Parasites and parasitic diseases of the Indian elephant, mithun and yak: An overview

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Received: 27 March 2012; Accepted: 6 June 2012

ABSTRACT

The Indian elephant, mithun and yak are utility animals. Each of them is a valuable natural resource and important constituent of India's unique biodiversity. However, their numbers have declined and their existence is facing several challenges, of which a major one is parasites and diseases caused by them. While much of the information on the parasites of Indian elephant dates back to the pre-mechanization British era, the setting up of dedicated Research Centres on Mithun and Yak by the Indian Council of Agricultural Research, has resulted in generation of considerable research data and regular flow of information in recent years. The elephant is unique regarding most of its internal (and a few external) parasites not being shared with other livestock hosts. As per updated information, the Indian elephant is parasitized by 39 helminths, made up by 8 trematodes including the most pathogenic Fasciola jacksoni, 2 cestodes and 29 nematodes including 3 filariid worms; among protozoa, only Trypanosoma, Babesia and ciliates are known; arthropods include the stomach bot Cobboldia, the louse Haematomyzus and at least 4 genera of ticks. The mithun, being phylogenetically related to cattle, seems to share the same set of internal and external parasites. To date 12 nematode genera, 6 trematode genera and 2 cestodes have been recorded; protozoa comprised coccidia (8 Eimeria species identified so far), Giardia, Cryptosporidium and Balantidium. In addition, serological evidence of Toxoplasma gondii and Neospora caninum exists. Of arthropods, only ticks are reported. The parasites of yak are not fully explored. So far 11 nematode genera, 7 trematode genera and 3 cestodes (2 of them only as cysts) are on record. Among protozoa, only Eimeria (2 species identified) and in arthropods, warbles (Hypoderma), 6 genera of ticks, louse, flea and biting flies have been reported in India.

Key words: Indian elephant, Mithun, Parasites, Parasitic diseases, Yak

The Asian elephant (Elephas maximus) is found in India in both the free-living state and in captivity. Although the estimated number of captive elephants in the country is only 3400–3600 or 11–12% of the total elephant population according to the census report of 2000, they have been regarded as a component of livestock by authorities such as Bhalerao (1934). Found in several protected areas, mainly in north-eastern, southern, Himalayan foothills and the island regions, the domesticated and trained elephants are traditional utility animals, used in timber-logging and draught purposes by forest departments, zoological gardens, performance in circus and in temples/palaces for religious and ceremonial purposes. Like in other domesticated animals, elephants are highly prone to a variety of parasites which undermine their health status and work capacity. Almost all of those parasites are known to occur in their wild counterparts also. The pioneering monograph of Bhalerao (1934) dealt only with the helminth parasites. Subsequently, an all-inclusive review on parasitic diseases (Arunachalam et al. 1996) and another one on helminth parasites of Indian elephants (Chakraborty 2003) were published. In the interim, a number of reports dealing with one or more parasites and association with disease, have piled up to justify a comprehensive update of the subject.

The mithun (Bos frontalis) is a unique bovine ruminants found in the hill regions of north-east India. It is a cross between the gaur (Bos gaurus) and the zebu (Bos indicus). Chromosomally identical with the gaur, mithun is also known as gayal (Gupta et al. 1999). This animal has importance in the economic, social, cultural and religious life of the tribal people. It has great potential for quality meat, milk and leather production. Apart from mithuns found in the free-ranging condition, a herd is also maintained at National Research Centre on Mithun (ICAR) in Nagaland. Available information on the parasites and parasitic diseases of mithuns is limited to sporadic and fragmentary reports and so far, there is no
proper review. Likewise, the yak (Bos poephagus) is a livestock species of immense importance in the tribal cold desert areas of North Sikkim, Ladakh, Arunachal and other Himalayan regions, as provider of meat, milk, fibre and transport. Yet there is paucity of available information on its parasitic infections since the advent of a small compilation (RangaRao et al. 1994).

Parasites and parasitic diseases of the Indian elephant

Helminth parasites: In his classic monograph, Bhalerao (1934) had documented 26 helminth parasites of the elephant recorded till then from various parts of India. These included 6 trematodes, 2 cestodes and 18 nematode parasites.

Trematodes: The most common pathogenic distome of Asian elephant is Fasciola jacksoni, the liver fluke of elephant. Infection has also been reported in elephants of Guwahati zoo (Chakraborty and Choudhury 1992), Dudhwa National Park, Lakhimpur, Uttar Pradesh (Singh et al. 1994), in captive and wild elephants of Assam (Islam 1997), and as the dominant prevalent parasite in 90 elephants from different temples of Gujarat (Jani 2008) and recently in a zoological park near Pune (Nighot et al. 2011). Islam (1997) made studies on several aspects of fascioliasis in Asian elephants. Prevalence in wild elephants was overall 33.78% while in captive elephants, it ranged between 18.18 to 62.28% according to locality. Young animals were most affected by the parasite and showed clinical signs of anorexia, constipation, diarrhoea, anaemia and icterus, with death occurring in severe cases. The adult parasite caused massive liver damage. Accordingly to Jani (2008), additionally there was dehydration and habit of soil-licking. The pathology of F. jacksoni infection in the bile duct of elephant has been reported (Chakraborty and Choudhury 1991,1992) by gross, histopathology, scanning electron microscopy (SEM) and energy dispersive X-ray microanalysis (EDAX). Grossly, the parasites were found attached to biliary epithelium and microscopically, the epithelial surface of the bile duct was covered by a necrotic tissue admixed with erythrocytes and ova of F. jacksoni. The liver parenchyma adjacent to the bile duct was replaced by fibrous tissue proliferation. SEM showed distortion of biliary epithelium which turned into a homogeneous mass. Singh et al. (1994) recovered flukes from the liver of a dead elephant and observed pathological changes, viz. haemorrhagic tracts, thickening of bile ductules, cellular infiltrations, cirrhotic changes and pseudolobulations. Recovery of parasite from the lung suggested aberrant migration. The egg of F. jacksoni is smaller and narrower than both F. hepatica and F. gigantica (Islam 2010).

Other trematodes parasitizing Indian elephants are the amphistomes, viz. Gastrodiscus secundus, Pseudodiscus collinsi, Phawkesii, Pfenderius papillatus, Pfenderius birmanicus and Tegumaea heterocaeae (Bhalerao 1934, Dutta and Bordoloi 1989, Arunachalam et al. 1996, Muralidharan and Keshavaprasad 2001). Of these, G. secundus and P. collinsi, both immature and mature forms, were recorded as concurrent infection from the caecum of 2 captive elephants at postmortem from the Kaziranga National Park, Assam (Islam et al. 1999). The accompanying lesions were oedema, pin-head haemorrhages and ulcerative patches on the caecal mucosa. Diarrhoea is a consistent sign of trematodiases, while oedematous swelling on the inter-mandibular region or on lower abdomen is frequently seen in the rumen fluke infection (Chandasekharan et al. 1982) and in fascioliasis (Sarma et al. 2005). The amphistome P. collinsi was reported singly from elephant in Mysore (Muraleedharan and Keshava Prasad 2001) and again from Karnataka by Ananda et al. (2011). Amphistome eggs were found at faecal examination in 13 of 33 elephants of Uttarakhand (Banerjee et al. 2005), and in a zoological park in Punjab (Sing et al. 2006).

The schistosome Bivitellobilharzia nairi, occurring in the portal blood vessels was described by Sundaram et al. (1972). Later, Islam (1994) reported its occurrence in captive elephants from Kaziranga National Park and Assam State Zoo, Guwahati. Schistosomiasis in elephant is a chronic and wasting form of disease. The animal becomes progressively weak with pale mucous membranes and increased bile pigments in urine. Treatment by hexachlorophene (Distodin) at 10 mg/kg body weight (b.w.) orally in 10 elephants infected with 3 species of amphistomes was 100% effective (Chandasekharan et al. 1982). Against fascioliasis, treatment with triclabendazole at 9 mg/kg (subject to a maximum of 7200 mg/animal) and oxyclozanide @ 7.5 mg/kg (not exceeding 6.8g/animal) were 100 and 72.16% effective, respectively (Islam 1997). Oxyclozanide bolus at 5 mg/kg b.w. was found effective treatment (Sarma et al. 2005) in 64 elephants infected with amphistomes and/or Fasciola in Assom.

Cestodes: Bhalerao (1934) had listed 2 cestodes occurring in elephants, viz. Anoplocephala manubriata found as adult tapeworm in the intestine and cystic Echinococcus granulosus in visceral organs. The former was subsequently recorded in an elephant in Kerala by Chandrasekharan et al. (1979a) who observed that the affected animal became anorectic, lost condition, ate mud and grit, and turned diarrhoeic. Oxyclozanide (Zanil) @ 3.4 mg/kg. b.w. as a single dose in food resulted in elimination of tapeworm segments and relief in symptoms (Chandrasekharan et al. 1979a). According to Panicker (1992), other drugs that can be tried include Niclosamide @ 75–100 mg/kg. b.w. oral, hexachlorophene @ 10 mg/kg. b.w. oral, Mансонил @ 5 mg/kg b.w. and Praziquantel @ 2.5–4 mg/kg. b.w. Oribatid mites were suspected to be the intermediate hosts but conclusive evidence was provided by McAloon (2004) who found developmental stages of A. manubriata in 5 species of oribatids in Kerala.

Nematodes: As many as 18 species belonging to 12 genera
were documented as parasites of Indian elephants in early literature (Bhalerao 1934), majority of them inhabiting the g.i. tract. Subsequent records were largely confirmatory of one or more of these from different localities. Accordingly, Grammocephalus elathratus and G. varedatus of liver in Tamil Nadu (Mudaliar and Alwar 1954); Quilonia travancra and Murshidia falcifera from caccum of two zoo elephants in Odisha (Patnaik and Acharjyo 1970); Equinurbia sipunculiformis from a diarrhoeic elephant in Uttar Pradesh Terai (Chhabra and Srivastava 1971); Amira pileata, Decrusia addicta, E. sipunculiformis, Q. travancra, Q. renniei, Murshidia marshida, M. falcifera and M. indica (all strongyles, predominantly caecal worms) were enlisted by Sundaram et al. (1971) from Kerala; Choniangium epistomum (caecum) from Asom (Datta et al. 1972); Bathmostomum sangeri (intestine and caecum), M. murshida, M. falcifera and D. addicta (Sathianesan et al. 1979) from Kerala, M. falcifera, Q. travancra and B. sangeri (Chandrasekharan et al. 1982) from Kerala, the spirurids Parabronema indicum, P. smithi (Chandrasekharan 1989, Panicker 1992) also from Kerala and A. pileata, D. addicta, Murshidia sp. and Q. renniei (Easwaran et al. 2003) all from Kerala. In between, records of nematode parasites additional to Bhalerao (1934) were also made as Strongyloides elephantis from an Indian elephant (Greve 1969), the stomach worm Haemonchus contortus (Rahman et al. 1970) on postmortem examination of an elephant in Mysore, the hookworm Grammocephalus hybridatus (both immature an adult worms) from a nodule in the stomach (Rajasekhariah et al. 1975), from the liver (Pillay et al. 1976) and from the lungs (Chakraborty et al. 1994), Q. sinhai (Gupta and Trivedi 1984), Q. guptai (Gupta and Jaiswal 1984). The latter 2 were reported as new species from elephants in Uttar Pradesh. Also reported was trichostrongylose infection from Asom (Lahkar and Das 1988). Oesophagostomum sp. was recorded on the basis of faecal examination occasionally (Datta and Bordoloi 1989, Jani 2008). Prevalence of Toxocara sp. along with strongyles was found at a national park in Bengaluru (Reddy et al. 1992). Out of Bhalerao (1934) list, Bunostomum foliatum (gastric tumours) remained unconfirmed and Toxocara lonchoptera (bile duct) got redesignated as Balascaris lonchoptera (Chakraborty 2003). The clinical signs observed in g.i. nematode infections included anorexia, mud-eating tendency, colic, reduced intake of food and water, paleness of visible mucous membranes, foetid diarrhoea, anaemia and eosinophilia (Rajamohan 1970, Lahkar and Das 1988, Chandrasekharan 1989, Suresh et al. 2001, Jani 2008). The pathologic effects of grammacephalosis on liver as observed by Pillay et al. (1976) consisted of pale, enlarged and fibroosed in consistency. The bile duct was thickened due to proliferation of connective tissue and hyperplasia, hepatic and kupfer cells loaded with bile pigments and sinusoids showed slight to moderate enlargement. In the opinion of Kalyanasundaram (1979), pathogenicity of gremmocephalosis is well marked and even a few worms can cause grave pathological symptoms. Chakraborty (2003) found strongylosis, predominantly severe Murshidia infection as the cause of fatality in an elephant calf.

Asian elephants are susceptible to g.i. parasitic infections in the wild (Wawe 1995, Dharmarajan 2000, Vidya and Sukumar 2002) and/or maintained in damp unhygienic conditions that may result in enhanced susceptibility to parasitic disease (Chandrasekharan et al. 1995, Suresh et al. 2001, Jani 2008). An epidemiological study at a zoological park (Suresh et al. 2001) found strongylosis to be predominant in summer (52.63%). Specific identification could be facilitated by coproculture to demonstrate third stage larvae (Bhat and Manickam 1998). In vitro survivability of strongyted larvae of elephants (Raman et al. 2001) revealed their viability for 4 to 7 months. Husbandry and variable treatment practices such as in temples in Kerala, also influenced the incidence of helminthic infections (Saseedran et al. 2003). Among ecological factors affecting the intestinal parasite loads, significantly higher loads were recorded during dry season in southern India (Vidya and Sukumar 2002). In Tamil Nadu, the prevalence of intestinal parasites was highest in summer followed by monsoon, significantly lower in males compared to females, and significantly higher in elephants maintained in the forest department system than the private system (Vanitha et al. 2011).

For the treatment of g.i. nematodiasis, a variety of anthelminitics have been tried with varying degree of success. The range included tetramisole (Sundaram et al. 1971, Datta et al. 1972), thiabendazole (Chandrasekharan et al. 1972a), Methyridine (Chandrasekharan et al. 1979b), thiophanate (Chandrasekharan et al. 1979c) and oxybendazole (Sathianesan et al. 1979). Comparative efficacy of 6 anthelminitics against strongylosis (Chandrasekharan et al. 1982) indicated mebendazole @ 3–4 mg/kg, levamisole at 3 mg/kg and morantel tartrate 5 mg/kg b.w. were 100% effective. Fenbendazole as single oral treatment at 5 mg/kg b.w. (Roy and Mazumdar 1988) or 2 doses of 50 g (Tripathy et al. 1997) was efficacious against murshidiosis in 200 elephants and 12 g in 200 ml water in 2 divided doses at 3 days interval against trichostrongylose infection (Lahkar and Das 1988). Fenbendazole at 5 mg/kg was later found (Rao et al. 1992, Singh et al. 2006) equally effective against strongyles and amphistomes, while a similar dose of albendazole (Suresh et al. 2001) led to complete recovery from strongylosis.

Elephants also suffer from cutaneous filariasis caused by Indofilaria pattabiramani (Alwar et al. 1959) and Lelephantis (Chandrasekharan et al. 1972b). The condition is characterized by cutaneous nodules oozing blood. Stephanofilaria was first recorded by Bhattacharjee (1967) and subsequently identified by Chatterjee (1984) and Tripathy et al. (1989) as indistinguishable from Sassamensis. The clinical manifestations were chronic progressive dermatitis
in the region of toes, heels of hind feet and right abdominal wall (Tripathy et al. 1989). Examination of skin scrapings and oozing blood over the lesion, revealed the presence of microfilariae. Histopathological examination of affected skin revealed hyperkeratosis, acanthosis, granulomatous reactions and perivascular cuffing. Clinical cure was achieved by application of 8% metrifonate ointment in vaseline and Himax base. Islam and Lahkar (1996) recorded the eyeworm *Theelazia* from the nictitating membrane of the right eye of a captive elephant.

**Arthropod parasites**

The stomach bots, larvae of *Cobboldia elephantis* flies, occur commonly in Indian elephants. They have been reported from Assam (Datta et al. 1972, Chakraborty et al. 1994), Tamil Nadu (Joseph et al. 1987) and Odisha (Panda et al. 2005). The flies lay their eggs on hairs in various parts of the body and at the root of the tusks in males. Affected animals become emaciated, anaemic and temperature becomes subnormal (Datta et al. 1972). Severe infestations with thousands of larvae may cause severe gastritis with vomition, abdominal discomfort and often prove fatal (Panda et al. 2005). Drugs used against bots in other animals, like dichlorvos, trichlorphon and ivermectin @ 0.2 mg/kg b.w. may be tried. The elephant louse *Haematothyphus elephantis* had been reported from Andhra Pradesh and Karnataka (Raghavan et al. 1968, Jagannath et al. 1979). Infestations were associated with dermatitis, dryness of skin and scale formation on the neck, ears, parts of the abdomen and region near the tail. Singh et al. (2006) and Godara et al. (2009) reported its occurrence in a zoological park in Punjab and a herd at Jaipur, Rajasthan, respectively. They provided morphological characteristics, clinical signs (which in heavy infestations included pruritus, hyperplasia and hair loss) and suitable treatment by sponging with butox (deltamethrin) 1:1000. Ticks reported from Karnataka (Jagannath et al. 1979) were *Rhipicephalus haemaphysaloides*. From Kerala (Panicker 1992), additional records included *Boophilus sp.*, *Haemaphysalis sp.* and *Ornithodoros savignyi*. Contrary to these, Ajith Kumar et al. (2011) failed to find any tick infestations on elephants in Wayanad ghats of Kerala. Elephants are also attacked by the biting flies like *Tabanus* and *Stomoxys* as evidenced by the incidence of trypanosomiasis (*T.evansi*) in them.

**Protozoan parasites**

*Trypanosoma evansi* is known to infect the elephant. The affected animal becomes dull, depressed, disinclined to move, has intermittent fever, pale mucous membranes, lachrymation, oedematus swellings on dependent parts and passes scanty, turbid urine (Panicker 1992, Arunachalam et al. 1996). Among other protozoa, occasionally recorded from the Indian elephant, mention may be made of *Babesia sp.* (Arunachalam et al. 1996), intestinal ciliates (Vardharajan and Pythal 1999) and coccidia (Banerjee et al. 2005). The reported seroprevalence of *Toxoplasma gondii* antibodies in captive elephants in Sri Lanka (Dangolla et al. 2006) should spur interest to explore its presence in neighbouring south India.

**Parasites and parasitic diseases of mithun**

As mithuns are phylo-genetically related to cattle and are kept under environmental conditions similar with cattle, there is strong likelihood that they may be subject to parasitisms similar to those known in cattle. Chakraborty (1992) found *Trichuris* spp. a common occurrence in captive herbivores including mithun. Captive mithuns at the Thiruvaranthapuram zoo in Kerala were found to have amphistomes and coccidial oocysts on faecal examination (Vardharajan and Pythal 1999). Several other reports dealing with *g.i*. helminths in mithuns are available (Modi et al. 1995, Rajkhowa et al. 2003b). A coprological survey of *g.i.* helminth infections in mountainous regions of Bhutan and Arunachal Pradesh (Tandon et al. 2005) recorded in mithuns 12 nematode genera, viz. *Trichuris, capillaria, Strongyloides, Toxocara, Ascaris, Oesophagostomum, Bunostomum, Mecistocirrhus; cooperia ostertagia, Thelazia and Dictyocaulus*, 4 trematodes, viz. *Fasciola, Gastrodiscoides, Gastrothylax* and *Paramphistomum*; and 2 cestodes, *Moniezia and Taenia* spp. In a study on intestinal parasitism in mithuns of 4 north eastern states, 70.27% of 37 animals were faecally positive (Rojkhowa et al. 2005). Of the 16 helminth species belonging to 15 genera, the 7 strongyle genera accounted for the maximum (54.05%) incidence. These were *Oesophagostomum radiatum, Bunostomum phlebotomum, Trichostrongylus sp.*, *Nematodirus sp.*, *Haemonchus placei, Mecistocirrus sp.* and *Cooperia sp.* The infection rate in young animals (1–3 months) was higher and they were mostly found parasitized with *Strongyloides papillosus, Toxocara vitulorum* and coccidia. In older animals, the longworm *Dictyocaulus* sp. was also recorded. The other entities included 5 trematodes viz. *F. asiatica, Fascioloides, Paramphistomum, Schistosoma bovis* and *S. indicum*. The only cestode was *Moniezia expansa*. In other epidemiological studies at the National Research Centre on Mithun, on 53 animals significantly higher nematode and cestode worm burden was found in calves below 1 year in age than those in 1–3 years and older than 3 years age groups (Chamua et al. 2006 2009). Prevalence of strongyle infection was higher in monsoon season in calves below 1 year of age. Amphistome infection was higher in winter. On the basis of morphological characters of ova and larvae, *T. vitulorum, S. papillosus, Trichuris sp.*, *Trichostrongylus sp.*, *Oesophagostomum sp.*, *Haemonchus sp.*, *Cooperia sp.* and *Bunostomum sp.* were recorded in faecal samples. *S. papillosus* and *T. vitulorum* were recorded only in calves below 1 year. The study also recorded *Eimeria* (mainly *E. bovis*) in age groups of below 1 year and 1–3 years.
According to a status report of internal parasitoses in mithun calves up to 9 months of age in Nagaland (Rajkhowa et al. 2007) infections determined by faecal analysis were calves up to 9 months of age in Nagaland (Rajkhowa et al. 2007). A status report of internal parasitoses in mithun calves up to 9 months of age in Nagaland (Rajkhowa et al. 2007) infections determined by faecal analysis were calves up to 9 months of age in Nagaland (Rajkhowa et al. 2007). A status report of internal parasitoses in mithun calves up to 9 months of age in Nagaland (Rajkhowa et al. 2007). A status report of internal parasitoses in mithun calves up to 9 months of age in Nagaland (Rajkhowa et al. 2007).

The clinical effects recorded were similar to those observed in other herbivorous mammals, such as the pathology of *F. gigantica* infected biliary epithelium in mithun (Chakraborty 2001). Haematological changes recorded in mithuns with g.i. nematodiosis (Rajkhowa et al. 2003b, 2004) included lowered values of Hb, PCV, TEC, TLC, total proteins and albumin. Microfilaraemia in mithuns of Nagaland (Rajkhowa et al. 2005a) possibly related to *Parafilaria bovicola*, is also on record. Anthelmintic treatment with a single dose of ivermectin at 0.2 mg/kg b.w. administered to animals with high faecal egg counts and showing clinical symptoms (Rajkhowa et al. 2003b) resulted in significant improvement in clinical and haematobiochemical parameters by day 14 post-treatment. The study on internal parasitoses in mithun calves (Rajkhowa et al. 2007) also recorded protozoan infections with *Eimeria* spp. (63%), *Cryptosporidium parvum* (52%), *Balantidium coli* (22%) and *Giardia* spp. (11%) mostly concurrent with helminthiasis in multiple infections with 3–4 different parasites. *Eimeria* spp. identified were *E. bovis, E. zuernii, E. cylindrica, E. ellipsoidalis, E. auburnensis, E. alabamensis, E. bukidnonensis and E. subspherica* (Rajkhowa et al. 2004, 2007). The occurrence of another species *E. canadensis* had been recorded (Agrawal 2001) from a zoo in Lucknow. Eimerian infections were highest in calves aged 3–6 months. Clinical coccidiosis (Chamuah et al. 2009) was also reported. The main clinical signs were haemorrhagic diarrhea, tenesmus, anaemia and unthriftiness. The prevalence of *C. parvum* in mithuns (Rajkhowa et al. 2006a) by a commercial enzyme-linked immunosorbent assay kit was overall 56%, higher (94%) in diarrhoeic animals in comparison to non-diarrhoeic group (51%). The prevalence was highest in young calves aged 8–15 days. Haemoproteozoan diseases like theileriosis, recorded in a gaur calf (Khan 1981), babesiosis in a crossbred mithun (Das et al. 1999) and trypanosomiasis (Rajkhowa et al. 2003a) were occasionally reported with clinical manifestations resembling those in cattle. In clinical babesiosis (Das et al. 1999), high body temperature (41°C), haemoglobinurca and anaemia were observed, as well as response to combination therapy with diminazene aceturate and oxytetracycline. Seroprevalence of *Toxoplasma gondii* antibodies in captive mithuns (Rajkhowa et al. 2006b) at 28% and in their free-ranging counterparts (Rajkhowa et al. 2008a) at 42% was recorded by modified direct agglutination test. Antibodies to *Neospora caninum* in captive and free-ranging mithuns of Nagaland (Rajkhowa et al. 2008b) was detected in overall 10% by a commercially available ELISA test. Mithuns were also subject to arthropod parasites like ticks *Boophilus microplus* (Rajkhowa et al. 2005c) with highest infestation during monsoon and lowest in winter. *Rhipepsalus* and *Haemaphysalis* spp. were also recorded. Acaricides like deltamethrin, amitraz and ivermectin were evaluated for their efficacy against ticks (Rajkhowa et al. 2005d) and deltamethrin (1.25%) at 2 ml/litre of water was found to have the highest (100%) efficacy.

Parasites and parasitic diseases of Indian yak

The parasitic fauna of the yak have remained relatively unexplored except for the occurrence of hydatid cysts (Katiyar and Sinha 1987, Rai et al. 1989, Ansari and Rai 1991). Found mainly in lungs and/or liver and occasionally in other organs, the prevalence was 42–96% (Ranga Rao et al. 1994). In a comprehensive study of yak and its hybrids in Ladakh, Sikkim and Himalayan regions of Indo-Nepal border in Uttar Pradesh (Ranga Rao et al. 1994) based on necropsy and coprological examination of eggs and faecal culture, 3 liver flakes, 4 amphistomes, 1 cestode and 9 nematodes were recorded. These were listed as *Fasciola hepatica, E. gigantica, Gigantocotyle explanatum, Cotylophoron cotylophorum, Gastrothylax crumenifer, Fiscoheudria cobboldi, Paramphistomum cervi, Moniezia Trichostrongylus, Ostertagia, Cooperia, Nematodirus, Biunostomum, Chabertia, Haemonchus, Mecistocirrus and Toxocara (Neoascaris) vitulorum*. Apart from these, cysts of *Coenurus* spp., hydatid cysts and adult *Setaria cervi* from peritoneum were recovered. Coprological examination revealed a high prevalence of *Strongylate* spp. (76.4%).

Prevalence of g.i. parasites in the cold desert area of North Sikkim (Bandyopadhyay et al. 2010) based on faecal examination of 348 yaks, revealed *Haemonchus* spp. as the predominant (6.89%) followed by *Nematodirus* spp. (1.72%), *Cooperia* spp. (1.43%) and *Dicrocoelium* spp. (0.29%). Another recent study on g.i. parasites of domesticated yak (Rahman et al. 2010) recorded overall occurrence of strongyles (17.36%), *Strongyloides* spp. (4.34%), *Toxocara* spp. (2.25%), *Trichuris* spp. (2.88%), amphistomes (0.52%) and *Moniezia* spp. (3.07%). On coproculture of positive samples, *Haemonchus, Biunostomum, Oesophagostomum* and *Nematodirus* spp. were identified. A solitary record of a filarid worm *Parafilaria bovicola* (Yadav et al. 2007) from yak in Arunachal Pradesh exists. The pathology of liver, lung and caecum of yak infected with *Fasciola, Dicrocoelium, Echinococcus* and *Trichuris* has been documented (Ansari et al. 1989). Anthelmintic studies in yaks were not available since Roy et al. (1986). Among protozoan parasites, coccidian are common (Ranga Rao et al. 1994, Rahman et al. 2010). The former author identified *Eimeria bennetti* and *E. zuernii*. Cases of babesiosis in yak in Arunachal Pradesh (Saud et al. 2005) with pyrexia, anaemia and haemoglobinuria, confirmed by blood smear examination and treated with diminazene aceturate, have been reported.
The arthropod, warble fly *Hypoderma* lineatum was initially reported from yak in Bhutan (Chaudhury 1970) but later on, also from Arunachal Pradesh (Sarvanan et al. 2006a). Six genera of ticks viz. *Boophilus*, *Ixodes* (2 species), *Haemaphysalis* (3 species), *Rhipicephalus*, *Amblyomma* and *Dermacentor* were recorded from Arunachal Pradesh and Sikkim (Geevarghese et al. 1997, Sarvan et al. 2008). Interestingly, the incidence of tick infestation was more in yak hybrids than in yaks. Incidence of common ectoparasites, viz. ticks, lice, flies (larva) and fleas (Sarvan et al. 2006b, 2009) overall was 27.96%, higher in field than in organized farm conditions. Apart from the ticks earlier named, lice *Damaslinia* spp., flea identified as *Ctenocephalides felis* and various flies such as *Tabanus*, *Sarcophaga*, *Lucilia*, *Calliphora*, *Chrysomyia* and *Hypoderma* were collected. Cypermethrin as spray was effective against ectoparasites like lice (Sarvan et al. 2006b).

Knowledge of parasites and parasitic diseases of marginal livestock as exemplified by elephant, mithun and yak, is still in its infancy and only baseline data are available so far. The elephant is particularly prone to a variety of parasites of which *Fasciola jacksoni* stands out as the most pathogenic as well as prevalent entity. There is need to explore its transmission cycle with the objective of minimizing losses. Diagnosis of parasitic diseases needs to be upgraded across the host species with enhanced use of modern molecular techniques such as PCR-based diagnosis as standardized for haemoprotozoan infections. Parasitic diseases in Indian elephants is in its infancy and only baseline data are available so far. The apparent absence of trypanosomiasis in Indian yak may be due to yak habitat of cold desert being inhospitable to the breeding of vector flies. Apart from the ticks earlier named, lice *Damaslinia* spp., flea identified as *Ctenocephalides felis* and various flies such as *Tabanus*, *Sarcophaga*, *Lucilia*, *Calliphora*, *Chrysomyia* and *Hypoderma* were collected. Cypermethrin as spray was effective against ectoparasites like lice (Sarvan et al. 2006b).

Knowledge of parasites and parasitic diseases of marginal livestock as exemplified by elephant, mithun and yak, is still in its infancy and only baseline data are available so far. The elephant is particularly prone to a variety of parasites of which *Fasciola jacksoni* stands out as the most pathogenic as well as prevalent entity. There is need to explore its transmission cycle with the objective of minimizing losses. Diagnosis of parasitic diseases needs to be upgraded across the host species with enhanced use of modern molecular techniques such as PCR-based diagnosis as standardized for haemoprotozoan infections like trypanosomiasis in captive wild herbivores (Shailaja et al. 2005). There are several obvious information gaps at present. In all the 3 host species, the ectoparasites have not been adequately explored and there is no record of sarcoptic mange or myiasis except for *Hypoderma* larvae in the yak. In Indian elephant, coccidia, if any, are yet to be reported and the relatively low incidence of trypanosomiasis may be due to low preference of biting fly vectors for the pachyderm. The apparent absence of trypanosomiasis in Indian yak may be due to yak habitat of cold desert being inhospitable to the breeding of vector flies. *Theileria* infections reported from yak in China has not been recorded in Indian yak and coccidian species of this animal have also not been studied fully. In the mithun, entities like *Theileria* and *Sarcocystis* have not been recorded so far. Keeping in mind the known host-specificity of coccidia, the *Eimeria* species identified in the mithun although morphologically indistinguishable from those in cattle, should be checked by cross-transmission studies for the possibility of being host-specific varieties in transition to evolving as distinct species. Similarly, *Cryptosporidium parvum* recorded from mithun should be characterized by genotyping as at least 2 other species, *C.bovis* and *C.andersoni* are known to occur in Indian bovines. The high positivity in young calves calls for rearing them away from adults. The seroprevalence of *Toxoplasma* is of zoonotic significance as mithun is also a meat animal.

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