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Helminth Infections of Livestock in Response to Changing Climatic Trends: A Review

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Research Article

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ABSTRACT

Parasitic helminthes are a major constraint worldwide and impact food security and incomes through their deleterious influences on livestock. Several pathogenic species e.g., *Haemonchus contortus* and *Fasciola hepatica* spend a large part of their complicated life-cycles as eggs, larvae etc., out on pastures and therefore, are directly affected by altered climatic conditions. Climate changes cause alteration in the dynamics of parasite transmission, spread of disease into naive populations and increasing the potential for host switching and exacerbating effect of some helminth diseases of livestock. The biological attributes of helminthes in relationship to their hosts and the environment are directly (distribution of helminthes) and indirectly (effects on hosts (range and abundance) affected by climate change/warming. Additionally, global climate change alters parasite epidemiology and, therefore, the effectiveness of current management and control strategies. Despite all the known and hypothesized postulations, the consequences of climatic changes on parasite-host interactions are difficult to forecast. The objectives of this paper are to review the impacts of climate change on parasitism and to explore how host physiology and parasite ecology can be better integrated to understand and predict the outcome of climate parasite interactions and host parasite dynamics. This review will be useful for future studies on this important interdisciplinary approach dealing with ecological aspects of helminthes as well as to those who are exploring new methods for examining the environmental quality and the interrelationship between climate alterations and the helminth parasitism.

INTRODUCTION

Parasitology has always been a discipline in which purely academic studies of the evolution of parasites, their life cycles, pathology and control of the major diseases of humans and their livestock have progressed [1]. Livestock produces 40% of global agricultural GDP and employs 1.3 billion people worldwide and creates livelihood for 1 billion people of the world. Livestock itself is seen as a major contributor to global environmental problems-contribute 18% of global greenhouse gases [2]. Parasitic helminthes or worms are a major constraint on livestock worldwide and impact food security and incomes through their deleterious influences on livestock, which is an important sector in agriculture [3]. The deleterious impact of helminthes on the livestock industry and their dependence on climatic conditions, predictions of long-term threats to animal health from climate change (climate warming) has attracted the attention of parasitologists in recent times [4]. The biological attributes of helminthes in relationship to their hosts and the environment are directly (distribution of helminthes) and indirectly [effects on hosts (range and abundance)] affected by climate change/warming. Determining how long-term climatic changes will affect the distributions of some helminth diseases (helminthoses) and to predict the important effects on helminthoses in livestock seems a daunting task.

Although the influence of climate on the development and mortality of the free-living stages of helminthes of livestock has been extensively studied and climate change might therefore be expected to affect parasite transmission, there is little published evidence [5,6]. Parasitic organisms being smaller, smart and prudent adapt and acclimate better than their hosts (more complex), and increases in climate variability make it easier for parasites to infect their hosts. Warm blooded creatures could also be less susceptible to helminthes than cold blooded creatures after unpredictable temperature fluctuations. For example, adult *Fasciola* (liver fluke) parasites, as they have larval stages and intermediate hosts out in the environment have been found to be greatly influenced by climatic alterations. Thus in line with the changes in climatic patterns, parallel changes in prevalence, seasonality and geographic distribution of most major helminthes of livestock is evident particularly *Haemonchus* spp., *Teladorsagia* spp., *Nematodirus* spp., *Fasciola* spp., and *Paraphistomum* spp., since survival and development of free-living stages is chiefly affected by temperature and moisture [7]. Therefore, the transmission rates, prevalence, intensity and pathogenicity of helminthes are expected to increase with increasing temperature, but only up to the extent of development and acquiring of immunity in the hosts to helminthes.

Based on the above background, this review paper was rationalized to include the latest developments of the influence of climate change in parasite-host dynamics in livestock sector with certain examples to illustrate key points, explain certain case studies and hypotheses based on various studies from different climatic zones of the world. Such a review can never be comprehensive, therefore, this review is a general description about the impact of climate change/warming on helminth parasitism and does not include any specific mention of a particular parasite rather it focuses on general helminth parasites (helminthes) of livestock. The objectives of this paper are to review the climate warming impacts on helminth parasitism and to understand and predict the outcome of climate warming and host-parasite interactions. This review will be useful for future studies on this important interdisciplinary approach dealing with ecological aspects of helminthes as well as to those who are exploring new methods for examining the environmental quality and the interrelationship between climate alterations and the helminth parasitism. In order to justify the objectives set in this review and to present a concise and elusive depiction of the text of the review, the paper is completed under the following subheadings:

1. How will climate change affect helminthes of livestock and the epidemiology thereof?
2. How will climate change affect parasite-host dynamics?
3. Can we predict climate change impacts on helminthoses of livestock?
4. Concluding assumptions and future work

1. How will climate change affect helminthes of livestock and the epidemiology thereof?

The aim of this section of the paper is to discuss the possible role of climate change in helminthoses in the current patterns of parasitic diseases. The climate in the world is changing, with a general trend towards warmer average temperatures and an extension of the herbage growing season over the past few decades. These changes may have implications for the epidemiology of helminthes of livestock because of its potential to have direct impact upon their free living stages in the environment and/or their intermediate hosts or vectors [8,9]. The economically important helminthes which are going to be influenced more are *Nematodirus battus, Teladorsagia circumcincta*, *Haemonchus contortus, Fasciola hepatica*, *Paramphistomum* spp. [7].

Climate change is now an accepted fact and the capacity of climatic conditions to modulate the extent and intensity of parasitism is well known since long ago [9]. Climate change likely will lead to increasingly favorable environmental conditions for many parasites and categorically NOT for all of the livestock parasites. However, predictions regarding climatic impacts on helminth parasitism often fail to account for the likely variability in host distribution and how this may alter parasite occurrence [9]. The current climate change scenario is expected to cause widespread shift in the pattern of a number of helminthes and alter the life cycle dynamics of vectors and parasites as well as dramatically influence the transmission potential of the vectors resulting in introduction of diseases into new areas (emergence) and or cause dramatic increase of the disease incidence in already endemic areas (re-emergence). However, the confirmation of the impact of climate warming on helminthoses has been reached very recently. We need an improved understanding of population genetics of the helminthes and the phenotypic and genotypic basis of adaptation to a changing climate.

Although helminthes are affected by climate change, their main difference with micro parasites lies on the usually longer life cycles of helminthes, longer generation times, slower population growth rates and longer time period needed for the response in the definitive host to become evident [9]. For example, discusses that the evolution of complex life cycles of trematodes that depend upon the availability of suitable environments for eggs, free-living stages, intermediate and final hosts might be thought to limit the survival of the parasites. Furthermore, the evolution of such complex life cycles of helminthes to enable adaptation to new niches created by climate change needs more time to be detectable than modifications in micro parasite populations. This has been the reason for previous studies to conclude that helminthes do not constitute priority targets in climate change impact studies and enough studies have not been conducted involving the helminthes and climate change [9]. Therefore, studies need to be carried out to emphasize the relationship between climate change and emerging and re-emerging helminth diseases.

Climate being an important epidemiological variable influences the helminthes of livestock differentially. For instance, tropical climates do not offer favorable conditions for the transmission and survival of some helminthes like nematodes including

Ostertagia and *Nematodirus* species; therefore, they are of more significance in temperate climatic regions of the world [10]. Similarly, other nematodes like *Bunostomum, Cooperia* and *Trichostrongylus* species prefer tropical climatic regions of the world. The climate warming will, therefore, alter the seasonal epidemiology of helminthes in livestock and these hypotheses have been proved in certain areas of the world. For example in their comparative studies on seasonal profile between Scotland and the Southwest have reported that the increased temperatures would tend to decrease the relative importance of spring disease, and increase the risk of autumn disease in Wales in recent years [11]. It is a well-known fact that accumulation of infective stages from successive generations of adult parasites is accelerated at higher temperatures, leading to higher parasite abundance and increased risk of disease from midsummer onwards. The need of the time is the establishment of national and regional systems for epidemiological monitoring that would assist the formulation of timely, evidence-based advice on impact of climate change on epidemiology of helminthes in livestock and the appropriate control strategies in future.

How will climate change affect parasite-host dynamics?

The climate change will have an impact directly and indirectly on livestock farming systems, the animals themselves and the helminth pathogens they contain. Will the rising and increasingly volatile environmental temperatures of climate change affect host-parasite interactions to a less or great extent, equally or unequally time will decide itself. However, it is not going to be a general phenomenon, but country and parasite-host specific. Impacts are likely to be most severe in livestock of developing countries [2]. Various reports specifically mention livestock disease risk as a direct consequence of climate change [12]. Under harsh environmental conditions of temperature, adult helminthes chiefly the gastrointestinal nematodes inside the host can enter an arrested stage (hypobiosis-aestivation) until conditions improve [13]. This pattern presents an interesting example of an ecological adaptation of a parasite to its local climatic conditions. Understanding the effects of climate change on the helminth epidemiology must, therefore, be a priority.

The rates of physiological processes in the majority of invertebrates are highly dependent on ambient temperature, and therefore, global warming will increase parasite development rates [14]. Knowing the temperatures that parasites need to grow and survive could help to determine the future range of infectious diseases under climate change. For example, in the Princeton University, researchers have developed a model on a species of nematode, *Ostertagia gruehneri that* can identify the prospects for nearly any disease-causing parasite as the earth grows warmer, even if little is known about the organism [15]. Thus knowing the parasite's body size, temperature dependence of the metabolism of a parasite, or the temperature dependence of its life cycle components, a model can be formulated to evaluate the impact of climate change on parasite fitness, and thus the regions in which the parasite may occur in the future.

Lafferty discusses about the range changes of parasites/pathogens, where he argued that for a given parasite, certain regions may become favorable, but others will also become unfavorable [16]. Therefore, we might expect range shifts, rather than range expansions. Many parasites are "ontogenetic niche specialists." That is, because of their complex life cycles, parasites end up occupying multiple specific niches during one generation. Pickles call this as "ecological mismatch" and explored this concept as it relates to climate warming [17]. That is, if the ranges of the hosts change with the climate, what happens to the range of the parasite? Each host might increase the size of its range, but if the hosts' ranges don't overlap, the parasite might actually lose some of its range.

In order to investigate into how climate impacts on different elements of transmission of helminthoses, correlative models have been developed which provide warnings of future risk of transmission of helminthes in a controlled grazing system, indicating a non-linear relationship between climate warming and parasite risk [4]. Global climate warming produces ecological perturbations, which cause geographical and phonological shifts, and alteration in the dynamics of parasite transmission, increasing the potential for host switching [18]. Climate warming may also be in the background of an ecological invasion, giving rise to disease agents or pathogen-vector/host complexes emerging in a newly colonised area [4]. The increased infection rates of *Haemonchus contortus*, *Teladorsagia circumcincta, Nematodirus battus* and *Fasciola hepatica* in temperate climates has been attributed to climate change, since the survival of the free-living stages is chiefly affected by temperature and moisture, and larval development rate is highly temperature dependent [19-23].

Can we predict climate change impacts on helminthoses of livestock?

In recent years, sharp increases in frequency and intensity of helminth diseases have been reported in livestock in certain regions of the world [11]. In the context of global climate change far-ranging effects might occur in the population dynamics and distributions of livestock helminthes, provoking fears of widespread increases in disease incidence and production loss. However, several biological mechanisms (including increased parasite mortality and more rapid acquisition of immunity), in tandem with changes in husbandry practices (including reproduction, housing, nutrition, breed selection, grazing patterns and other management interventions), might act to mitigate increased parasite development rates, preventing dramatic rises in overall levels of disease [24].

Climate warming in temperate regions tends to increase the developmental success of parasites, might be expected to increase pasture contamination with infective stages and may be one driver behind this trend [25]. For example, there have already been reports of altered seasonal patterns of nematode and liver fluke infections in northern parts of the UK [7]. In Switzerland, unpublished data suggest that *H. contortus* transmission is occurring at higher altitudes than previously recorded, and in Sweden, transmission occurs near the Arctic Circle [26]. Adult *Fasciola* parasites, as they have larval stages and intermediate hosts out in the environment that are exquisitely affected by their local micro-climate, have been found to be greatly influenced by climatic alterations. An interesting example can be taken of UK where ffasciolosis was historically only been identified in the wetter west of Scotland, and the drier east of the country was traditionally free from this parasite. However, since 2002, the presence of *F. hepatica* has been confirmed on most farms in the south east of Scotland [7]. Early evidence suggests that, on balance, global warming will increase nematode challenge to grazing sheep in temperate Europe, with faster development of infective larvae in summer and prolonged development into autumn outweighing effects of lower survival in milder winters for *Teladorsagia* and *Trichostrongylus* spp., while milder winters would facilitate over-winter survival of *Haemonchus* [27]. These epidemiological changes have been related to increased rainfall, or localised flooding, and the maintenance of suitable microhabitats, prompting speculation about the adverse effects of climate change. As a consequence, effective management of fluke disease has become problematic in traditional fluke areas in western regions of the UK [27]. Effective monitoring, including the investigation of disease outbreaks, is required to define the current prevalence of helminth parasitism and provide a benchmark to measure any future changes. However, the study of the effects of climate change on the endemic diseases of livestock is still in its infancy [8,12]. It is therefore, predicted that climate change will extend the seasonal window for parasite transmission and lead to amplification of parasite populations, disease outbreaks in host populations and spread of disease into naive populations.

The changes in climatic variables can alter parasite ecology by affecting host and geographic distribution, infection pressure, prevalence and intensity of parasites and can do so directly (via free-living stages) or indirectly (by affecting hosts) [28]. The climate change will also result in heavier and less frequent rainfall leading to greater extremes of weather (wetness and dryness) resulting in more variable numbers of parasites and greater nutritional stress on hosts with consequent reduced resistance to parasites. The construction of predictive computer models for the effect of climate change on helminth diseases requires baseline data on various species of important parasites that is currently lacking. We need further studies to explore how physiology and disease ecology can be better integrated to understand the outcome of climate–disease interactions.

Although there have been a number of studies aiming to link the recent changes in helminthoses abundance and distribution with environmental change, there is a lack of predictions for future helminth risk to livestock [6,7,9,11,19]. A number of programmes have been developed to determine a species climate envelope by matching current distribution with climatic parameters, such as CLIMEX, HABITAT, DOMAIN and SPECIES [29-32]. In addition to these generic models, species-specific correlative models have also been developed, however these models have primarily been applied to species of conservation importance and invasive alien species [4]. To date, correlative predictive models of helminthoses have focussed on *F. hepatica* due to the close relationship between weather and fasciolosis outbreaks and the worldwide importance of fasciolosis. Predicted climate changes will theoretically at least, have profound effects on epidemiology of helminthes of livestock, particularly for those having intermediate hosts out in the environment and whose free-living stages are sensitive to temperature, humidity and rainfall [33-40].

Concluding assumptions and future work

Global climate change is a dominant factor for current and future trends in helminth diseases in livestock with both direct and indirect impacts on livestock production, animal health and welfare. However, the study of the effects of climate change on the helminth diseases of livestock is still in infancy. There are still gaps in our knowledge in relation to the biology of parasites and pathogens and how they will respond to changing climatic conditions. Therefore, future studies on helminthes with an objective to minimize sampling effort and maximize useful bio-monitoring information are recommended. Much remains to be learnt regarding the climatic impacts, identification of key areas and implementation of effective, efficient, support and control for maintaining productivity in the face of major future climate challenges. Long-term parasitological surveys with improved methodologies, rigorous sampling design, and modeling procedures are needed to monitor long term change in global climate in relevance to parasites and to elucidate the impacts of climate change on the community structure of helminth parasites.

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