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Ecological and health impacts of animal movements in parasite dissemination

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Abstract

Animal movements are a fundamental ecological process, essential for survival, reproduction, and habitat exploration. However, these movements also play a pivotal role in the transmission and dissemination of parasitic pathogens. From livestock migrations and pet relocations to global trade and wildlife forays, each form of movement can introduce parasites into new environments, causing outbreaks and shifting disease dynamics. This review explores the types and implications of animal movements in parasite epidemiology, discusses species-specific risks, highlights notable case studies, and provides an evidence-based framework for disease prevention and control. The review underlines the urgent need for integrated surveillance systems and biosecurity protocols to manage parasitic diseases that affect both animal and human populations.

Keywords: Animal movements, parasitic pathogens, migration, seasonal movements

Introduction

Animal movements refer to the various ways in which animals change their physical location or position in their environment. Animals move for many reasons, often to improve their chances of survival. Whether it's searching for food, avoiding predators, or finding a mate, movement is essential to meeting basic needs. These movements can range from short, localized shifts within a specific area to long-distance migrations that span significant distances. Animals exhibit different movement patterns based on factors such as their species, behaviour, life stage, and environmental conditions. The study of animal movements provides insights into their behaviours, interactions, and ecological roles. Movement patterns can be categorized into several types:

- **Migration:** Migration is the controlled, seasonal migration of animals over a relatively large distance, when they move from one area to another and then back again. It is more or less synchronized. This behaviour is often driven by changes in resources, climate, or breeding conditions (Dingle, 1996) ^[4]. The passage of some fish species upstream to spawn or the migration of birds between their breeding and wintering sites are two examples.
- **Dispersal:** Dispersal involves the movement of individuals away from their birthplace or their current location to establish new territories or populations. It is not necessarily directional or seasonal and does not necessarily involve return to the point of origin. This movement is crucial for genetic diversity, population expansion, and adaptation to changing environments (Poulin *et al.*, 2021) ^[14]. In order to escape competition within their natal territory, young animals frequently disperse.
- **Nomadism:** Some animals exhibit a nomadic lifestyle, characterized by irregular and unpredictable movements in search of food, water, or suitable habitats. Nomadism is common in certain herbivores that follow changing vegetation patterns or grazing opportunities.
- **Local Movement:** Local movement refers to relatively short-range shifts within a particular area or home range. Animals engaging in local movement are often driven by daily activities like foraging, mating, and territorial defence.

These movements help individuals access different resources within their established territory.

- **Territorial Movement:** Territorial animals move within and defend a specific area against intruders of the same species. These movements are essential for protecting resources, finding mates, and establishing dominance within a particular territory.
- **Daily or Circadian Rhythms:** Many animals exhibit regular movements tied to the daily cycle of light and darkness. For instance, nocturnal animals are active at night, whereas diurnal creatures are active during the day.
- **Navigational Movements:** Navigation is a guided movement of animals or birds from one location to the other. Some animals, such as migratory birds and certain insects, have the ability to navigate across vast distances using cues like the Earth's magnetic field, celestial landmarks, and environmental cues.
- **Exploratory Movement:** Animals may engage in exploratory movements to learn about their environment, find new resources, or locate potential mates.

The various types of animal movements play critical roles in ecological processes, including nutrient cycling, seed dispersal, and predator-prey interactions. Understanding these movement patterns is essential for studying species behaviour, population dynamics, and the spread of diseases and parasites.

How animal movements contribute to parasite spread

The connection between animal movements and the spread of parasites is a crucial factor in understanding how infectious diseases propagate. In spite of strict regulations on animal movements, outbreaks usually occur as a result of legal or illegal animal movements. Here's how animal movements contribute to parasite spread:

- **Introduction of parasites to new areas:** Animals carrying parasites can introduce these pathogens to regions where they were not previously present. When infected animals move from one place to another, they bring along parasites and their infectious stages, such as eggs, larvae, or cysts.
- **Transmission through Direct Contact:** When animals move, they often come into contact with other animals. This close proximity can lead to the direct transfer of parasites from one host to another. Parasites can be transmitted through physical contact, mating, grooming, or fighting.
- **Contamination of the Environment:** Infected animals shed parasite eggs, larvae, or cysts into the environment through faeces, saliva, or other bodily fluids. These infectious stages can persist in the environment and be picked up by other animals that come into the same area later.
- **Vector-Borne Parasites:** Some parasites rely on vectors (such as mosquitoes, ticks, and fleas) to spread from host to host. Animal movements can influence vector distribution, increasing the risk of vector-borne disease transmission.

Migration and Seasonal Movements

Migratory animals, such as birds and certain mammals, can carry parasites across vast distances during their seasonal migrations. This movement can introduce parasites to new geographic areas, impacting both local wildlife and domestic animals. Migration of animals may result inter-species interactions involving large number of individuals of different

geographic locations. Hence migration may generate super spreader hosts and infection hot spots in time and space (McKay and Hoyer, 2016) ^[11]. For example, finches likely introduced *Trichomonas gallinae* from the UK to Scandinavia, and various migratory species have helped transmit haemosporidian parasites like *Plasmodium relictum* the cause of avian malaria between continents and even to Hawaiian honeycreepers after mosquito vectors were introduced. Parasites infecting migratory hosts often attain significantly wider spatial distribution compared to those associated with non-migratory hosts. This enables them to expand their geographic range and increases the potential for host-switching. Relying on migratory hosts also places evolutionary pressure on parasites to synchronize their life cycles and phenological events such as development, reproduction, and transmission with the host's movement patterns. In some cases, natural selection may even favor parasites that can alter or influence their host's migratory behavior to optimize transmission opportunities. (Poulin *et al.* 2021) ^[14]. Migratory animals are often at a higher risk of parasitic infections compared to non-migratory species, primarily due to a physiological trade-off between the energy demands of long-distance travel and the maintenance of immune function. As these animals traverse multiple and often ecologically distinct habitats ranging from breeding and wintering grounds to stopover sites they encounter a broader array of parasites, leading to greater exposure and infection risk (Leung & Koprivnikar, 2016) ^[9]. This heightened exposure is reflected in studies showing that migratory species tend to harbor more diverse parasite communities than their sedentary counterparts. Parasites, in turn, face unique challenges and opportunities when associated with migratory hosts. Being transported over long distances can expand a parasite's geographical range and genetic diversity while increasing chances of host-switching. However, this also imposes selective pressures on parasites to adapt their life cycle timing, development rates, and survival strategies to match the hosts' migratory schedules and fluctuating environmental conditions (Cohen & Satterfield, 2020) ^[2]. Parasitic infections can directly impact migration success by reducing host performance, causing delays, increased stopovers, disorientation, or even mortality. In some instances, parasites may evolve mechanisms to manipulate host behavior, modifying migration patterns in ways that enhance parasite transmission. This dynamic creates a reciprocal coevolutionary relationship between hosts and parasites, where each influences the evolutionary trajectory of the other.

Trade and Livestock Movement

The movement of livestock for trade, agriculture, and food production can spread parasites across regions and even between countries. Animals are often transported long distances, potentially carrying parasites with them. Unofficially traded animals pose a major risk of spreading infectious diseases as they are always not subjected to veterinary controls. Outbreak of human sleeping sickness caused by *Trypanosoma brucei rhodesiense* in Uganda is caused by movement of its reservoir host cattle without proper screening through the markets. Apart from trading of livestock, global trading of wild life and wild life products is also huge, which results in vast number of direct and indirect contact of wild animals with livestock and human beings. For example, introduction of two ornamental fresh water fisher the sunbleak (*Leucaspis delineatus*) and the top mouth gudgeon

(*Pseudorasbora parva*) in to UK in mid-80's, lead to the recent detection of an opisthorchid fluke (*Pseudamphistomum truncatum*) in English otter population as the both fishes act as intermediate host for the latter. Modern international trade in livestock continues to influence the epidemiology of foodborne parasites. Despite restrictions in some countries such as Australia banning live livestock imports from all nations except New Zealand since 1952 trade remains extensive. The Food and Agriculture Organization (FAO) tracks trends in global livestock movement, showing increases in pig exports between 1997 and 2007. This has significant implications, as pigs are major reservoirs of *T. solium*, *T. spiralis*, and *Toxoplasma gondii*, all of which pose considerable public health burdens if meat inspection systems are inadequate (FAO, 2007) [5].

The mass importation of cattle has also been linked with parasite outbreaks. In Israel, the incidence of bovine cysticercosis increased from 4% to 38% following the large-scale import of live cattle (Pozio & Zarlenga, 2013) [16]. A similar incident occurred in the Netherlands in 2007, where cattle imported from Romania were found to carry *Echinococcus granulosus*, a parasite previously eradicated in the country. This prompted the re-introduction of targeted surveillance strategies to maintain parasite-free status (Craig *et al.*, 2007) [3].

Urbanization and Human Associated Movements

People are moving from rural to urban areas as a result of the acceleration of urbanization in recent decades. In 1900, only 10% of the global population lived in cities; by the early 21st century, this rose to 50%, and urban expansion is expected to continue. Urbanization leads to rapid and permanent environmental changes, often reducing biodiversity. As urban areas expand; wildlife may come into closer contact with domestic animals and humans. This can lead to the spread of parasites that can infect both wildlife and people (Moloi, 2024) [12].

Globalization

Globalization, a primarily human-driven phenomenon, involves the extensive movement and exchange of goods, people, animals, and organisms across the globe. While globalization facilitates economic growth, trade, and knowledge sharing, it also has significant unintended consequences particularly the spread of infectious agents, including zoonotic and foodborne parasites (Robertson *et al.*, 2014) [17]. For example, liver fluke Because of the post-domestication mobility of herbivores across continents, *Fasciola hepatica* has spread throughout the world. Its distribution is closely associated with the global transport of cattle, sheep, and other large ruminants (Mas-Coma *et al.*, 2009) [10]. Similarly, *Trichinella spiralis*, a foodborne nematode parasite primarily associated with pigs, has achieved near-global distribution. This spread is thought to have been aided by the synanthropic movement of rats that traveled alongside humans, promoting the dissemination of the parasite even in areas without pig farming (Pozio, 2007) [15]. Small-scale animal movements such as inter-farm grazing, breeding, veterinary visits and practices like pastoralism and animal fairs also play a crucial role in the spread of parasitic diseases by allowing close contact between animals from different regions, promoting the spread of diseases. Sheep and goats, frequently moved for grazing, sale, mating, or treatment, often transmit helminths like Trichostrongylids and other gastrointestinal parasites. Communal grazing and lack

of quarantine lead to anthelmintic resistance and the spread of parasites such as *Fasciola hepatica* via contaminated water or *Thelazia* spp. through ocular secretions. Parasites like mange mites and lice may spread via contact with contaminated surfaces (e.g., fence posts). Bringing in new animals without proper quarantine can introduce drug-resistant parasites, mange mites, or tick-borne infections. Breeding practices in sheep and goat also pose a risk of spreading parasitic diseases such as *Toxoplasma gondii*, *Neosporacanthium*, and *Besnoitiacapræ*. Movements to agricultural shows, veterinary clinics, or slaughterhouses may lead to environmental contamination and parasite transmission to or from other animals (Vasileiou *et al.* 2015) [20].

Does all movements carry parasites?

Nevertheless, dissemination of the various parasitic forms in the environment does not always result to subsequent infection. In the case of helminths with a direct life-cycle, presence of parasite eggs or infective larvae is necessary. In the latter case, hatching of the excreted eggs and development of the larvae, a process strongly influenced by environmental factors (Morgan and van Dijk, 2012) [13], is necessary. Hence, grazing of sheep or goats during the summer in areas with increased temperatures would not always result in presence of infective forms, as the ambient conditions decrease hatchability of eggs and lead to death of larvae (Taylor *et al.*, 2007) [19]. In the case of coccidian parasites, infection of adult animals at grazing is of little clinical significance itself. But these animals will later release oocysts, frequently when they are kept in the near postpartum period, which might cause their young to get infected.

(Saratsis *et al.*, 2011) [18]. Of course, coccidian infections of growing or fattening lambs or kids occur when these animals graze with the adults before slaughter. In the case of helminths with an indirect life-cycle, infection of other sheep or goats depends on the presence of the intermediate host, e.g., snails, ants or acari (genus Oribatidae), (Taylor *et al.*, 2007) [19]. Finally, ectoparasites that have been disseminated in the environment, have a limited life span outside a host, hence after that, they may not infest new animals.

Migratory escape and migratory recovery

One effective adaptive tactic to lower parasite infestations is animal migration. The migratory escape hypothesis suggests that animals migrate to avoid areas of high parasite prevalence, seeking refuges with lower infection risks (Poulin, 2021) [14]. This strategy is supported by examples across taxa from shorebirds evading vector-borne haemosporidians while migrating through higher altitudes and coastal habitats during non-breeding season to monarch butterflies and juvenile fishes escaping seasonal parasite loads. Additionally, migratory movements may spatially separate juveniles from infected adults, further lowering transmission. In contrast, the migratory recovery hypothesis proposes that migration allows infected individuals to recover by moving through or into environments unfavorable for parasite survival. For example, anadromous fish leave coastal water and return to river habitats to recover from sea lice when heavily infested as the sea lice cannot tolerate fresh water.

Zoonotic implications

Trypanosoma evansi, a tabanid-transmitted parasite causing surra in livestock, has recently emerged in parts of Southeast Asia particularly the Philippines with high mortality linked to

herd improvement driven livestock movements. Similarly, *Trypanosoma brucei rhodesiense* sparked a new sleeping-sickness outbreak in Uganda when infected cattle were traded in markets lacking adequate screening or disease control. In the UK, domestic pets are likely to spread *leishmaniasis*, *Dirofilaria immitis*, *babesiosis*, *Echinococcus granulosus*, and *E. multilocularis* to people.

Prevention of diseases during animal movement

Observation of the following steps by various stakeholders such as farmers, herdsman, consumers, traders, local governments, etc., can go a long way in prevention of diseases during movement of animals.

- Movement of animals from one location to another, within country and between countries is recorded.
- Only legal movement is permitted.
- Borders of adjoining countries are fenced to avoid illegal and unquarantined entry of animals.
- All new animals undergo quarantine check-up. Quarantine rules require that the animals are isolated and closely watched for 14 days to rule out diseases and if animals are found infected, they are denied entry.
- Only disease-free and vaccinated animals are allowed to enter new areas.

Conclusion

Animal movements whether natural migrations, trade-related translocations, or small-scale farm-level relocations are a major ecological force contributing to the spread of parasitic diseases. These movements enable parasites to cross natural barriers, reach naïve host populations, and expand their geographic range, often resulting in increased infection risks, emergence of drug-resistant strains, and zoonotic spill overs. Large-scale movements such as pastoralism, livestock trade, and animal fairs can disseminate pathogens across regions and even continents. Similarly, small ruminant movements for grazing, breeding, or veterinary care foster the transmission of gastrointestinal and ectoparasitic infections. Wildlife translocations and pet travel, if poorly regulated, also facilitate the spread of emerging parasites, some of which have serious zoonotic implications.

From the parasite's perspective, host movement serves as both a survival strategy and a selective pressure, shaping parasite life cycles, virulence, and transmission patterns. Host-parasite coevolution in the context of movement is an ongoing arms race, with ecological and evolutionary consequences for both sides. Given the rising pace of globalization, habitat alteration, and climate-driven shifts in animal movement patterns, the risks associated with parasite dissemination are likely to increase. Mitigation strategies such as quarantine protocols, vector control, pasture management, and policy-driven biosecurity measures are essential to limit the impact. A One Health approach that integrates veterinary science, wildlife ecology, and public health is critical to monitor, manage, and prevent the spread of parasitic diseases associated with animal movements.

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Conflict of Interest

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