Review Article

Safeguarding Public Health: A Comprehensive Review of Parasitic Zoonoses in Sri Lanka and Effective Prevention Strategies.

ABSTRACT

Parasitic zoonoses present a severe public health challenge in Sri Lanka, a nation with diverse ecosystems and complex socio-economic conditions. This detailed review explores the range of parasitic infections affecting the Sri Lankan population, providing a thorough examination of zoonotic helminths, protozoa, and arthropod-borne diseases. The analysis covers zoonotic helminths, including nematodes such as *Ascaris lumbricoides*, *Trichuris trichiura*, and *Ancylostoma* spp., as well as filarial parasites like *Dirofilaria repens*, *Brugia* spp., and *Wuchereria bancrofti*. Trematodes such as *Schistosoma* spp. and cestodes including *Spirometra sparganum*, *Bertiella studeri*, *Dipylidium caninum*, and *Taenia* spp. are also discussed. Data from various studies illustrate their prevalence and regional impact. Protozoal infections like Leishmaniasis, Toxoplasmosis, Malaria, and Trypanosomiasis are examined to reveal their epidemiological patterns. The review also investigates arthropod-borne diseases, including rickettsioses spread by different species of ticks and myiasis caused by *Oestrus ovis* and *Chrysomya* spp. Prevention and control strategies are assessed, focusing on vector management, public education, and reservoir host control. Innovations in research, technology, meat inspection, and measures to address risks from foreign travellers are analysed. Governmental strategies regarding resource allocation, research funding, and public health initiatives are evaluated. The review underscores the importance of improving water quality, sanitation, animal health management, and regulatory frameworks. International collaboration is highlighted as essential for strengthening Sri Lanka's response to parasitic zoonoses, offering actionable insights for policymakers and health professionals.

Keywords: Parasitic Zoonoses, Sri Lanka, Helminths and Protozoa, Arthropod-borne Diseases, Disease Prevention and Control

1. INTRODUCTION

Parasitic zoonoses refer to infections caused by protozoa, helminths, and arthropods that naturally spread between vertebrate animals and humans [1]. Comprehensive evaluations of parasitic zoonoses in Sri Lanka have been undertaken periodically, highlighting a wide array of these organisms [2].

1.1 Zoonotic Helminth Infections

Moderate to severe infections with nematodes that have zoonotic potential, such as *Ascaris lumbricoides, Trichuris trichiura,* and hookworm, have been documented among children residing in five districts within the plantation sector of Sri Lanka—specifically Nuwara Eliya, Ratnapura, Kandy, Badulla, and Kegalle—in 2009, four years after the cessation of a 10-year preventive chemotherapy program [3].

Rodents are significant in the context of parasitic zoonoses, serving as both hosts and reservoirs for numerous zoonotic diseases [4]. A study conducted in the Kandy district from 2006 to 2007 identified eleven parasite species, which included four zoonotic helminths: *Hymenolepis diminuta* (rat tapeworm), *Moniliformis moniliformis, Cysticercus fasciolaris*, and *Raillietina* species. According to the findings of this research, tapeworms have constituted the largest portion of the parasitic infections (52.4%), followed by *Cysticercus fasciolaris* (42.7%) and strongyle-type eggs (19.0%). The study has also identified mixed infections in 23.8% of cases, involving two specific combinations. One combination

included *Raillietina* species, *Hymenolepis diminuta*, and *Cysticercus fasciolaris*, while the other combination consisted of *Hymenolepis diminuta, Xenopsylla cheopis, and Moniliformis moniliformis* [4].

In 1950, the presence of *Hymenolepis diminuta*'s parasitic ovum was identified for the first time in a 2-year-old girl receiving paediatric care in Sri Lanka, formerly known as Ceylon [5]. Another case surfaced in 2014 involving a 5-year-old boy presenting with fever, watery stools, abdominal pain, and recurrent febrile convulsions [6]. Human infestation by *H. diminuta* is rare due to the requirement for humans to ingest cysticercoid larvae from contaminated arthropods via food or contaminated objects [7]. Globally, only a limited number of cases have been documented [6].

Bertiella studeri, or the monkey tapeworm, is a zoonotic parasite transmitted to humans via accidental ingestion of infected mites carrying its cysticercoid larvae. The first human case of *B. studeri* infection was documented in Central Province in 1976 [8]. Subsequent infections have been noted in children from Dikwella and Kahawatta areas in Sri Lanka [8][9]. Research suggests the Ceylon toque monkey (*Macaca sinica*) and grey langur (*Presbytis entellus*) are the most likely reservoir hosts of this parasite in these regions [9][10]. Between 2007 and 2017, 24 paediatric cases have been reported, predominantly in Central Province [11].

In Sri Lanka's urban slums, cats and dogs, common companions, often transmit zoonotic parasites, especially in densely populated areas where disease spread is heightened [12]. Close contact with pets and poor sanitation increase the risk of infections. Parasites can be transmitted directly through contact with infected animals or indirectly via unsanitary conditions, highlighting the urgent need for improved hygiene and preventative measures to mitigate the risk of zoonotic disease spread in these vulnerable communities [13]. Canine gastrointestinal parasites, such as *Toxocara canis*, *Strongyloides* spp., *Entamoeba coli*, hookworms, *Trichuris* spp., *Giardia duodenalis*, *Spirocerca lupi*, *Toxascaris* spp., and *Taenia* spp., pose significant health risks to humans [14].

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In a comprehensive study spanning from 1995 to 2015 at the University of Peradeniya, *Toxocara* antibodies have been identified in the serum of patients—including adults, children, and infants—suspected of ocular toxocariasis. This research has revealed a significant seropositivity rate, with the highest prevalence in the 10–14 age group at 16.12%. Ocular manifestations associated with *Toxocara* infections, such as Ocular Larval Migrans, had been notably prevalent, with 34.19% of cases linked to uveitis, 21.94% to reduced vision, 12.9% to vitritis, and 7.74% to choroiditis [15]. Complementing these findings, a sero-epidemiological study from 2003 reported a 43% seropositivity rate for *Toxocara* antibodies among children aged 1 to 12 years [16]. This alarming statistic points to a widespread issue within the paediatric population. Furthermore, research studies have highlighted the zoonotic potential of other parasites, including *Ancylostoma caninum and Dipylidium caninum,* among Sri Lankans [17][18]. The cat tapeworm *Taenia taeniaeformis* and the cat hookworm *Ancylostoma tubaeforme* have also been sporadically reported in humans in Sri Lanka [19][20]. These findings suggest a critical gap in veterinary care and zoonotic awareness, which may exacerbate the risk of parasite transmission to humans.

Helminth parasites can be transmitted to humans through direct and indirect routes, primarily via faecal contamination, soil exposure, or the consumption of undercooked or raw meat [21]. A key example is the zoonotic transmission of hookworms from dogs and cats. Infective larvae in the filariform stage can penetrate human skin, leading to cutaneous larval migrans (CLM) [22]. A study of devotees at the Nallur temple in Jaffna found a significant 58.2% prevalence of CLM among those with lesions [22]. Workers in agriculture, breeding, farming, and gardening—who handle potentially contaminated soil or sand (in the absence of direct animal contact)—are at increased risk and should consider CLM a serious occupational hazard [23]. Additionally, wandering rats often contaminate food and water sources with helminth eggs from their droppings. This close proximity between reservoir hosts and human activities highlights a critical public health threat.

Most cases of ocular helminthiasis are incidental, arising from the aberrant migration of juvenile or immature worms within host tissues. In Sri Lanka, ocular helminthiases have predominantly been attributed to nematode species, including ascarids, filariids, and strongylids [24]. Additionally, there have been documented cases of accidental sub-conjunctival infections in humans caused by adult avian trematodes, specifically *Philophthalmus spp* [25][26]. Furthermore, a pronounced case of ocular trematodiasis affecting three children has been documented in the North Central Province of Sri Lanka, and it has revealed two DNA sequences associated with trematodes. One has been identified as basal

to *Diplostomum sp*., while the other one has been clustered with *Braunina cordiformis, Cyanthocotilidae sp., and Holostephanaus sp* [24].

Schistosomiasis, commonly referred to as bilharzia, is a debilitating disease caused by parasitic trematodes of the genus *Schistosoma*, also known as blood flukes [27]. This condition is characterized by chronic illness and significant health challenges. While there have been no documented cases of endemic schistosomiasis within Sri Lanka, an imported instance of urinary schistosomiasis has been reported in 1986. This case involved *Schistosoma haematobium*, a strain that was acquired from Mali, West Africa [28].

In 1925, Sri Lanka was the site of the world's first documented case of human ocular parastrongyliasis, caused by *Parastrongylus (Angiostrongylus) cantonensis*, commonly known as the rat lungworm. This pioneering case marked the beginning of our understanding of this parasitic disease in humans. Subsequent reports in 1988 and 1997 have further elucidated the prevalence of this condition in the region [29][30]. More recently, the discovery of two additional cases in Sri Lanka has underscored the pressing need for enhanced medical intervention for this serious ophthalmic condition [31][32]. The risk of human infection with this zoonotic disease is significantly influenced by increasing rodent populations, which can facilitate the spread of the parasite to humans.

Human sparganosis is a zoonotic parasitic affliction caused by the larval stage of the cestode *Spirometra sparganum*. Adult tapeworms typically reside in the intestines of various domestic and wild canines and felines [33]. Human infections usually occur through the consumption of raw or undercooked flesh from infected frogs, snakes, or freshwater fish. Humans act as incidental hosts, leading to larvae migrating to subcutaneous tissues, muscles, or potentially critical organs such as the genitourinary tract, pleural or abdominal cavities, scrotum, spinal cord, or brain [34]. While subcutaneous sparganosis can often be treated effectively with surgical excision, infections involving critical organs like the brain or eyes can result in severe complications, particularly if larvae have been present for extended periods and exhibit invasive behaviour. The first two cases of human sparganosis in Sri Lanka were documented in 1997, and since then further cases have been reported in 2001, 2007, and 2008 [33][35][36].

Human gnathostomiasis, a parasitic infection endemic to several Asian countries, was first documented in Sri Lanka in 2002 [37]. This disease is caused by the third-stage larvae of the nematode *Gnathostoma*. Adult parasites typically reside in the gastric linings of carnivorous mammals such as felines and canids. The nematode's life cycle involves two aquatic hosts: initially, *Cyclops*, followed by various freshwater fish that consume infected *Cyclops*. Humans usually get infected through the ingestion of raw or inadequately cooked freshwater fish or by drinking untreated water contaminated with *Cyclops* [38]. The first cases in Sri Lanka involved a 4-year-old boy in Colombo and a 48-year-old man in Chilaw, both infected with *Gnathostoma spinigerum*, confirmed by microscopic examination [37]. In October 2020, a Sri Lankan who had resided in Sri Lanka and subsequently travelled to Geneva in September 2020 for academic purposes was also diagnosed with *G. spinigerum* infection and validated through Western blot analysis utilizing antiserum targeting the *G. spinigerum*-A3L antigen [39]. These reports highlight a critical gap in recognizing and reporting gnathostomiasis in Sri Lanka, suggesting that the disease may be significantly underreported. This underscores the need for enhanced diagnostic efforts and surveillance to better understand the disease's prevalence and distribution in the region.

Sri Lanka experiences the highest burden of dirofilariasis among Asian nations, primarily caused by *Dirofilaria repens* [40]. Since 1962, cases have been reported intermittently, with notable surges observed between 2010 and 2012 [40]. Remarkably, *Dirofilaria immitis* has not yet been recorded in the country. Both cats and dogs serve as reservoirs for *Brugia malayi* and *D. repens*. Specifically, *D. repens* and *Brugia ceylonensis* have been found in the Western Province, while *B. malayi* and *D. repens* have been reported in the Western and North Central provinces, particularly affecting dogs [41][42]. Although human infections are rare and typically do not produce microfilariae, they can still cause severe clinical manifestations such as subcutaneous nodules, ocular lesions, and meningoencephalitis while making humans dead-end hosts. Surgical intervention is often required for effective removal of the worms in such instances [42].

The first documented human case of dirofilariasis in Sri Lanka dates back to 1962, with numerous cases subsequently identified, including both ocular and subcutaneous forms, affecting a range of patients from infants to adults [43][44][45]. Notably, in 2009, a case of human dirofilariasis complicated by

meningoencephalitis from Germany involved a patient who had travelled extensively for nine months in southern India and Sri Lanka, suggesting potential travel-related transmission [46]. Most cases in Sri Lanka have been concentrated in the Central Province, indicating a potentially higher risk of *D. repens* infection in this region [47]. However, the observed prevalence may also reflect underreporting or under-diagnosis in other parts of the country, suggesting that the true extent of dirofilariasis in Sri Lanka might be more widespread than currently recognized.

Lymphatic filariasis (LF), also known as "elephantiasis," is a debilitating and disfiguring tropical disease caused by the parasitic worms *Wuchereria bancrofti*, *Brugia malayi*, and *Brugia timori*, transmitted by *Culex* mosquitoes [48]. LF has been persistently endemic in Sri Lanka for centuries [49]. Since 1989, extensive anti-filarial campaigns have targeted eight districts—Colombo, Gampaha, Kalutara, Galle, Matara, Hambantota, Puttalam, and Kurunegala—across the Western, Southern, and North Western provinces using mass drug administration (MDA) to eliminate the disease [48]. Principally, during this period, Malayan filariasis caused by *B. malayi* was reported to have been completely eradicated, leaving *W. bancrofti* as the sole causative parasite for LF in Sri Lanka [50]. However, in 2017, a post-MDA surveillance study revealed a concerning resurgence of Bancroftian filariasis in certain areas and the unexpected re-emergence of Brugian filariasis after four decades [51][52].

1.2 Zoonotic Protozoal Infections

Cutaneous leishmaniasis (CL), a notable vector-borne parasitic disease, was first documented in Sri Lanka in 1992 [53]. This disease is caused by a specific genetic variant of *Leishmania donovani* and has become a significant focus of medical research due to its unique epidemiological features in the region. Investigations from 2001 to 2005, covering districts such as Kandy, Matale, Kurunegala, Anuradhapura, Vavuniya, Trincomalee, and Jaffna across the Central, North Central, North Western, Northern, and Eastern provinces, representing diverse agro-climatic zones, consistently identified *L. donovani* as the sole species causing CL in Sri Lanka [54]. The disease's spread and the increase in human cases are likely attributed to historical antimalarial campaigns, limited professional awareness, and recent military operations that brought people into closer contact with the sylvatic cycle [55]. Most CL cases have been found in low-lying, arid, and intermediate zones where *Phlebotomine* sandflies are abundant, with no cases reported in high-altitude regions [54].

Toxoplasmosis, an infectious disease caused by the intracellular coccidian protozoan *Toxoplasma gondii*, poses significant risks to foetal health due to its ability to transverse the placental barrier and infiltrate foetal tissues. This can lead to severe outcomes such as spontaneous abortions and congenital anomalies [56]. Recent research reveals a notable difference in seroprevalence between two groups: healthy pregnant women and those who have had spontaneous miscarriages. Specifically, 62.2% of healthy pregnant women tested positive for *T. gondii* IgG, compared to 37.8% of women who experienced miscarriages, suggesting a potential link between toxoplasmosis and pregnancy loss [57]. Moreover, epidemiological data from 2009 to 2015 indicate an alarming increase in toxoplasmosis cases, predominantly affecting males. In a single year, the National Hospital of Sri Lanka recorded five cases of central nervous system toxoplasmosis, all among HIV-positive patients [58]. This underscores the critical intersection of HIV and opportunistic infections, with increasing HIV/AIDS prevalence in Sri Lanka heightening the risk of HIV-associated toxoplasmosis, which can mimic neoplastic lesions, complicating diagnosis and management [58].

Malaria, a serious vector-borne disease instigated by the protozoan parasite *Plasmodium*, is primarily transmitted through bites from infected female *Anopheles* mosquitoes [59]. Historically, Sri Lanka has struggled with malaria, predominantly caused by *Plasmodium falciparum* and *Plasmodium vivax* [60]. The principal vector, *Anopheles culicifacies*, has been persistent in many regions of Sri Lanka for decades. A significant development occurred in December 2016 when *Anopheles stephensi*, a secondary malaria vector, was first detected on Mannar Island. Since then, this species has been identified in several districts, raising concerns about a potential malaria resurgence [61]. Sri Lanka has experienced several malaria epidemics throughout its history, notably in 1934–1935, 1967–1969, 1986–1987, and 1990–1992 [61][62]. Although Sri Lanka achieved the World Health Organization's certification for malaria eradication in 2016, the country remains vulnerable to reintroduction of malaria due to the influx of people from malaria-endemic regions and the continued presence of vector mosquitoes in the country [61][63].

A case-control study conducted at Lady Ridgeway Hospital in Colombo, Sri Lanka, revealed that 9.3% of paediatric patients with diarrhoea were found to have parasitic infections. Notably, 6.5% of these cases involved parasites known to cause diarrhoea. The investigation identified *Cryptosporidium spp.*, *Giardia lamblia*, and *Entamoeba histolytica* in stool samples [64]. In a separate study conducted in the Kandy district, which included both adults and preschool-aged children, the prevalence of parasitic cysts and oocysts was assessed. This study found a prevalence of 0.8% for *Giardia* cysts and 0.3% for *Cryptosporidium* oocysts among stool samples from preschool children [65].

Entamoeba histolytica, a zoonotic protozoan parasite, causes amoebiasis in humans. The infection spreads through the ingestion of mature cysts or trophozoites found in the faeces of infected individuals or asymptomatic carriers. Inside the large intestine, trophozoites can either stay in the intestinal lumen, leading to non-invasive infections, or penetrate the intestinal mucosa, causing invasive conditions like amoebic colitis or intestinal amoebiasis. Additionally, trophozoites may enter the bloodstream and affect extra-intestinal organs such as the liver, brain, and lungs, resulting in extra-intestinal amoebiasis [66].

Amoebic Liver Abscess (ALA) is the most common form of extra-intestinal amoebiasis and can be severe, with high morbidity and mortality if not treated promptly [67]. The earliest known case of hepatic amoebiasis in Sri Lanka, formerly Ceylon, was reported in 1821 [68]. Since then, many ALA cases have been documented, especially in the northern regions of Sri Lanka, with no cases reported elsewhere in the country [68]. A longitudinal study at Jaffna Teaching Hospital from July 2012 to July 2015 revealed a notable decline in annual ALA incidence from 9 cases in 2012 to 3 cases in 2015. The study also highlighted that the majority (94.2%) of patients were men aged 31 to 50, indicating a specific demographic trend [69].

Trypanosomiasis, a disease caused by protozoan parasites of the genus *Trypanosoma*, affects a broad range of hosts, including humans, domestic animals, and wildlife. These parasites are predominantly transmitted through the bites of blood-feeding tsetse flies. The two primary forms of pathogenic human trypanosomiasis are Human African Trypanosomiasis (HAT), commonly known as sleeping sickness, and Chagas disease, endemic to Latin America [70]. To date, conventional forms of trypanosomiasis have not been documented in Sri Lanka. Nonetheless, an exceptional case of human trypanosomiasis was reported in the country in 1999. This atypical case of human trypanosomiasis involved the parasite *Trypanosoma evansi*, which was identified through both morphological assessment and molecular confirmation [71].

Balantidiasis is a zoonotic disease caused by the ciliated protozoan *Balantidium coli*. This parasite primarily infects pigs, which serve as its principal reservoir, but can also affect other primates, including humans, and occasionally guinea pigs, dogs, and rats [72]. Although often asymptomatic, balantidiasis can present with clinical features resembling those of dysentery caused by *Entamoeba histolytica*. Symptomatic cases are marked by mucous-bloody diarrhoea, abdominal cramps, fever, nausea, and vomiting [73]. In Sri Lanka, the first documented instance of human infection with *Balantidium coli* emerged in 2011. The case involved a female patient who was found to have a concurrent infection with *Strongyloides stercoralis* and *Balantidium coli*, in addition to Pemphigus vulgaris [74]. This case remains the sole recorded occurrence of balantidiasis in Sri Lanka, highlighting the rarity and complexity of this protozoal infection in the region.

In addition to the well-documented protozoal zoonoses, an intriguing case of *Cyclospora* infection was identified in a foreign visitor in the year 2000 in Sri Lanka, as reported by Dissanaike (2002). This particular instance highlights a significant aspect of protozoal diseases that may otherwise go unnoticed. Dissanaike's observations point to a critical limitation in current diagnostic protocols: the routine measurement of oocysts and their sporulation is not systematically performed [2]. This omission raises concerns about the potential underreporting of *Cyclospora* cases, suggesting that many infections may remain undetected due to inadequate diagnostic practices.

1.3 Zoonotic Arthropod infections

In Sri Lanka, rickettsial infections have emerged as a significant public health issue, with increasing evidence of their widespread occurrence. Rickettsial pathogens, transmitted primarily by ectoparasites such as ticks and mites and occasionally by lice and fleas [75], have been identified throughout the country, with a notable concentration in the Central Province [76]. Recent research in the Kandy and Kurunegala districts has clarified the role of specific arthropod vectors in these infections. Studies

focusing on rodent populations revealed key vector species including *Xenopsylla cheopis* (the oriental rat flea), *Rhipicephalus haemaphysaloides*, *Ixodes ceylonensis*, *Haemaphysalis spinigera*, and *Stivalius aporus* [77]. These species are crucial in the transmission of rickettsial diseases, illustrating the complex ecological interactions between hosts and vectors.

A comprehensive 16-year study from 2001 to 2016 in Kandy found a significant correlation between intra-aural tick bites and unilateral facial palsy in 29 patients. This study also noted high incidences of otoacariasis and seropositivity for spotted fever rickettsioses among those affected. Several tick species were implicated, including *Dermacentor*, *Amblyomma*, *Rhipicephalus*, and *Hyalomma*, highlighting the intricate relationship between tick-borne pathogens and facial nerve disorders [78]. Further research has broadened the scope of known rickettsial vectors. Rickettsiae were detected in *Amblyomma testudinarium* from wild boars, *Rhipicephalus sanguineus* from domestic dogs, and *Amblyomma clypeolatum* from star tortoises [79]. These findings emphasize the wide ecological range of rickettsial pathogens and the need for extensive multi-host surveillance to manage and control these diseases effectively.

Myiasis, a parasitic infestation caused by the larvae of dipterous flies, poses significant concerns in zoonotic disease dynamics with implications for human health. While myiasis commonly affects skin wounds, it can also involve less frequent sites such as the eyes, nasal passages, digestive tract, and urogenital areas [80]. The first known human case of myiasis in Sri Lanka was documented in 1954 and involved a nasal infestation by *Chrysomya bezziana Villeneuve* [81].

Ophthalmomyiasis, a form of ocular involvement, occurs in less than 5% of human cases and is primarily caused by the larvae of *Oestrus ovis*, which are obligate parasites of the nasal and sinus cavities in domestic ruminants like sheep and goats [82]. Ophthalmomyiasis is categorized into external types—affecting superficial ocular structures such as the eyelid and conjunctiva; and internal types—involving deeper ocular tissues, including the anterior and posterior chambers [83]. In Sri Lanka, myiasis is relatively rare. The first recorded case of human ophthalmomyiasis was in 2004 in the Puttalam district [84], and a more recent case involved a 28-year-old sailor in 2022, highlighting the sporadic nature of this infection in the region [85].

Cutaneous myiasis encompasses three primary forms: furuncular, migratory, and wound myiasis [86]. Research conducted at Kalutara and Colombo General Hospitals beginning in July 1997 identified two larval species: *Chrysomya bezziana* and *Chrysomya megacephala*. Notably, *C. megacephala* was recorded for the first time in Sri Lanka, while *C. bezziana* was found to be more prevalent [87]. Further studies between 2016 and 2017 across eleven hospitals in the Central Province revealed 28 cases of cutaneous myiasis, with 26 being wound myiasis and two cavity myiasis affecting the male urogenital tract. In this study, both *C. bezziana* and *C. megacephala* were identified, with larval morphology assisting in precise identification [81].

2. PREVENTION AND CONTROL

For a pathogen to successfully establish an infection in humans or other vertebrates, it requires a confluence of specific stimuli [88]. The outcome of this interaction is heavily influenced by the host's response, which is shaped by genetic factors and innate resistance mechanisms [89]. However, the establishment of disease is not solely the result of direct contact between host and pathogen; it is also significantly impacted by the surrounding environmental context. This environment can be divided into three interconnected domains: physical, biological, and socio-economic factors, each playing a crucial role in modulating disease susceptibility and progression [88].

Key climatic variables such as temperature, humidity, wind patterns, and rainfall, along with physical features like topography, river systems, soil types, and landscape variations—from mountains to plains—are crucial in shaping disease dynamics [90]. Additionally, biological factors extend beyond the pathogens themselves to include reservoir hosts, vectors responsible for transmission, and the surrounding vegetation [91]. Furthermore, the host's microenvironment, including genetic predispositions, biochemical profiles, and levels of innate and acquired immunity, is critical in determining susceptibility to infections [92]. Social and economic conditions, including human movement patterns, urban development, infrastructure projects, and cultural practices, also significantly impact disease prevalence, persistence, and dissemination [93][94]. These interconnected variables collectively shape the complex landscape of disease ecology.

Effective management of parasitic zoonoses requires a multifaceted approach involving various preventive and control strategies. Essential measures include promptly diagnosis, comprehensive patient care, vector management, vigilant disease monitoring, control of reservoir hosts, community engagement, and strategic partnerships [95]. Timely diagnosis and management are pivotal for reducing disease incidence, preventing complications, and mortality [96].

In Sri Lanka, national surveys have shown a significant reduction in lymphatic filariasis (LF) and soil-transmitted helminthiases (STH) prevalence, from 6.9% in 2003 to 1% by 2017. Mass chemotherapy with diethylcarbamazine and albendazole played a key role in decreasing the prevalence of LF while reducing the microfilaria rate from 0.21% in 2001 to 0.06% and 0.03% in 2016 and 2022, respectively, reflecting continued progress in managing these parasitic diseases [48][97].

2.1 Vector Control

In managing vector-borne diseases such as leishmaniasis, where vaccine development remains a challenge, preventive strategies focus on reducing exposure to vectors (sand-flies, mosquitoes, ticks, fleas, etc.) through chemical, biological, and environmental control measures [98].

Chemical control methods, such as indoor residual spraying (IRS), are widely used globally and have proven effective in reducing disease prevalence in regions like Morocco [99]. However, the growing issue of resistance among sand fly populations, observed in studies across Africa and Asia, complicates the long-term effectiveness of these chemicals [100][101]. This resistance highlights the necessity of a diversified approach, integrating both biological and environmental controls.

Biological control approaches utilize microorganisms like *Bacillus thuringiensis israelensis* (BTI) and *Bacillus sphaericus* or macro-organisms like larvae-eating fish, which target larvae of vectors and offer promising alternatives to chemical controls [60][102][103]. These biological agents are effective in reducing larval populations, but their practical application across diverse settings requires further research and validation.

Environmental control strategies aim to modify the habitats of vectors to disrupt their breeding cycles. [104]. Sand flies typically reproduce in dark, humid environments rich in organic matter, such as wall crevices. Effective environmental management practices include plastering or applying cement skirting to walls and floors to eliminate these breeding sites by rendering them inhospitable [105][106].

In the context of zoonotic diseases like rickettsiosis, ectoparasites—ticks, fleas, mites, and lice—serve as critical vectors. These parasites infest a range of animals, including domestic pets, livestock, and wildlife such as birds, rabbits, and rodents [107]. To control zoonotic pathogens, timely acaricide treatments for companion animals and agricultural livestock are crucial. Acaricides help eradicate ectoparasites, thereby mitigating the risk of zoonotic infections in humans. Implementing rigorous acaricide application strategies alongside other control measures can significantly enhance public health outcomes and ensure a safer environment for both humans and animals.

2.2 Education and Public Awareness

Sri Lanka currently experiences a lower severity of zoonotic infections compared to Western nations, underscoring the potential for enhanced prevention strategies [108]. Effective management of zoonotic parasitic infections influenced by ecological factors requires comprehensive education, increased awareness, and behavioural modifications, including improved dietary practices.

For zoonoses transmitted by nematodes and cestodes, where cats and dogs serve as intermediate hosts, robust pet management is crucial. Regular deworming of pets and preventing their access to human food sources not only curb the transmission of parasitic zoonoses but also underscore the importance of responsible pet ownership.

Pregnant women should be provided specific guidance on safely interacting with cats, as they can be vectors for *Toxoplasma gondii*. Adhering to rigorous hygiene practices during and after contact with cats is essential to mitigate risk. Additionally, to prevent CLM, maintaining strict hygiene protocols, including the use of appropriate gloves and footwear, are important measures.

2.3 Control of the Reservoir Hosts

To combat zoonotic diseases linked to reservoir hosts and strengthen community involvement, a strategic approach is crucial. Rodents, significant carriers of parasitic zoonoses, necessitate targeted population control efforts [4]. Improper waste disposal is a major factor contributing to rodent overpopulation. Therefore, implementing rigorous waste management practices and launching comprehensive public education campaigns are essential. These measures will help reduce the rodent population and prevent the spread of parasitic zoonoses, ultimately fostering a healthier environment.

In Sri Lanka, researchers have identified 33 parasitic zoonotic species in humans, five of which—*Balantidium coli*, *Plasmodium spp.*, *Sarcocystis spp.*, *Bertiella studeri*, and *Echinococcus granulosus*—are also present in monkeys, serving as potential reservoir hosts [2]. The intrusion of monkeys into human areas is driven by deforestation, habitat degradation, and the fragmentation of wildlife corridors due to agricultural and urban development. To address these emerging threats, it is vital to implement proactive strategies, including habitat conservation and restoration, sustainable agricultural practices, and development plans that prioritize the preservation of wildlife corridors and habitat connectivity [109]. This holistic approach will improve biodiversity conservation and mitigate zoonotic disease transmission between wildlife and humans.

2.4 Meat Inspection

Preventing parasitic zoonoses requires crucial efforts from veterinarians and public health inspectors, focusing on strict adherence to meat inspection protocols. These measures are vital as zoonotic parasites often use intermediate hosts like cattle, goats, and pigs. Examples include *Echinococcus granulosus*, which can cause hydatid cysts in the liver and lungs, and cysticerci from *Taenia* and *Sarcocystis* species found in pork and beef.

In 2018, a case of cystic echinococcosis, or hydatid disease, was reported in a young adult in Sri Lanka, emphasizing the importance of this issue [110]. Additionally, human echinococcosis has been detected in communities near slaughterhouses in the Western province of Sri Lanka through blood sample analyses [111].

To mitigate zoonotic risks, it is imperative to examine all meat parts meticulously and remove suspected parts. Consumers also have a responsibility to have thoroughly cooked meat to prevent the acquisition of these diseases. Such measures are essential for safeguarding public health and minimizing parasitic zoonoses.

2.5 Research and Inventions

To combat parasitic zoonoses effectively, harnessing cutting-edge scientific advancements and leveraging comprehensive research is crucial for the innovation of novel vaccines and immunological therapies. Selecting and breeding hosts with inherent resistance to parasitic diseases has proven successful in mitigating the impact of these diseases [112]. The overarching aim is diminishing both pathogenicity and clinical manifestations associated with zoonoses. Improving diagnostic techniques and protocols (e.g., *Cyclospora* oocysts detection) is essential for better understanding and controlling infections in Sri Lanka.

Moreover, the increasing global interest in indigenous and Ayurvedic medicine offers a unique opportunity to enhance anti-parasitic agent development. Integrating traditional knowledge and ayurvedic practices with modern science could lead to discovering new parasiticides from plant-based ethno-medicinal resources. This synergy could significantly boost efforts to tackle parasitic diseases, improving both prevention and treatment outcomes.

2.6 Mitigating Parasitic Risks from Foreign Arrivals

To safeguard Sri Lanka from the infiltration of parasitic zoonoses via foreign travellers, it is imperative to adopt a multifaceted strategy. First and foremost, the implementation of stringent health screening and quarantine measures for individuals arriving from endemic regions is essential. This should be

complemented by an enhancement of surveillance mechanisms at entry points to promptly identify and manage potential cases of parasitic infections (e.g. Malaria, Visceral Leishmaniosis).

Educational initiatives targeting travellers are equally critical. These programs should emphasize the dangers of parasitic diseases and the necessity of adhering to stringent hygiene practices, such as avoiding exposure to contaminated soil and water sources. Furthermore, bolstering public health campaigns to elevate awareness and foster preventive behaviours among both residents and visitors will be crucial in mitigating risks.

2.7 Governmental Strategies and Interventions

Effective government intervention is pivotal in managing and preventing parasitic zoonoses in Sri Lanka. To address these challenges comprehensively, a coordinated approach encompassing several key governmental activities is essential.

2.7.1 Allocation of resources and research funding

A foundational step in combating parasitic zoonoses is securing government support and funding for research. By investing in scientific studies, the government can enhance understanding of parasitic diseases, develop advanced diagnostic tools, and identify effective treatment strategies. Funding should also extend to research on emerging threats and the development of innovative control measures.

2.7.2 Public awareness and education campaigns

Public awareness campaigns are crucial in educating citizens about parasitic zoonoses, their transmission, and preventive measures. Government-led initiatives should focus on disseminating information about hygiene practices, safe handling of animals, and the risks associated with contaminated water and soil. These campaigns can be delivered through various channels, including the media, community outreach, and educational institutions.

2.7.3 Routine diagnostics and surveillance programs

Implementing mass-scale routine diagnostic programs is essential for the early detection and management of parasitic infections. The government should establish comprehensive surveillance systems to monitor the prevalence of parasitic diseases across different regions. Regular diagnostics, coupled with robust data collection and analysis, will enable timely intervention and control measures.

2.7.4 Water Quality and Sanitary Infrastructure

Ensuring clean and safe water is a critical component of preventing parasitic infections. The government should prioritize water quality management by investing in infrastructure improvements, such as advanced water treatment facilities and regular testing. Enhancing sanitary infrastructure, including waste management systems and sewage treatment, is equally important to reduce the risk of contamination and disease spread.

2.7.5 Animal health management and control

Effective management of animal health is vital to controlling zoonotic diseases. Government initiatives should include programs for controlling the stray animal population through neutering and spaying, as well as enforcing responsible animal control practices. Strengthening animal health services and vaccination programs will also help reduce the incidence of parasitic diseases transmitted by animals.

2.7.6 Policy and Regulatory Framework

Developing and enforcing robust policies and regulations is essential for managing parasitic zoonoses. The government should implement and regularly update guidelines for disease prevention and control,

ensuring compliance across various sectors, including agriculture, healthcare, and environmental management. Strong regulatory frameworks will support coordinated efforts and ensure the effective application of preventive measures.

2.7.7 International collaboration

Collaboration with international health organizations and neighbouring countries is crucial for addressing parasitic zoonoses. The government should engage in partnerships to share knowledge, resources, and best practices. International cooperation will enhance surveillance capabilities, facilitate research, and enable coordinated responses to emerging parasitic threats.

Through these concerted efforts, the government can effectively mitigate the risks associated with these diseases and safeguard public health.

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