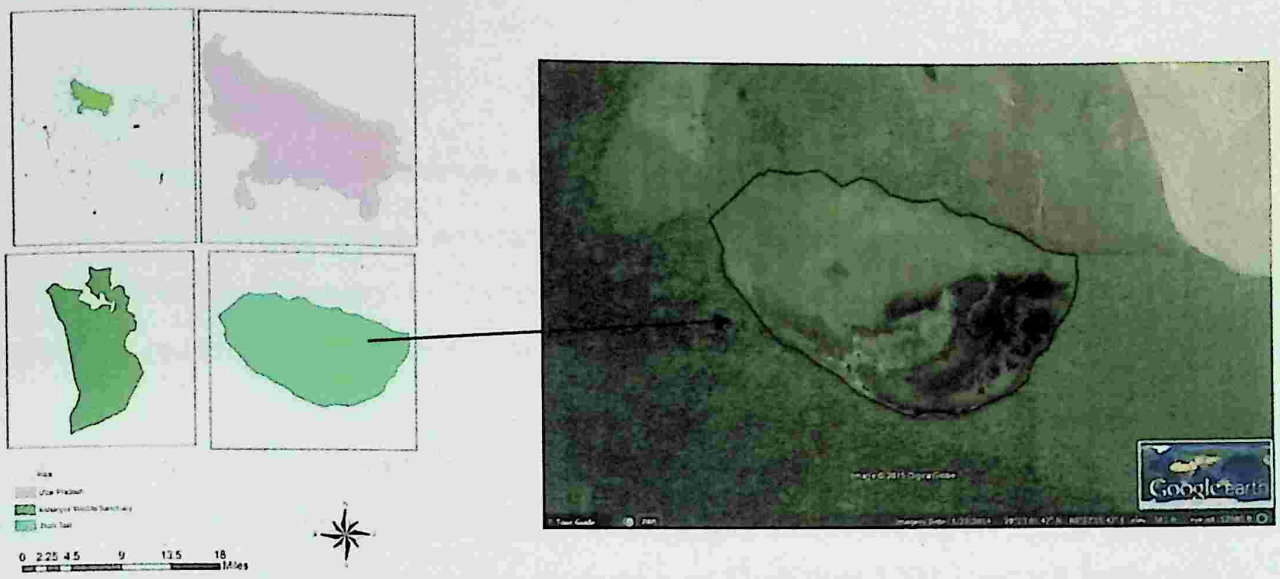


Plate 3.2: Intensive study area Jhadi Tal (JT) within the Kishanpur Wildlife Sanctuary, Dudhwa Tiger Reserve, Uttar Pradesh

3.3 STUDY PERIOD

This study was conducted between December 2014 and March 2015 with study at JJ during December, 2014 to January 2015 and at JT between February and March 2015.

4. METHODOLOGY

4.1 Rapid Reconnaissance Survey and selection of Intensive study area

The rapid reconnaissance survey was carried out at Jhilmil Jheel Conservation Reserve and Kishanpur Wildlife Sanctuary to identify the intensive study area based on presence of swamp deer and probable interaction with livestock.

For the intensive study, Jhilmil Jheel area (JJ) of Jhilmil Jheel Conservation Reserve, and Jhadi Tal (JT) of Kishanpur Wildlife Sanctuary were selected. Jhilmil Jheel is considered as an area with high swamp deer-livestock interaction as More than 1300 livestock have been reported to use Jhilmil Jheel Conservation Reserve on a daily basis (Tewari *et al.* 2011). Jhadi Tal of Kishanpur Wildlife Sactuary on the other hand, is assumed to have minimal interaction between swamp deer and livestock as human settlement is present only in north-eastern side and the western side is bounded by Kheri Branch canal of the Sharada canal system (Midha, 2008).

4.2 Population Abundance

Data on population structure of Swamp deer was collected through direct observations as described by Tewari (2009) and Khan *et al.* (2015). Repeated total counts were carried out on daily basis (n=36 for Jhilmil Jheel and n=15 for Jhadi Tal) to determine abundance of population of various ungulate species present at the area. The abundance was done from suitable vantage points and maximum number observed was recorded separately based on sex and age (adults/sub-adults). High power binoculars (10X50) were used to count animals in herd. Individuals in the group were classified into different age and sex classes based on direct count. The classification of groups as adult and sub adult during study period was based on Martin (1977) with appropriate modifications as 5 and above brow tines on backside pair of antlers for Adult male, 2-3 brow tines on backside pair of antlers for Sub adult male, bulky and shaggy abdomen for Adult female and two third the size of adult female for Sub adult female. The data collected were entered and analyzed using MS excel to calculate the total number of individual at each site. Similarly the livestock populations using the area were also counted.

4.3 Space use by swamp deer, livestock and sympatric herbivores

Swamp deer, livestock as well as other sympatric herbivores were sampled assuming their distribution to follow a random Poisson process (Pielou, 1969). For estimation of area use by particular species, grids of 20X20 = 400 meters cells were utilized to overcome potential biases of small sample size on parameter estimates. Grids were laid on ArcMap ver. 10.2 and all grids were searched for presence of indirect signs for dung/ pellet as well as sign of hoofmarks for swamp deer, livestock as well as for other sympatric herbivores (Fig. 4.1).

Figure 4.1: Grid Map for space utilized at (A) Jhilmil Jheel and (B) Jhadi Tal

Two observers were involved in the operation to overcome error in detection of signs for presence/absence of ungulate. For Jhadi Tal, the area submerged with water was not considered for indirect sign survey as it is not possible to get indirect presence signs of pellet/ dung for submerged area. The indirect signs detected were recorded for each grid as 0 for absence and 1 for presence in MS Excel sheet. Additionally, for each grid, GPS co-ordinates were also recorded.

4.4 Study level of Interaction

The area used by Swamp deer, conspecifics and domestic livestock was plotted on the grids, laid on ArcMap ver. 10.2 and the overlapping of areas utilized by Swamp deer and livestock were also mapped.

4.5 Coprological examination:

4.5.1 Sample size

Fresh pellet samples were collected by random sampling without disturbing the animals; by waiting for the swamp deer herd to vacate the area at both the study sites. Simultaneously, random sampling was also performed to collect dung samples from livestock in both the study areas. Based on previous population estimates of 320 (Tewari and Rawat, 2013) and 400 (Midha and Mathur, 2010) swamp deer individuals at JJ and JT respectively (Tewari *et al.*, 2013).

The sample size was calculated according to Thrusfield (1986) by considering 20% expected prevalence and 5% accepted error at 95% confidence interval using this formula: N=1.962 *Pexp (1 - Pexp)/ d2; where, N=required sample; Pexp=expected prevalence; d=desired absolute precision. A total of 246 swamp deer were selected by simple random sampling method. 20% of livestock population was sampled at each site to assess the parasitic prevalence based on similar study carried by Buagale *et al.*, 2014. The inter-sample distance was maintained at 50 cm distance, to ensure unique individual sample (Boagale *et al.*, 2014).

To determine the effective sample size for parasitic infection/ disease, the species accumulation curve (Kenneth, *et al.*, 1975) was drawn by plotting number of parasite present against number of total sample collected for each study species for each study area. Randomization for the collected data were done on MS excel followed by counting number of parasite species present for each 5 samples.

4.5.2 Biological sample collection, preservation and laboratory analysis

Before collection, pellets were visually assessed for the consistency and appearance (plate 5.3). Fresh pellet/dung samples were collected and preserved in 10% formaldehyde and subjected to laboratory examination to assess the parasitic infection. Dung samples were

observed qualitatively for consistency, color, odor, presence of mucous, blood and parasite segments and observations made for each sample were recorded. For qualitative and quantitative analysis of parasitic load, fresh faecal samples weighing 20 gm to 30 gms were collected in sample collection vials. The samples were preserved in 10% formalin saline and appropriately labeled till further examination. Coprological examination included both qualitative test employing floatation and sedimentation techniques and quantitative test employing Modified Mc master technique to assess the Egg per gram (EPG) of dung as described by Soulsby, 1982.

4.5.2.1 Qualitative test

The flotation method is a qualitative test for the detection of nematode and cestode eggs and coccidia oocysts in the faeces. It is based on the separating of eggs from faecal material and concentrating them by means of a flotation fluid with an appropriate specific gravity (saturated sugar like Sheather's sugar solution or salt solution with a specific gravity of 1.2-1.25). The procedure involves triturating 3-4 pellets in mortar with a little volume of water using a pestle and sieving into a narrow cylindrical tube that is allowed to stand for 5 -10 minutes. After discarding the supernatant, the sediments were suspended again in floatation fluid (Sheather's sugar solution) and centrifuged at 2000 rpm for 2 minutes. After discarding the supernatant, the sediments were suspended again in Sheather's sugar solution (454 g granulated sugar +355 ml tap water+ 6ml full- strength (37%) formaldehyde).The tube is covered with a cover slip taking due care to avoid air bubble. The centrifuge tube is centrifuged at 2000 rpm for 2 minutes and the cover slip carefully removed and placed over a microslide, to be observed under microscope at 10 X and 40 X for detection of parasitic ova.

The sedimentation technique (Formol-ether concentration method) is for detecting trematode eggs in the faeces as most of the trematode eggs are relatively large and heavy compared to nematode eggs. This technique concentrates trematode eggs in sediment. Procedure involves emulsifying 1g of dung pellets in 7ml of 10% formol-saline and keeping it for 10 minutes to facilitate fixation. It is then strained through a sieve. The filtrate is added to 3 ml of ether and centrifuged at 2000 rpm for 2 minutes. The supernatant is discarded (pipette, decant) very carefully. The sediment is transferred to a microslide and covered with a cover slip and observed under microscope under 4X and 10 X.

4.5.2.2 Quantitative test

The McMaster counting technique was the quantitative technique is used in the coprological study to determine the number of eggs present per gram of faeces (e.p.g.) in each parasite positive sample. Flotation fluid (Sheather's sugar solution- 454 g granulated sugar +355 ml tap water+ 6ml full- strength (37%) formaldehyde)) is used to separate eggs from faecal material in McMaster counting chamber with two compartments. After weighing 4 g of faeces, the sample is placed into a cylindrical container having a narrow mouth and 56 ml of floatation fluid is added. The content is mixed thoroughly with a stirring device. The faecal suspension is then strained through a strainer to another container. While stirring a sub-sample of is taken with a Pasteur pipette and both side of the McMaster counting chamber are filled. It is then allowed to stand for 5 minutes and later examined under microscope at 10 X 10 magnifications.

Eggs found within the engraved area of both chambers are identified and counted. The number of eggs within grid of each chamber is counted, and those outside the squares are ignored. The total is multiplied by 200 for nematode and cestode (Soulsby, 1986) and multiplied by 50 or trematode (Shrivastava et al, 2004), which gives the eggs per gram of faeces.

EPG of 300 and above was considered as significant load in the population (Soulsby, 1986).

4.5.6 Identification of Eggs:

The identification of parasitic ova was based on morphological studies as described by Soulsby (1982). Assistance from experts at Centre for Wildlife Forensic and Health, Nanaji Deshmukh Veterinary Science University, Jabalpur were taken for confirmations of the parasitic ova detections.

Parasite egg identification based on Soulsby, (1982) and other keys (Table. 4.1)

Table 4.1: Different parasites eggs identification keys (Salawu)

Parasitic ova	Identifying features
Ova of Trematodes	The eggs of different species of trematode vary in thickness; their colors may vary from yellow, to a dark brown. The digenean egg is usually operculate, in common with other platyhelminthes. Exceptions to this may occur however, the most important being with the schistosomes as the eggs are non-operculate, and are ornamented with spines.
Ova of Nematode	Doubled layer, uniform border, presence of morula is the key identification for egg detection of nematode eggs.
Ova of Cestode	Two types of larval form namely the Cestodarians and the Eucestodes The cestodarians larvae or lycophore are free swimming, being covered in cillia. They have a set of ten hooks at the extreme anterior of the body, thus differing from the larval eucestodes, which are equiped with 3 pairs of hooks. Anteriorly they are armed with penetration glands. The bodily form of these larvae bears a marked resemblance to the larvae of the trematodes, such as the miracidium in the digeneans, and the larval monogenean, the oncomiracidium between the two major groups of platyhelminth parasites. In contrast, the egg of the cyclophyllideans tapeworms is very different, having a very thick, resistant egg shell, with no operculum.

4.6 Assessing the prevalence percentage

Prevalence of Parasitic infection was calculated in the Swamp deer and livestock population as the number of individuals infected in the total individuals sampled in a given area and calculated as follows (Thrusfield, 1986):

Prevalence percentage = (Number of positive sample (Individuals)/Number of samples tested) X 100.

The species wise parasitic prevalence in total Swamp deer and livestock population was derived as follows:

Species-wise parasitic prevalence = (Individuals infected with particular parasite/Total positive sample) X 100.

4.7 Egg per gram analysis:

As described by Soulsby (1986) and Shrivastav (2004) parasitic load was counted as egg per gram (EPG). For that the McMaster egg count for positive samples were multiplied with 200 for nematode and cestode, and by 50 for trematodes Later, average mean EPG was calculated for each study species at both study area. Significant difference between the average parasitic load of swamp deer in between the Swamp deer population of Jhilmil Jheel and Jhadi Tal was tested using Mann-Whitney U test by software SPSS (SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc).

5. RESULTS

The present study is an attempt at assess the prevalence of endo-parasites in swamp deer and livestock including studying the probable role of livestock diseases at the Swamp deer-livestock interface.

5.1 Population abundance

In study site I (JJ), the number of individuals of swamp deer encountered varied from 3-151 (82.83±11.82, 95% CI). The maximum number of individuals of male, female, sub-adult and fawn during the study period was given in table 5.1. Subsequently in study site II (JT) number of individuals of swamp deer encountered varied from 115-419 (195.37±42.45, 95% CI) (Table 5.1).

In study site I (JJ), the number of individuals of livestock encountered varied from 24-83 (55.25 ±10.92, 95% CI). The maximum number of individuals of Cattle, buffalo and calves, during the study period was given in table 5.1. Subsequently in study site II (JT) number of individuals of livestock encountered varied from 5-35 (21.25±5.58, 95% CI).

Table 5.1 Maximum Swamp deer and livestock count at JJ and JT during the study period

Area	Swamp Deer				Livestock			
	Male	Female	Sub-adult/ fawn	Total	Cattle	Buffalo	Calves	Total
Jhilmil Jheel	29	72	52	153	39	32	13	84
Jhadi Tal	65	180	190	435	4	26	5	35

Previous record provide an estimate of 320 and 1300 swamp deer and livestock in Jhilmil Jheel Conservation Reserve (Tewari, 2009) and 400 swamp deer in JT with no estimate of livestock. Informal interaction (personal interviews) with the villagers revealed an estimated livestock population in the intensive study area to be 534.

5.2 Species diversity and space use by swamp deer, livestock and sympatric herbivores at the study sites

Sympatric wild herbivores coexisting with swamp deer at JJ were Chital, wild pig, sambar, nilgai and elephant that utilized 37.67%, 15.42%, 1.18%, 0.09% and 0.02% of the total space respectively. At Jhadi Tal, Chital, wild pig, hog deer and nilgai shared 12%, 32.21%, 16.5% and 0.08% of the area respectively with swamp deer. Detailed area occupancy by different herbivore species at Jhilmil Jheel is presented in figure 5.1 and at Jhadi Tal is presented in figure 5.2.

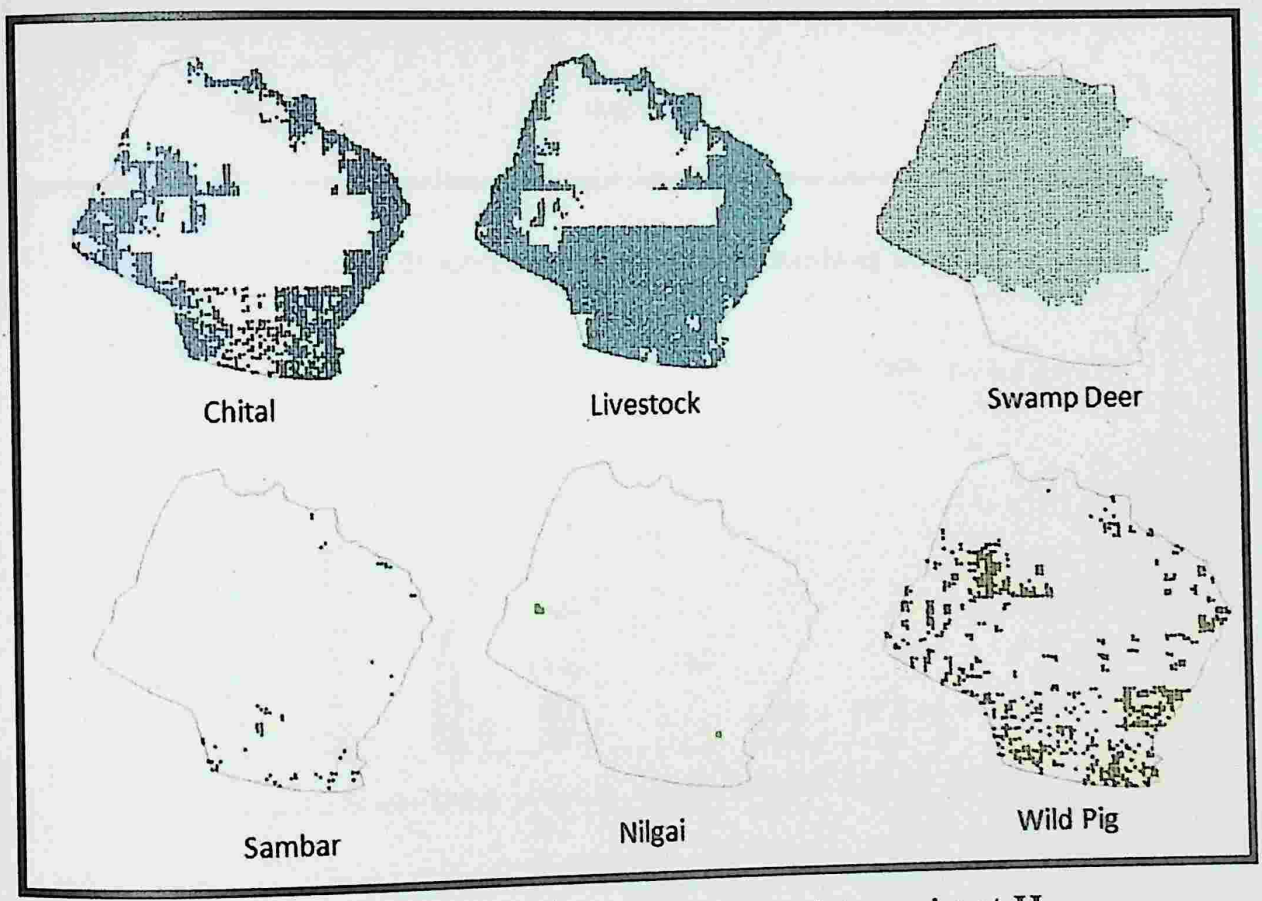


Plate.5.1: Area use map by different ungulate species at JJ

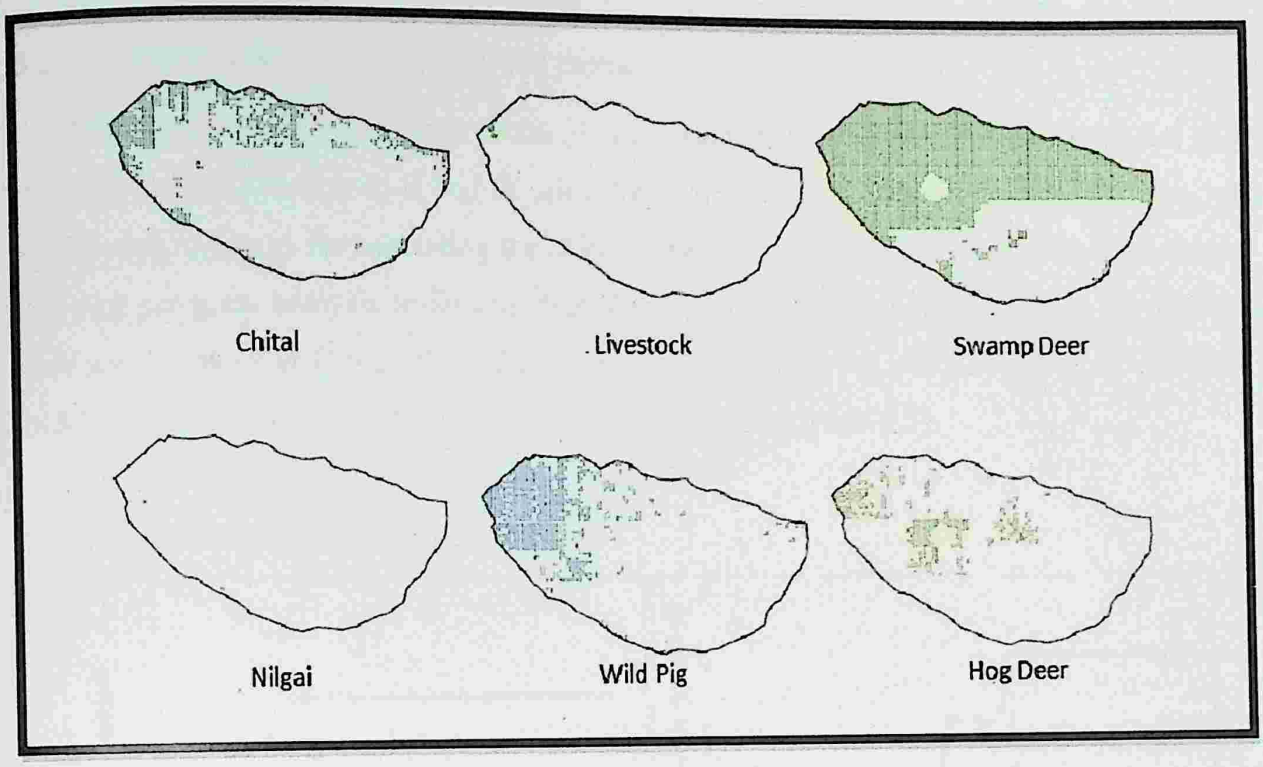


Plate 5.2: Area use map by other ungulates at JT

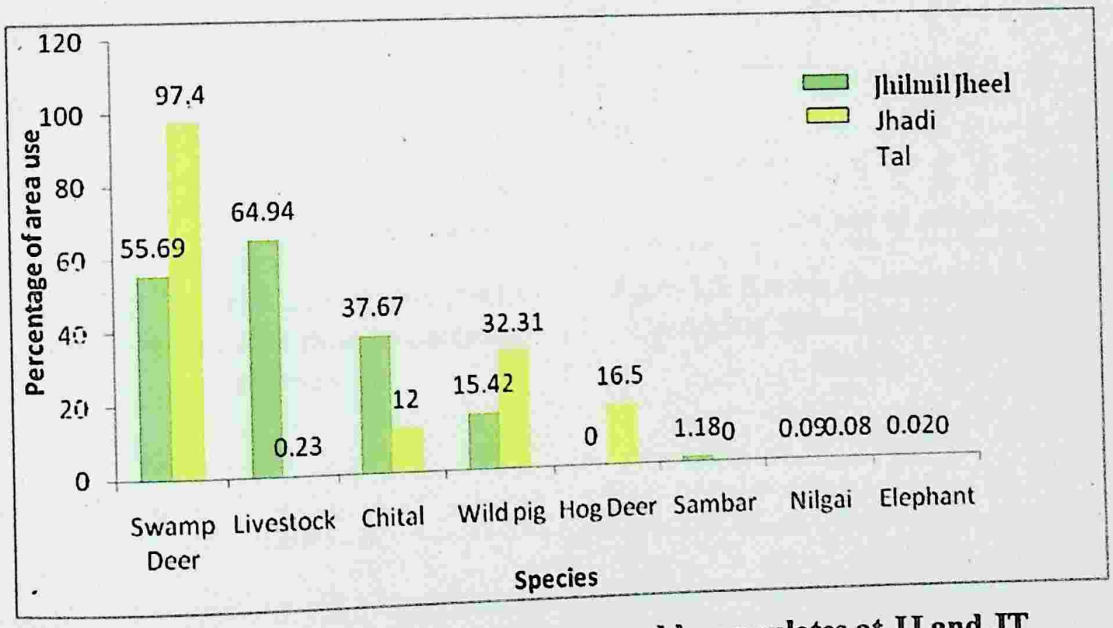


Figure 5.1: Percentage of area used by ungulates at JJ and JT

The space use pattern for various ungulate species found shows that Swamp deer use 55.69% of the total area of Jhilmil Jheel and 97.4% of Jhadi Tal. For livestock the area use for Jhilmil Jheel was 64.94% and 0.23% for Jhadi Tal. The area use of chital, wild pig, sambar, nilgai and elephant at Jhilmil Jheel was 37.67%, 15.42%, 1.18%, 0.09% and 0.02% respectively. The area use for chital, wild pig, hog deer and nilgai at Jhadi Tal was 12%, 16.5%, and 0.08% respectively.

5.3 Parasitic Species accumulation curve

As discussed in the methodology, a total of 260 swamp deer samples at each location and 240 and 105 livestock sample at JJ and JT respectively were screed for parasitic presence. Species accumulation curves for estimating the effective sample size needed for assessing prevalence and egg per gram analysis in Swamp deer showed that the effective sample size for swamp deer and livestock at JJ was 75 and 140 respectively (Figure 5.2 and 5.3) and at JT was 185 and 50 for swamp deer and livestock respectively (Figure 5.4 and 5.5).

5.3.1. Jhilmil Jheel Conservation Reserve

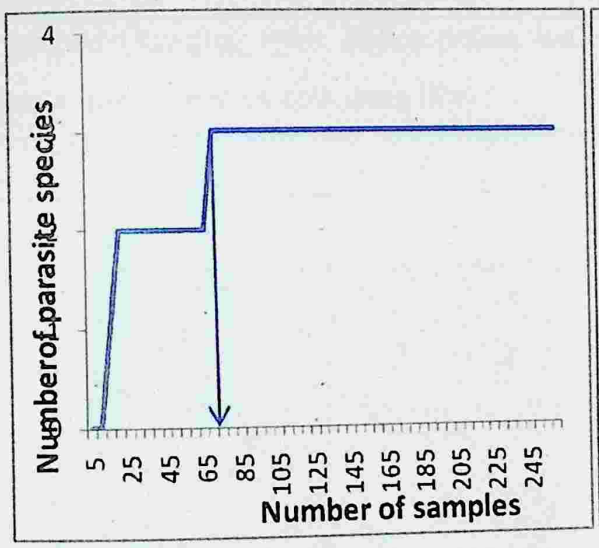


Figure 5.2: Species accumulation curve for swamp deer at Jhilmil Jheel Conservation Reserve

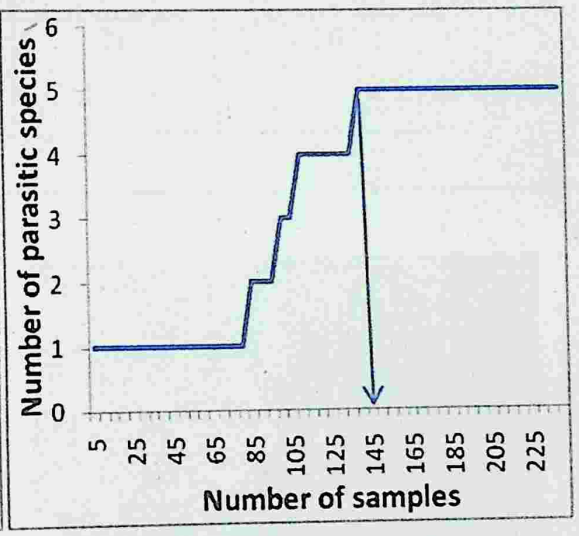


Figure 5.3: Species accumulation curve for livestock at Jhilmil Jheel Conservation Reserve

5.3.2. Jhadi Tal

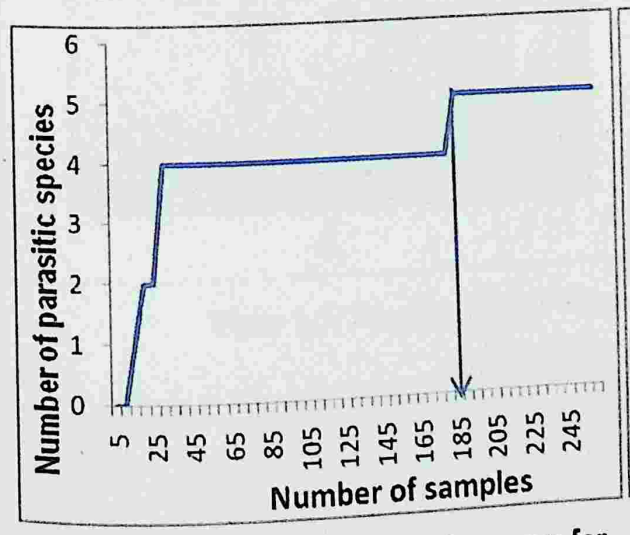


Figure 5.4: Species accumulation curve for swamp deer at Kishanpur Wildlife Sanctuary

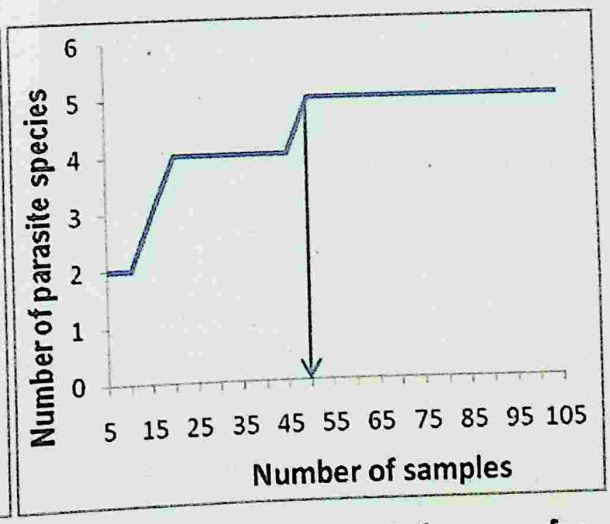


Figure 5.5: Species accumulation curve for livestock at Kishanpur Wildlife Sanctuary

5.4 Results of coprological examination:

5.4.1 Dung attributes

Based on consistency, the samples were categorized into normal, clumped and semi solid pellets as tabulated in table 5.2. Analysis of these samples revealed dung consistency to be associated with parasitic presence in the individual.

Table 5.2: Consistency of pellet samples of Swamp Deer

Consistency	Jhilmil Jheel	Jhadi Tal
Normal (individual pellets, well formed and shiny)	239	230
Clumped (Ranging from Sticky pellets with excess mucus or even cow dung like)	21	30

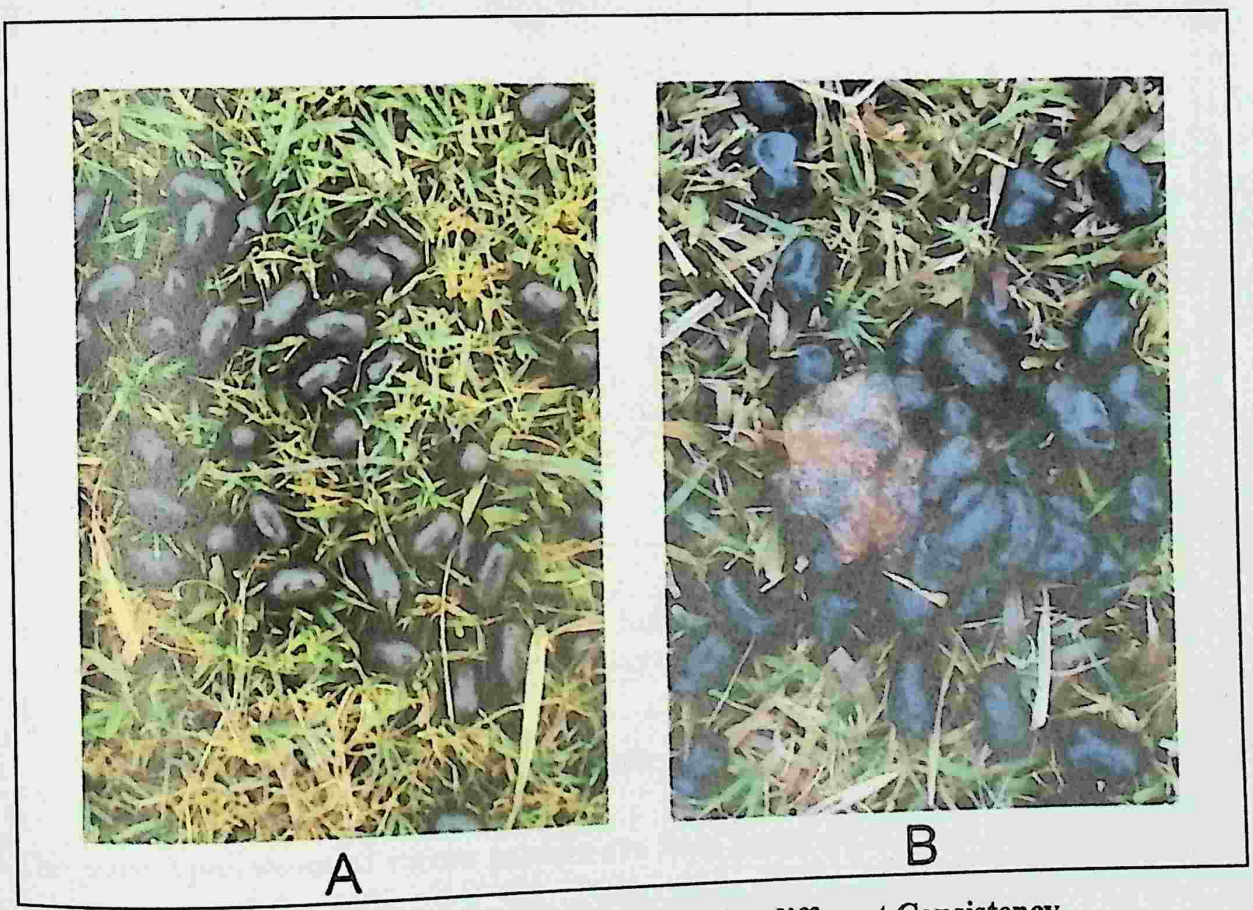


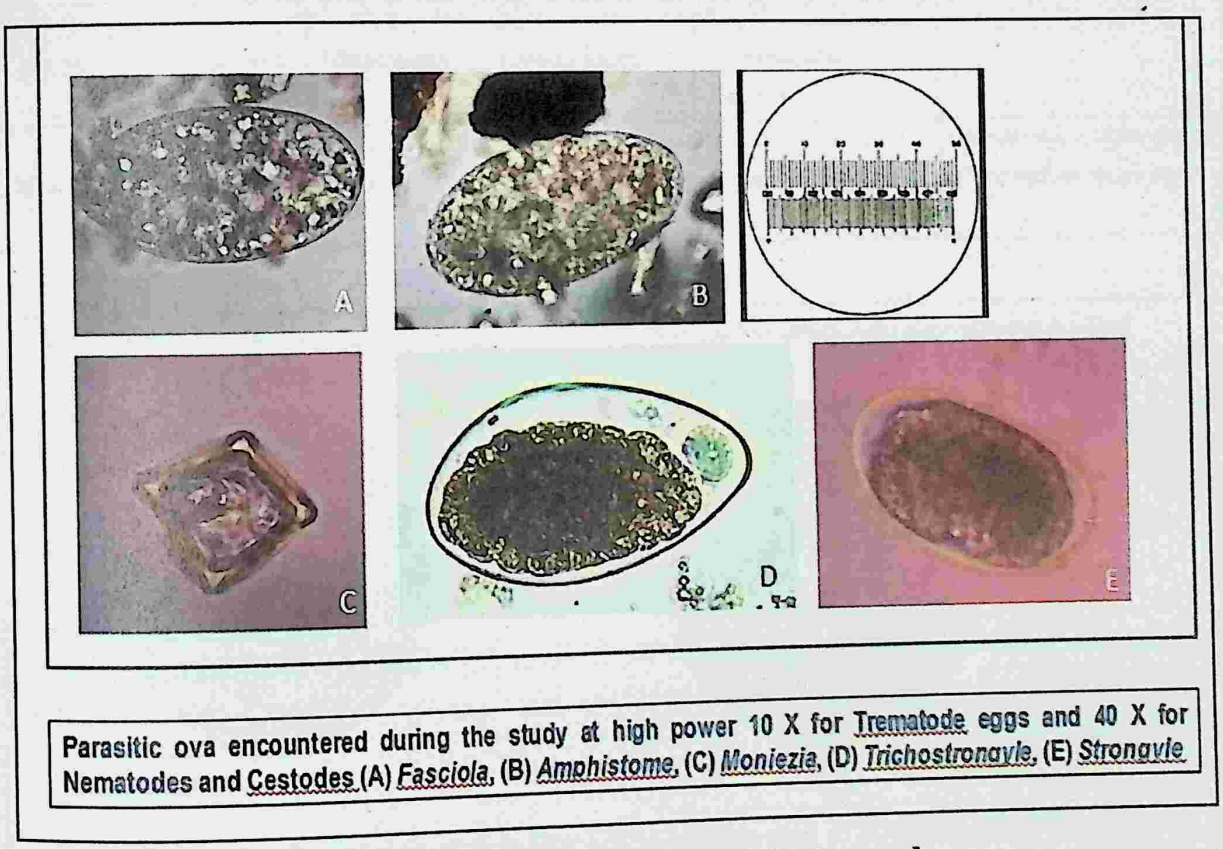
Plate 5.3: Swamp Deer Pellets showing different Consistency

A. Normal, B. Clumped

5.4 .2 Parasitic prevalence of swamp deer

Of the total samples collected and screened for parasitic ova, the overall prevalence of parasitic ova in the swamp deer population at JJ and JT was 15.38% and 12.69% respectively whereas the overall parasitic prevalence in livestock population at JJ and JT was 95.41 % and 60 % respectively.

Based on the laboratory analysis using standard protocols of floatation and sedimentation methods, presence of nematode, trematodes, and cestodes were confirmed and identified based on morphological attributes and classified as parasitic ova belonging to *Strongyle*, *Trichostrongyle*, *Moniezia*, *Fasciola* and *Amphistome*. (Plate 5.4)



Parasitic ova encountered during the study at high power 10 X for Trematode eggs and 40 X for Nematodes and Cestodes (A) *Fasciola*, (B) *Amphistome*, (C) *Moniezia*, (D) *Trichostrongyle*, (E) *Strongyle*

Plate 5.4 Parasitic genera found during study

The percent prevalence of various parasite ova from samples that tested positive for parasite presence was calculated for both species and the details are provided below.

The life cycle, infective stage, incubation period, intermediate and probable species under each genus are provided as Table 5.5.

Table.5.3 Attributes of parasite genera encountered in the study

Parasitic ova based on morphological attributes	Life cycle	Infective stage	Incubation period	Intermediate host	Probable Genus and species
Strongyle	Direct	Larval stage 3 (L3)	15-24 Days (Lowest temperature) 3 Days (Highest temperature)	Direct infection with Larva	*Haemonchus contortus* *Nematodirus battus* *Nematodirus filicollis* *Nimatodirus spathiger* *Cooperia curiticae*
Trichostrongyle	Indirect	Cysticercoides	4-7 Days	Oribatid mite	Trichostrongyle *vitrinus* *Trichostrongyle axei*
Moniezia	Indirect	Cysticercoides	4 Months	Oribatid mite	*Moneizia benedeni*
Fasciola	Indirect	Miracidium	10-12 Days	Snail (*Lymnaeidae* family)	*Fasciola hepatica*
Amphistome	Indirect	Metacercaria	12-21 Days	Snail (*Planorbis*, *Bulinus*, etc)	*Paramphistomum gotoi* *Paramphistomum cervi*

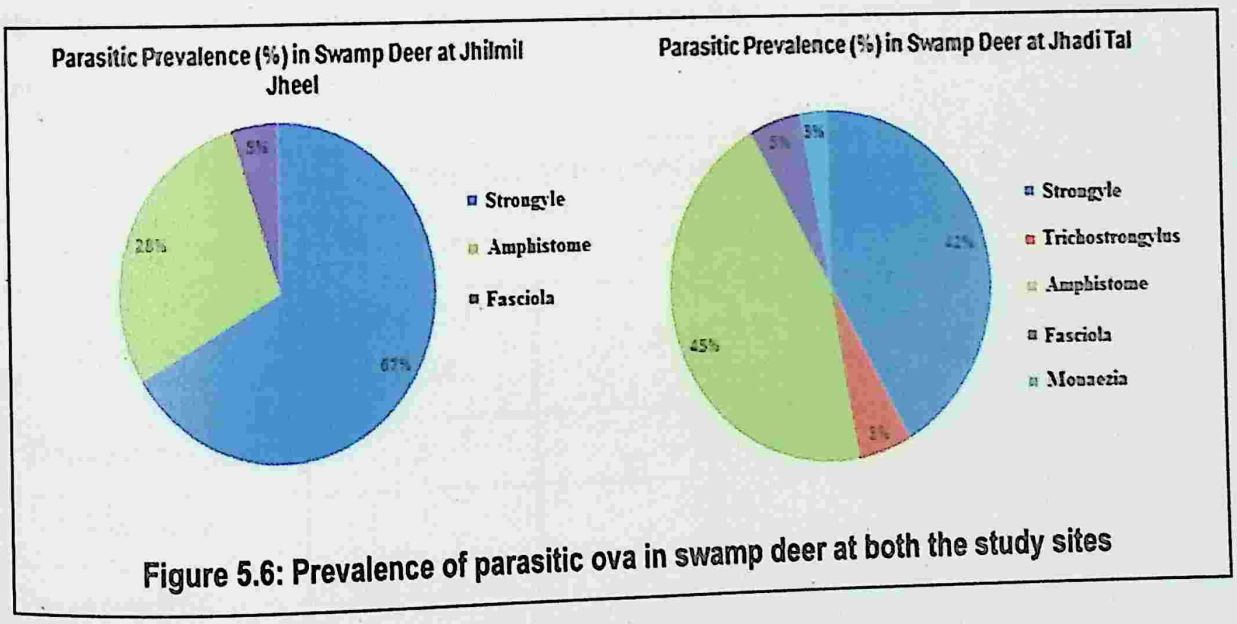


Figure 5.6: Prevalence of parasitic ova in swamp deer at both the study sites

In JJ, *Strongyle* group was the most prevalent parasitic ova (67%) followed by *Amphistomes* (28%) and *Fasciola* (5%). In JT, *Amphistome* was the most prevalent at 45%, followed by *strongyle* (45%), *Fasciola* (5%), *Monezia* (5%) and *Trichostrongyle* (3%). (Figure 5.6)

5.4.3 Swamp deer parasitic Load (Egg per Gram of dung pellets)

The load of different parasitic ova in the swamp deer population at both the sites is presented below;

***Strongyle*:** The mean EPG was 642.85 ± 33.10 and 544 ± 53.15 at Jhilmil Jheel for Jhadi Tal respectively. (Table 5.6)

***Trichostrongylus*:** Not present in Jhilmil Jheel but EPG for Jhadi Tal was 200 (only 1 sample is positive) (Table 5.6)

***Moniezia*:** Not present in Jhilmil Jheel but EPG for Jhadi Tal was 200 (only 1 sample is positive) (Table 5.6)

***Fasciola*:** The overall mean EPG was 100 ± 28.86 and 50 (only 1 sample is positive) at Jhilmil Jheel for Jhadi Tal respectively (Table 5.6)

***Amphistome*:** The mean EPG was 109.09 ± 6.09 and 96.87 ± 5.53 at Jhilmil Jheel for Jhadi Tal respectively. (Table 5.4)

Table. 5.4 Parasitic (EPG count per gram of dung) for Swamp deer of Jhilmil Jheel and Jhadi tal

	Eggs per gram (Median ± SE)	
Parasitic ova	Jhilmil Jheel	Jhadi Tal
Strongyle	642.85 ± 33.10	544 ± 53.15
Trichostrongylus	-	200
Moniezia	-	200
Fasciola	100 ± 28.86	50
Amphistome	109.09± 6.09	96.87 ± 5.53

The average parasitic load (egg per gram of dung) in Swamp deer of JJ and JT was 487.5± 46.30 and 363.64± 49.97 respectively. There was significant difference in median of parasitic load between two study sites (M-W test, Z=-3.082, p=0.002) Further, EPG also showed that

swamp deer population at Jhilmil Jheel had considerably higher parasitic load than swamp deer population at Jhadi Tal as depicted in Table 5.4.

Table 5.5: Details of single and mixed infection at JJ and JT for swamp deer

Species	Study Site	Samples with single parasitic ova %	Samples with mixed infection (> 1 parasitic species) (%)	Samples negative for presence of parasites (%)
Swamp deer	JJ (N=260)	14.62% (38)	0.77% (2)	84.62% (220)
	JT (N=260)	11.15% (29)	1.54% (4)	87.31% (227)

5.4.4 Parasitic prevalence for livestock

Livestock in JJ, had an overall parasitic prevalence of 95.41% with *Amphistome*, *Strongyle*, *Trichostrongyle*, *Moniezia*, and *Fasciola* ova amounting to 91%, 6%, 1%, 2%, 1% respectively whereas livestock samples from JT revealed the overall parasitic prevalence of 60% with *Strongyle*, *Trichostrongyle*, *Amphistome*, *Moniezia* and *Fasciola* accounting to 49%, 4%, 41%, 4% and 2% respectively (Figure 5.7).

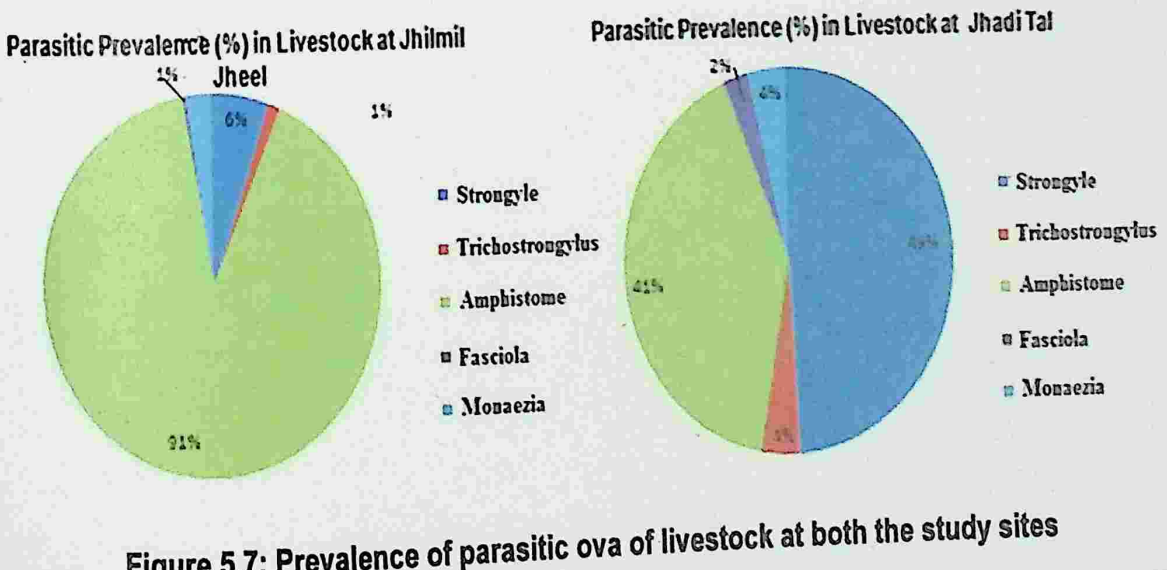


Figure 5.7: Prevalence of parasitic ova of livestock at both the study sites

Of the total number of dung samples screened for parasitic ova, 14.62% and 11.15% of the swamp deer population at JJ and JT had infection with single parasite while 0.77% and 1.54% had infection with multiple parasites. Eighty seven percent and 42.86% of livestock

harbored single infection whereas 8.33% and 17.14% had mixed infection at JJ and JT respectively (Table.5.6)

Table 5.6: Details of single and mixed infection at JJ and JT for livestock

Species	Study Site	Samples with single parasitic ova %	Samples with mixed infection (> 1 parasitic species) (%)	Samples negative for presence of parasites (%)
Livestock	JJ (N=240)	87.08% (209)	8.33% (20)	4.58% (11)
	JT (N=105)	42.86% (45)	17.14% (18)	40% (42)

5.4.4 Interaction

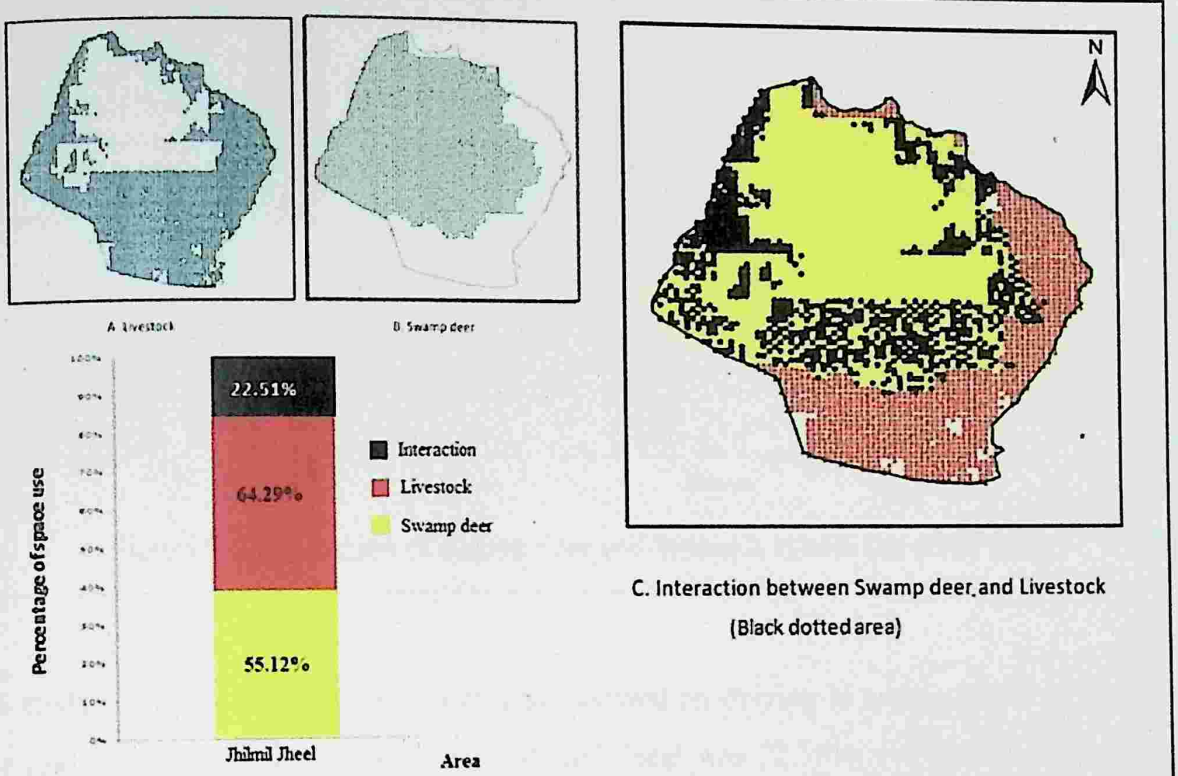


Plate 5.5 Swamp deer- livestock interaction at Jhilmil Jheel

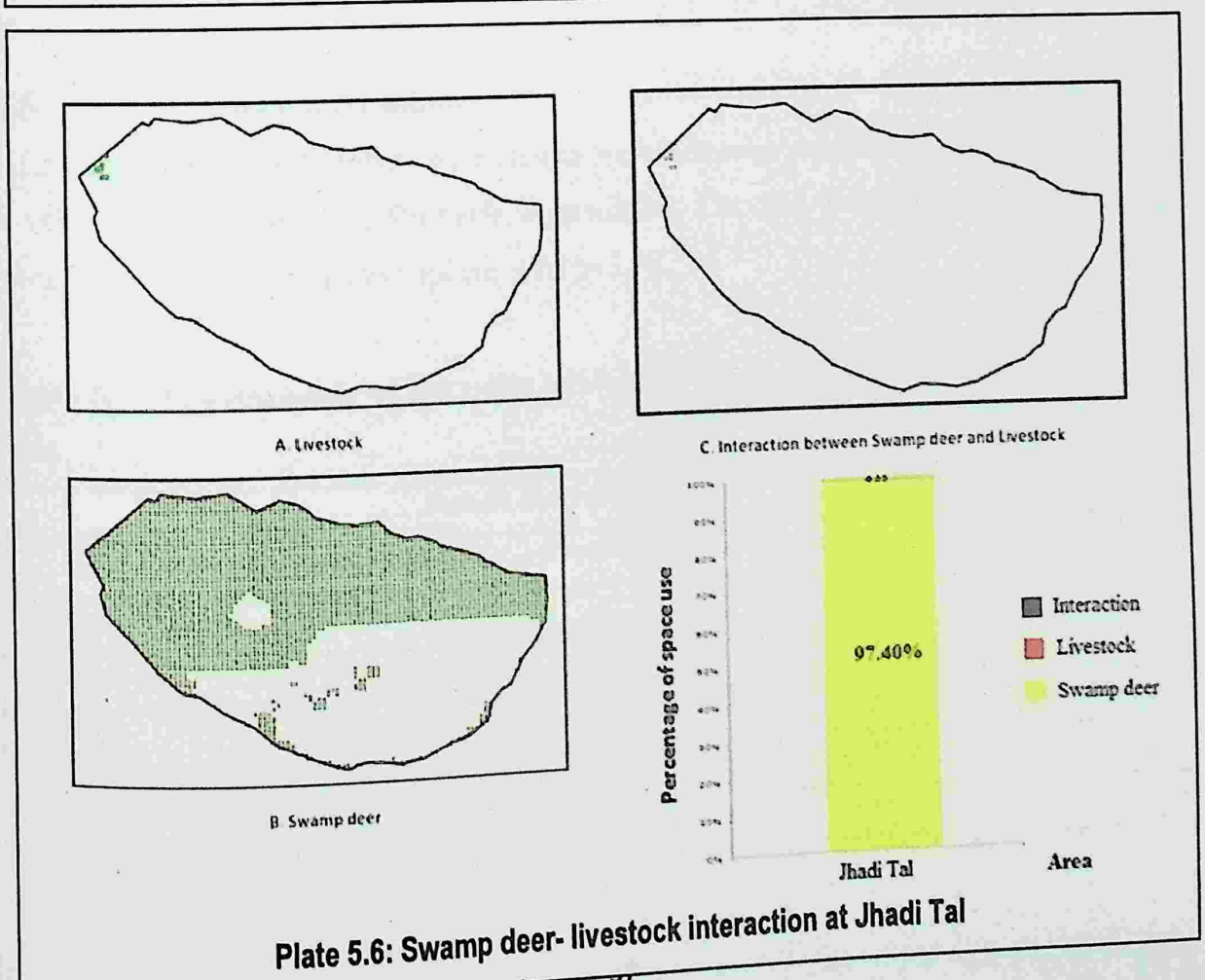


Plate 5.6: Swamp deer- livestock interaction at Jhadi Tal

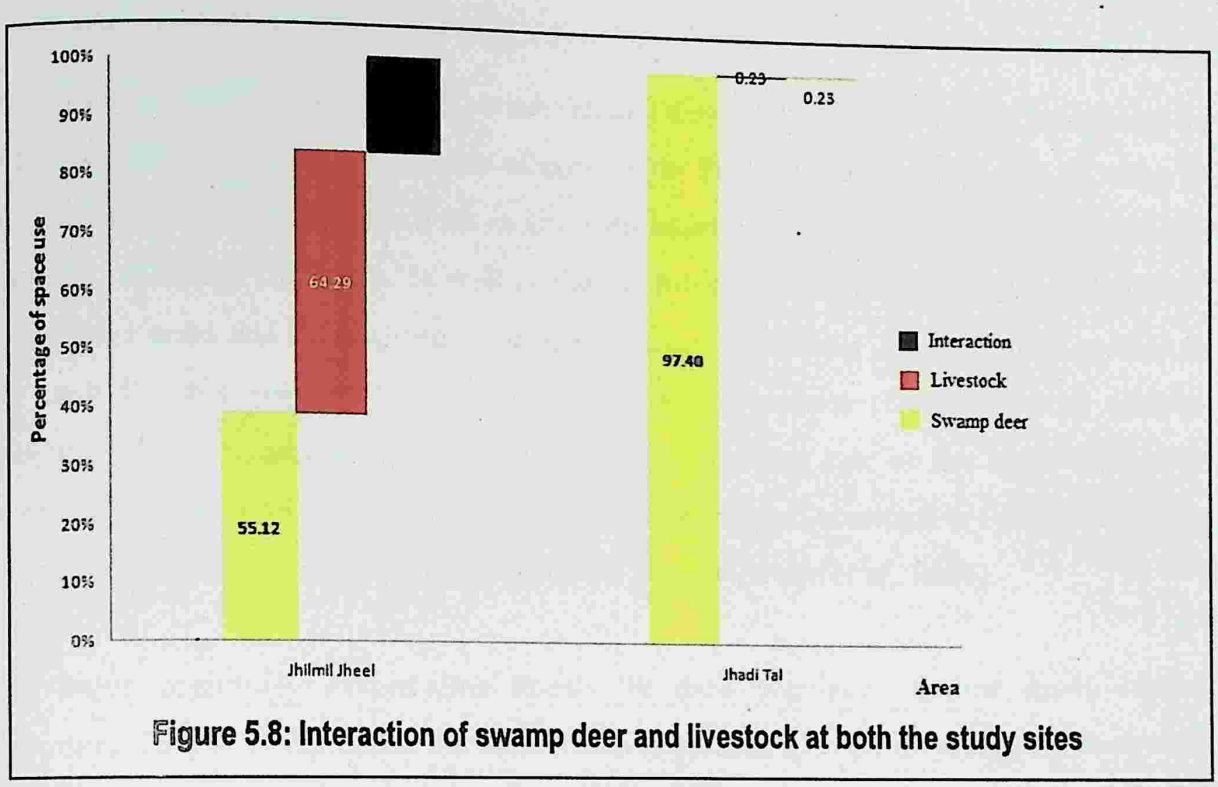


Figure 5.8: Interaction of swamp deer and livestock at both the study sites

The study of space use pattern at both sites showed an overlap in areas utilized by Swamp deer and livestock. The overlap area at Jhilmil Jheel was 22.50% and limited overlap was seen at Jhadi Tal (0.13%) at as depicted in figure 5.8.

5.5 Commonality of parasites:

At JJ, *Strongyle*, *Amphistome* and *Fasciola* were common parasites between livestock and Swamp deer, whereas at JT, *Strongyle*, *Amphistome*, *Fasciola*, *Trichostrongyle* and *Moniezia* were common between the two species (Table 5.7).

Table 5.7; Commonality of Parasites between livestock and swamp deer at both study sites

Parasite ova	Jhilmil Jheel (JJ)		Jhadi Tal(JT)	
	Swamp Deer	Livestock	Swamp deer	Livestock
Stongyle	+	+	+	+
Amphistome	+	+	+	+
Fasciola	+	+	+	+
Trichostrongylus	-	+	+	+
Moniezia	-	+	+	+

6. DISCUSSION

Cervids are integral components of varied habitats they inhibit and are widely considered to be functionally important components of ecosystem. This belief is based largely on what is known about their direct interactions as key facilitators by acting as a link between primary producers and apex carnivores as well as their indirect interactions, both as key consumers within food webs and as "engineers" of habitat structure. Swamp deer, the study species is one such flagship species. Long term survival of this species is threatened by various anthropogenic pressures (Tiwari, 2009). Additionally, being one of the most vulnerable species of deer from the Indian subcontinent, with distribution restricted to isolated localities in north and central India and parts southwestern Nepal (Qureshi *et al.*, 2004).

Any factor potentially exacerbating threats for their population decline needs careful evaluation. This work represents the first structured parasitic prevalence study at Swamp deer livestock interface, from two of the eight prime locations (Jhilmil Jheel Conservation reserve and Kishanpur Forest Division) reported for the northern population of swamp deer in India.

The species, by its habitat preference renders itself vulnerable to parasitic infections as these areas are also the preferred sites for livestock from nearby villages. Lack of informed management practices at these sites is one of the main causes for lack of veterinary care of non-descript livestock that is reared in the area. Minimal investment is made on these livestock; thereby raising the concerns on disease shared in-between livestock and wild populations in the vicinity. Perusal of available literature indicated few systematic studies on wildlife diseases and disorders for the species. Most such studies are restricted to reports on incidence of parasitic infection in either captive wild animals or on a small sample size of free ranging population. The present study is an attempt to establish a rationale on diversity and distribution of parasitic infections in Barasingha at population level. This study also looks at the presence of gastro-intestinal parasites in swamp deer and the livestock with particular focus on commonality of parasites, to evaluate their likely impact on conservation of the swamp deer.

Population estimation through direct observation at both sites showed divergent trends with a fairly good population at JT and lesser population at JJ compared to earlier reported population (Midha *et al.*, 2010 and Tiwari *et al.*, 2013). While the population decline; at JJ

has been primarily attributed to 2013 floods from river Ganga (Singh, H. K., Pers. Comm.) The Study was limited to winter months and proper assessments could be made had the study been of longer duration. During the initial days of study in Jhilmil Jheel only 3 swamp deer were observed which increased to the observed increased number of swamp deer as counted 153 and in Jhadi Tal also as the highest count as 419 and lowest count as 134. Systematic studies need to be carried out to ascertain the causes for this observed decline.

The high level of livestock- swamp deer interaction at JJ (22.5% of the area) compared to JT (0.13% of the area) may be attributed to human settlement located comparatively nearer to JJ (500 meters) than in JT (1.9 Km). It was also observed that area use by swamp deer was restricted to a small region in JJ. This may be attributed to the negative impact on these species by physical presence of livestock, as opined by Natalia *et al., 2014;* which may have altered their area use. In terms of space use, livestock share about 22.5% of the Swamp deer habitat in JJ. Whereas limited overlap (0.13%) has been reported from JT.

While parasitic ova encountered at Jhilmil Jheel were that of *Strongylus spp.*, *Amphistome* and *Fasciola*, whereas in Jhadi Tal *Strongylus spp.*, *Amphistome*, *Fasciola*, *Trichostrongylus spp.* and *Moniezia* were all common between two species. The richness of parasite in JT appears to be more as compared to that in JJ and may be attributed to the larger size and moist substrate for most of the year facilitating the proliferation and survival of intermediate host that are important to maintain the infection (Sousby, 1986).

Coprological examinations carried out in the study showed an overall prevalence of parasitc ova of 15% and 12% at JJ and JT respectively. Results though show only little differences in the parasitic prevalence percentage between population of swamp deer have been encountered; these may be attributed to the swamp deer of JT moving out in the human dominated landscapes during night (personal communication/ field survey) thereby picking up infection.

Even though the area of interaction at JT is low, the animals SD still have similar parasitic prevalence.

Though the parasitic prevalence reported in the present study has been low as compared to other studies on Barasingha in Kanha Tiger reserve (Shrivastav *et al.*, 2001) and in Kaziranga

(Chakraborty *et al.*, 1996), and may be attributed to sampling restricted to shorter period (winter months) with environmental conditions that limit survival of parasites outside the host. Study carried out by Shrivastav *et al*, 2004 revealed higher prevalence during rainy season. The present study revealed parasitic ova of *Strongylus*, *Trichostrongylus*, *Moniezia*, *Fasciola* and *Amphistome*, either as single infection or as mixed infections from both the sites. In JJ, parasites ova of *Strongylus* were prevalent in 67% of swamp deer population, being the most prevalent parasite in swamp deers, followed by *Amphistomes* (28%) and *Fasciola* (5%). In JT, *Amphistomes* (40%) was the most prevalent parasite, followed by *Strongylus* (45%), *Fasciola* (5%), *Monezia* (5%) and *Trichostrongylus* (3%). A study in Kanha Tiger Reserve on Swamp deer described similar results with *Strongylus spp.* to be maximum (98.71%) followed by *Amphistome* (88.65%), *Strongyloides* (32.21%), *Trichuris* (18.55%), *Monizia expansa* (11.85%), *Coccidia* (7.47%) and *Monizia benedeni* in Barasingha (4.63%) (Tiwari *et al.*2009). Both the areas have been reported to be used by livestock and chances of spillover of infection cannot be ruled out.

The parasitic ova observed in this study have been reported previously in swamp deer as well as sympatric herbivores from different areas across country (Chakraborty and Islam, 1996, Shrivastav et al., 2001, 2004, 2006). *Strongylus spp.* is among the most characteristic parasites of the gastrointestinal system of ruminants throughout the world. (Hoberg et al., 2001). The *Strongyle* ova hatch and moult into infective L3 larvae on pasture that have the ability to infect the host directly / indirectly. Moisture is critical for larval survival, and warmth speeds development to as little as 3 days. Interestingly, both JJ and JT provided favorable conditions with moist environment present across the habitat. This may have led to high prevalence of *Strongylus spp.* in present as well as earlier studies.

Amphistomiasis occurs wherever ruminants, planorbid snail population and metacercaria are concentrated in a small area. (Balaji *et al.*, 2013) The snails multiply rapidly in warm, wet environments and can also subsequently survive dry conditions. Moreover metacercaria stage of the Amphistomes cling/ climb up on the herbage in and around water sources that facilitates entry into the host (Radostits *et al.*, 2006). Both the study sites have water logged bodies, which are potential breeding grounds for these snails. Amphistomes was recorded to the extent of 20% and 40% at JJ and JT for swamp deer. Interestingly, the livestock sampled at JJ had very high prevalence of Amphistomes with 91.27% prevalence and livestock sampled at JT had just about 41% prevalence. The infection might have happened during the

last year and the eggs are being passed from mature worms. Hence, it is likely that livestock population in and around JJ may act as potential source for merozoites of Amphistomosis, that develop to infective metacercaria inside Planorbid snails.

A low prevalence of *Moniezia* was reported during the study. Though *Moniezia spp.* is one of the most common parasites in domestic animals they usually do not cause clinical disease except with heavy infections. Eggs passed in proglottid segments in feces are taken up by mites living on pasture. An intermediate stage develops in the mite over 4 months which matures to the adult tapeworm in the host after the mites are consumed during grazing. Very severe infections can cause intestinal obstruction predisposing to enterotoxemia and, potentially, intestinal rupture. However, a chance of development is very good as soil mites can be so numerous on a pasture that even if only 3% are infected (with 4-13 cysticercoids each), a grazing ruminant may ingest over 2,000 cysticercoids per kilogram of grass. Once inside the intestine of mites, the eggs hatch and the oncospheres penetrate into the haemocoel and develop to the cysticercoid stage (Stehman and Smith, 1995).

On a world-wide basis, *Fasciola* has been important fluke in deer as well as other sympatric herbivores. *Fasciola gigantica* among wild cervids and other herbivores of India has been reported from Swamp Deer by Verma *et al.* (1994) as well as Spotted Deer and Black Buck by Rao and Acharjyo (1969, 1972), and Indian Rhinoceros by Bhattacharjee and Haldar (1971). The epidemiology of *Fasciola* is dependent on temperature which controls the life cycle stages developing out of the mammalian host. The ecology of the lymnea (intermediate host) is also important as it requires calcareous substrates with lentic water, pH (some acid), presence of aquatic vegetation and a temperature between 15 and 22°C (Urquhart *et al.* 1996). It is assumed that wild hosts are not able to maintain populations of these flukes, without the presence of suitable domestic hosts (Pybus, 2001). Hence it can be inferred that domestic animals are definitely playing a key role in transmitting the parasite to swamp deer in both the regions exposing them to vegetation infected with metacercaria of *Fasciola*. Though the study revealed low prevalence of Fasciola infection in both swamp deer and livestock, the infection can result in serious consequences in the long run as snails of the Lymnaeidae family act as its intermediate host and both JJ and JT is potential area for the snail as well as infection. Additionally, maximum incidence of *Fasciola* is usually seen either in pre-winter, post-rainy season, when conditions are favorable for proliferation of snails (Choubisa, 2008).

Low prevalence observed in present study may be because of the winter season during which the study was carried out.

Results of the present study also correlate with the observations made by Shrivastav and co-workers (2001) in Kanha Tiger reserve with respect to commonality in the genus of parasites observed. However, prevalence percentage varied with *Strongyles* described at the rate of 98.71% to be maximal followed by *Amphistomes* (88.65%), *Strongyloides* (32.21%), *Trichuris* (18.55%), *Moniezia expansa* (11.85%), *Coccidia* (7.47%) and *Monizia benedeni* (4.63%) in Barasingha. The overall prevalence rate in Barasingha observed in study (15.28 in JJ and 12.69 in JT) is also much lesser compared to other studies where it was 51.03% in study by Srivastav and co-workers (2001) and 21.85% reported by Chakraborthy and Islam (1996) in Kaziranga National.

Higher parasitic prevalence and EPG recorded at JJ could be one of the limiting factors responsible for the declining trend in population. Although the swamp deer sampled in this study visibly appeared healthy, the high prevalence of some of the studied pathogens may have significant consequences for their population dynamics. Parasites are known to exhibit a correlation both in their numbers and in their effects with the physical condition of the host. This effect is most likely to be influenced by nutrition of the host, especially when it is largely determined by the availability of food and presence of competing species at the same area. Young animals, because of the demand on their nutritive intake for growth-are in a relatively poor position to withstand attacks by parasites and succumb to infection.

The study included an estimation of population size of swamp deer and livestock and understanding their space use patterns. The study provided an overview of the prevalent parasites between the wild and domestic animals at the wildlife-livestock interface limited to a grassland system. The parasitic infection in swamp deer and their co-inhabitant livestock appeared qualitatively and quantitatively parallel denoting the fact that the infection is being maintained in the environment through interaction between these animals. These parasitic infections may be exposing the swamp deer to a number of other diseases and may be one of the factors contributing to decline in their population. Even though the study was conducted only for a short period of time, it could highlight the presence of parasitic diseases at the interface. However, a detailed study encompassing all seasons would be effective in addressing the issue.

Though limited in scope, the study was instrumental in highlighting the necessity of a systematic approach for addressing an unexplored facet of factors limiting wildlife abundance and distribution. Results of the present study also suggest that the understanding of parasite prevalence and likelihood of disease events is poorly known for both sites. Similarities in the gastrointestinal parasites and the life histories of wild and domestic ruminants, coupled with a detailed knowledge of the ecology and life cycle of the parasites, render the host – parasitic system particularly amenable for a multi disciplinary assessment that can lead to an effective development of management interventions aimed at protection of cervids in their natural ecosystems.

7. MANAGEMENT IMPLICATIONS:

Though parasites alone rarely play major role in host extinction, these can contribute negatively when combined with other environmental factors and stressors (Wilcove et al., 1998). Following management practices can be considered to regulate the prevalence of any parasitic disease.

Intensive Livestock Management: The study revealed prevalence for parasitic diseases among livestock at Jhilmil Jheel and Jhadi Tal and therefore necessitated the need for developing effective management strategies to prevent and control spread of infection spreading to other species including Swamp deer. The interventions include a planned disease surveillance and management programme, ensuring proper scientific management of livestock and restricting movement of livestock to wild ungulate habitats through proper checks at entry points. This can be facilitated by promoting selective breeding of indigenous cattle having desirable attributes in lieu of the current practice of rearing large herds including unproductive animals that are left free to graze. This entails an extensive outreach program targeting human settlements in close proximity of Swamp deer habitat.

It is prudent to explore intensive management through habitat manipulation to address parasitic control strategies (Pienaar, 1967) including bio-control strategies (Terry, 2013). However to be effective, these methods requires a thorough knowledge of the ecology of the disease. Few specific examples are available of the successful use of this type of management for diseases of wildlife. Fire is a powerful tool for habitat manipulation and has been used occasionally in disease management

The issues raised in the present study merit further detailed investigation encompassing both parasitic and non-parasitic diseases for developing practices that effectively addresses their management and exchange at the domestic - wild ungulate interface.

8. REFERENCES

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