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World Journal of Ecology

ISSN 3068-5001

Editorial

Lung Fluke Infection In Tigers (*Panthera tigris tigris*) And Leopards (*P. pardus fusca*) In Indian Habitats: Its Prevention Challenging.

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EDITORIAL

India is home to a variety of wild felids species that inhabit diverse forest habitats or ecosystems. These are commonly referred to as "cats." In animal kingdom, these cats belong to the Felidae family, which falls under the Carnivora order and the Mammalia class. This family is broadly divided into two subfamilies, namely Pantherinae (which includes large cats) and Felinae (which includes small cats). Among the large cats, the tiger (*Panthera tigris tigris*) (**Figure 1a**) and the Indian leopard (P. *pardus fusca*) (**Figure 1b**) are the most commonly found in the country. However, the Asiatic lion (*P. leo*) is also found but only in the Gir Forest of Gujarat state of the country. However, several species of smaller wild cats, such as the leopard cat (*Prionailurus bengalensis*), marbled cat (*Pardofelis marmorata*), rusty-spotted cat (*P. rubiginosa*), jungle cat (*Felis chaus*), fishing cat (*P. viverrina*), caracal (*Caracal caracal*), Asian golden cat (*Catopuma temminckii*), Asian wildcat (*Felis silvestris*), Eurasian lynx (*Lynx lynx*), and Pallas's cat (*Otocolobus manul*), are also found in diverse forest habitats of different regions in the country. However, some of these small cat species are eurytopic, widely distributed in diverse forest habitats or found in many parts of the country, while others are stenotopic to particular habitats or found only in specific habitats within regions.

Among the many species of wild felines, tigers and leopards are important apex predators that not only control populations of diverse species of wild herbivores and ruminants, but also help maintain healthy ecosystems by preventing overgrazing and preserving biodiversity [1]. As 'umbrella species', the conservation of these predator species protects numerous other wild species and their habitats, thereby contributing to reduced deforestation and having a positive impact on the climate. Furthermore, these wild predators can indirectly contribute to seed dispersal and forest regeneration, and their presence influences human-wildlife interactions, significantly reducing crop damage for farmers. Indeed, their presence is an indicator of a healthy, balanced ecosystem. Conservation efforts for these large cats protect vast areas of forests and grasslands, benefiting countless other species and reducing deforestation rates. The presence of these apex predators also attracts nature-based tourism, providing local communities with employment and economic opportunities. The iconic status of tigers and leopards raises awareness about the importance of biodiversity and sustainable practices, garnering broader public support for conservation efforts. In the country, there are several factors that constantly pose threats to these highly valuable predatory animals or felines. These include illegal poaching, territorial conflicts, habitat fragmentation, and parasitic diseases. Therefore, protecting the populations of these big cats is extremely important [2]. Parasitic helminths, causing diverse serious helminthiases, have a significant impact on the health of these wild cats. Studying parasitic activity in wild populations, especially among carnivorous animals, is important because these parasites can also spread to domestic animals and even humans [3,4]. However, various types of internal parasites (flukes, tapeworms, nematodes, and protozoans) and external parasites (arthropods and acarines) can negatively impact the health of wild cats. Among the helminths or digenetic

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Received: 07-November-2025, Manuscript No. WJOE - 5235 **; Editor Assigned:** 08-November-2025 **; Reviewed:** 28-November-2025, QC No. WJOE - 5235 **; Published:** 23-December-2025.
Citation: **Shanti Lal Choubisa.** Lung Fluke Infection In Tigers (*Panthera tigris tigris*) And Leopards (*P. pardus fusca*) In Indian Habitats: Its Prevention Challenging. World Journal of Ecology. 2025 December; 14(1).

trematode parasites, the lung fluke, *Paragonimus* spp. (**Figure 1c**), causes a serious disease called "*paragonimiasis*" in tigers and leopards, which is a major cause of illness and death in these large carnivores. However, the severity of the disease and mortality rates depend on the parasite load or degree of parasitaemia i.e., the number of lung fluke parasites present in the lungs [5-7].

Lung flukes, or *Paragonimus* species, are digenetic trematode parasites that live in the lungs of their definitive hosts, such as non-vegetarian humans and wild carnivorous animals (mammalians). They are also commonly known as flatworms and belong to the genus *Paragonimus* within the family *Paragonimidae*, and the phylum Platyhelminthes, class Trematoda (flukes). In fact, their life cycle is very complex, involving three hosts instead of two as found in other species of digenetic trematode parasites: a definitive host (carnivorous mammals), and two freshwater intermediate hosts—gastropods (snails) and crustaceans (crabs and crayfishes). Adult lungworm parasites are found only in the definitive host, while their various larval stages, such as sporocyst, redia, and cercaria, and metacercaria are found in the first and second intermediate hosts, respectively [8]. However, the most important larval stage, the metacercaria (encysted), is found only in the second intermediate hosts, crabs (Sinopachys, Candidopachys, Sundathelphusa, Paratelphusa, Geotelphusa, and Renguna) and crayfishes (Cambarus), and this stage is highly infectious or infective. Humans can become infected when they eat these freshwater crabs and crayfishes raw or undercooked, as the encysted metacercariae are present in their muscles and gills. Tigers and leopards, can also become infected by hunting and eating wild boars or other animals that harbour these parasites, or by consuming organisms containing metacercariae. In fact, wild boars and some small rodents act as paratenic hosts for these trematode parasites [9]. In the intestines of tigers and leopards, these metacercariae release immature or juvenile lungworms from their metacercariae cysts. These juveniles migrate through various tissues to the lungs, where they develop or mature into adult worms. Interestingly, these adult worm cysts in the lungs also contain numerous eggs (**Figure 1d**).

Figure 1. The top predators tigers (a) and Indian leopards (b) are found in various Indian habitats to be infected with lung fluke parasites of the genus Paragonimus (c). Their yellowish-brown, oval, and perforated eggs (d) are found in the feces of these wild felides. Source: [27]

Lung fluke infection can cause a serious disease called paragonimiasis in tigers and leopards. This disease is a type of zoonotic or food-borne parasitic zoonosis. Pathological signs of this disease in tigers and leopards, although less frequently reported than in humans, can include pulmonary symptoms such as congestion and edema, pneumonia and bronchitis, bronchiectasis, areas of lung collapse, formation of granulomas (clusters of inflammatory cells), cough, difficulty breathing, and possibly hemoptysis (coughing up blood), as well as lung lesions such as cysts and inflammation (**Figure 2**). Extra-pulmonary forms can also occur, causing abdominal pain or neurological problems, although these are rare [10,11]. Heavy infestations of these parasites can even lead to the death of these top predator animals. Interestingly, not only adult trematode parasites cause disease in their primary hosts, but their larvae (sporocysts, rediae, and cercariae) also cause pathogenesis in their intermediate snail host [12-16].

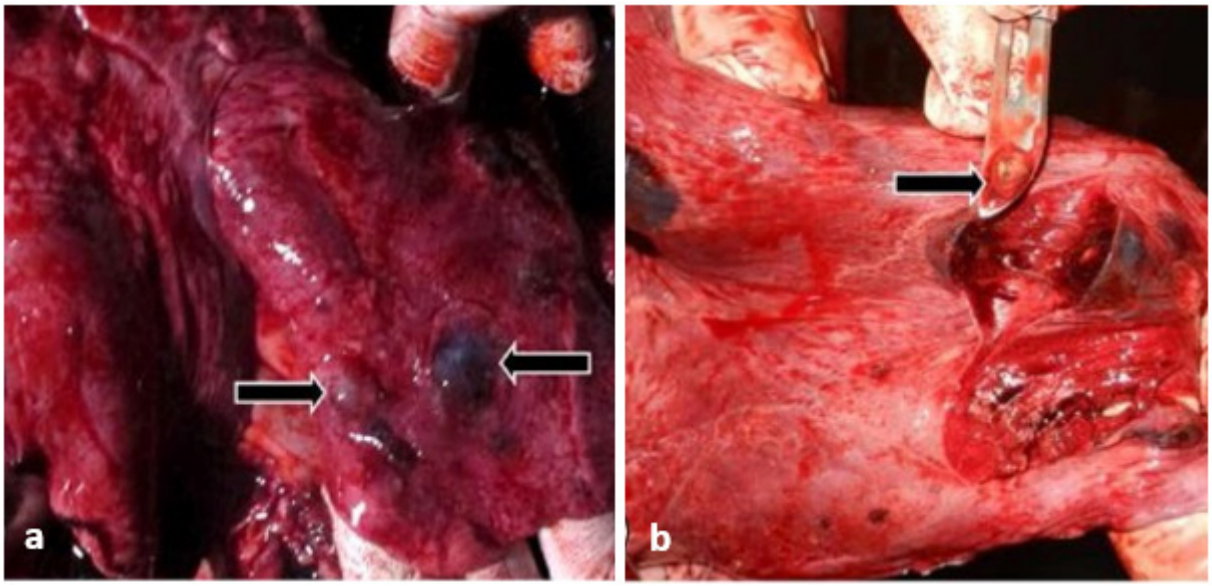

Figure 2. (a) Lungs of a tiger infected with flukes revealed pathological signs as congested, emphysematous, and pneumonic with discrete raised transparent to dark encysted lesions (arrow). (b) Incision of encysted lesions contained fluke (arrow) along with haemorrhage, necrosis, and brownish exudate. Source: [27].

In the country, lung fluke infections in tigers and leopards have been reported by researchers or workers based on examination of scat samples, carcasses, and necropsy findings [17-30]. These trematode parasites have also been reported from several countries, such as Siberia, Japan, Korea, China, Taiwan, Philippines, Indonesia, Malaysia, Thailand, Sri Lanka, USA, Cost Rica, etc. [10,30]. The prevalence of this parasitic infection in wild felids varies considerably across different forest regions of the country. The highest prevalence of lung fluke infection in leopards, at over 80%, has been reported in the Katapurna Wildlife Sanctuary, Akola, India [17-30]. A recent study in various forest areas of the Nilgiris in Tamil Nadu found that 42.85% of tigers and 20% of leopards were infected with lung flukes [30]. These findings suggest that lung fluke infection in tigers and leopards inhabiting diverse forest areas in India is more prevalent, posing a threat to the conservation of these important wild animals. However, many species of domestic animals and humans in the country are also affected by various types of trematodiases [31-35]. The occurrence of these diseases can be predicted based on the species of snails and their cercarial larvae [36-50], as well as the types of freshwater aquatic habitats [51-56] present in a particular environment.Whatsoever, heavy lung fluke infections in tigers and leopards often result in mortality. Therefore, preventing these parasites infections in these apex predator species is crucial, providing significant conservation support. However, preventing and controlling lung fluke infections in tigers and leopards remains challenging. However, this may be possible by eliminating the parasites in captive tigers and leopards and disrupting their complex life cycle.

Control measures for captive tigers and leopards are much more direct and effective, including:

(a) Dietary control: The most important measure is to prevent these cats from eating raw or undercooked freshwater crabs or crayfish. In some areas, meat from infected paratenic hosts (wild boars, pigs, rodents, etc.) can also easily transmit the parasite, so all meat should be thoroughly cooked.

(b) Food source: It is essential to obtain food from areas where lung flukes are not found. Food that has been exposed to crustaceans from freshwater sources should be strictly avoided

(c) Strict sanitation: For facilities holding captive wild animals, it is important to ensure that freshwater supplies are not

contaminated with parasite eggs and that water supplies are not drawn from water bodies where the snails and crustaceans are found. This also includes protecting water sources from contamination by feces from other infected animals. It is also important that freshwater supplies are free from fluoride contamination, otherwise these captive animals are likely to develop fluorosis as in animals [57-65] and humans [66-71]. In fact, most ground and fresh water sources in the country are contaminated with fluoride [72,73].

(d) Prophylactic treatment: Regular veterinary checkups and deworming protocols can help prevent and treat infections. Medications are effective against lung fluke infections.

Prevention of lung fluke infection in tigers and leopards across diverse forest areas in the country is very difficult or nearly impossible. However, the following prevention strategies may prove useful:

(a) Habitat management: Reducing populations of intermediate hosts is a key strategy, although extremely challenging in wild environments. This may include controlling the numbers of freshwater snails and crustaceans in areas inhabited by feral cats.

(b) Controlling paratenic hosts: Managing populations of paratenic hosts, such as wild pigs, which transmit the infection, may help reduce infection rates in large predators.

(c) Surveillance: Regular monitoring of tiger and leopard populations through faecal analysis can help determine the prevalence of lung flukes. This helps wildlife managers detect the disease and identify high-risk areas.

Acknowledgements

The author thanks to Dr. Darshana Choubisa, Professor, Department of Prosthodontics, Geetanjali Dental and Research Institute Udaipur, Rajasthan313002, India and Dr. Pallavi Choubisa, Assistant Professor, Department of Obstetrics and Gynaecology, RNT Medical College and Pannadhay Zanana Hospital, Udaipur, Rajasthan 313002, India for cooperation.

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