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EMERGING TRENDS IN VETERINARY PARASITOLOGY: ANIMAL HEALTH, DRUG RESISTANCE, AND SUSTAINABLE PARASITE CONTROL APPROACHES WORLDWIDE

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ABSTRACT

Veterinary parasitology is changing fast due to the pressures created by public concern about the health of animals, zoonotic diseases, climate change, and the increasing prevalence of drug resistance against antiparasitic agents. The development of new techniques for improving parasite detection, monitoring drug resistance, and establishing sustainable control strategies (for livestock, pets, and wildlife worldwide) is a major focus of current research in this area. Technological advancement in molecular diagnostics, sequencing genomes, and utilizing Artificial Intelligence technologies allow for earlier identification of parasitic infections as well as differential treatment of parasitic infections based on individual animals' needs. Current issues with conventional anthelmintic resistance also represent a significant challenge globally, especially in grazing animals, and are causing reduced treatment efficacy and economic loss. Researchers are now investigating alternative, eco-friendly methods of controlling parasites (including naturally occurring chemical agents, plant-derived therapeutics, vaccines, biological control agents, selective treatment protocols, and integrated parasite management systems). Additionally, climate change and international transportation of animals are being recognized as having a significant impact on the geographic distribution of parasites and their vectors; thus creating new risks to animal health and public health. Sustainable parasite management is also recognizing the need for reduced reliance on chemicals to control parasites, greater emphasis on managing farms to be sustainable, and the adoption of the One Health concept, which refers to the interconnectedness of animal health, human health, and environmental health.

Keywords: *Veterinary parasitology, animal health, drug resistance, sustainable parasite control, zoonotic parasites, integrated parasite management, anthelmintic resistance, One Health, molecular diagnostics, climate change.*

Introduction

Veterinary parasitology is important to both improving animal health, as well as improving livestock production throughout the globe. Helminths, protozoa, and ectoparasites are capable of infecting animals and thereby preventing growth, reproduction, and immunity from developing. Consequently, infections with these parasites can have an adverse impact on livestock producers and the agriculture/veterinary sectors, and lead to substantial economic losses. For many developing countries, particularly those reliant on livestock as a means of their rural livelihood and food security, the burden of parasitic diseases is still an impediment to sustainable animal production. Many parasites impact not only domestic animals, but they also create zoonotic disease risks, which pose a threat to human health, and are transmitted directly or indirectly from animals to humans. As a result of the increased demand for animal products, the development of effective parasite management practices in veterinary medicine has been emphasized. In order to lessen the impact of parasitic infections to global animal health systems, both veterinarians and researchers are working to develop new and improved methods for diagnosing parasites, preventing parasitic infections, and treating parasitic infections. In addition to addressing disease control, modern veterinary parasitology is also focused on supporting public health, environmental sustainability, and economic development through integrated approaches designed to enhance animal welfare and reduce the global burden of infectious disease(Taylor et al., 2016)

The geographical distribution and epidemiology of animal parasites and their vectors have changed significantly due to climate change and globalization. The rise in temperatures globally, changes in rainfall, and disturbance of the environment have created a multitude of favorable conditions to enhance the survival and transmission of many parasitic organisms in areas where they were previously not endemic. Therefore, diseases once limited to tropical/subtropical regions are being reported in temperate regions, making it increasingly likely that new or renewed parasitic diseases will occur. The increased movement of animals globally and the increase rate of international trade, and means of transportation into areas with no prior exposure to certain types of parasites will create major veterinary health issues for authorities around the world due to the increasing spread of parasites across borders. As vector-borne parasites (i.e. ticks, mosquitoes, flies) expand into new ecologic zones, these parasites contribute to the transmission of zoonotic diseases to both humans and animals. All of these changes will necessitate ongoing surveillance of animals for parasites, updated epidemiologic research on the effects of climate change and globalization on transmitters and transmission of parasites, and improved preventive measures to help control the increased potential for transmission of parasites (Otranto &Deplazes, 2019)

Antiparasitic Drug Resistance: A Major Challenge for Veterinary Parasitology The rapid emergence of antiparasitic drug resistance, particularly anthelmintic (i.e., deworming) drug resistance in livestock, is one of the most serious new challenges in veterinary parasitology. Antiparasitic drug effectiveness has declined due to frequent and uncontrolled deworming, leading to increased difficulty and expense in controlling parasites. Antiparasitic drug resistance has been widely reported in the gastrointestinal nematodes of sheep, goats, cattle and horses, resulting in reduced productivity and increased mortality in some instances. In most farming situations, farmers continue using chemical treatments for parasites without proper diagnoses or rotating their use, leading to accelerated selection of resistant henopods. This new issue represents a significant threat to the sustainability of livestock industries and requires urgent action to develop alternative strategies for parasite management. Researchers are currently investigating the genetic mechanisms of antiparasitic drug resistance and developing advanced diagnostic tools to enable early detection of drug resistant strains of parasites (Kaplan &Vidyashankar, 2012)

There is a growing body of research demonstrating the efficacy of sustainable parasite control methods as a viable alternative to the use of excessive chemicals to treat parasitic infections in animals. Integrated parasite management utilizes multiple techniques such as rotational grazing, biological control measures (e.g., parasitic wasps), nutritional supplementation, selective treatment, and breeding resistant animal varieties

to decrease the number of parasites and minimize their impact on the environment. The use of plant-based medications or herbal medicine that contain natural antiparasitic compounds is also being investigated as an environmentally friendly alternative to pharmaceutical medications. The development of vaccines for major parasitic diseases is a focus of current research as they provide long-lasting solutions to these diseases and decrease our reliance on anthelmintics. Biological control techniques, such as the use of nematode-attacking fungi, have shown positive results in the management of parasitic larvae in grazing animals. The adoption of these sustainable approaches enhances animal welfare, eliminates drug residues from animal products, and minimizes the contamination of the environment through drug use (Hoste et al., 2015) Veterinary parasitology is being transformed by current technology advancements in diagnostics, monitoring and control of parasitic diseases. The rapid and accurate identification of parasites is also enhanced by these advanced diagnostic techniques, including molecular diagnostics (PCR), genomic sequencing and immunological assays, which allow for rapid detection of parasites even in the early stages of an infection. The incorporation of new technologies such as artificial intelligence and data-driven technologies into veterinary research will also help to predict an outbreak of a parasite and improve the systems for surveillance of diseases. Precision veterinary medicine is being supported by these new technologies, which allow for targeted treatment strategies based on the species of parasite and the organisms resistance patterns. In addition, the One Health model provides increased importance to assuring the success of veterinary parasitology as it accounts for the relationship between animal health, human health and environmental conditions. In order to control zoonotic parasites and prevent new outbreaks going forward, collaboration between veterinarians, physicians, ecologists, researchers and other health professionals will be critical (Bowman, 2021)

Importance of veterinary parasitology

The study of parasitic diseases of domesticated animals and wildlife and humans is the field of veterinary parasitology which is an essential discipline of veterinary medicine. Animals suffer from parasites which can be divided into three categories; protozoa, helminths, and arthropods. The presence of parasites can cause malnutrition, decreased productivity, growth retardation, and death of an animal through severe infection. Major economic losses to livestock industries throughout the world occur from decreased proizvodnje (milk, meat, wool, and eggs) attributed to parasitic diseases. In developing countries, where agricultural and livestock production are important to economic survival, food security and rural development are significantly hampered by parasitic infections. Veterinarians who specialize in veterinary parasitology should provide effective assistance with the understanding of life cycles, transmission routes, and preventive strategies that contribute to the effective management of diseases of animals and the welfare of animals. These veterinarians also have an important role in developing effective therapeutic strategies and control programs that contribute to the further decrease in rates of infection in livestock and the increase in productivity from livestock. Veterinary parasitology is a field that is critically affected by the ongoing research and surveillance that support the objectives of ensuring healthy populations of animals and supporting sustainable agricultural systems worldwide (Soulsby, 1982)

The role of veterinary parasitology has become more significant in recent years, primarily because many animal parasites have zoonotic potential and may infect people. There are many diseases caused by parasitic infections that have the ability to transmit from animals to humans, such as toxoplasmosis, echinococcosis and cryptosporidiosis. Due to the close interaction of humans with animals, particularly those who live in a farming community, they are at an increased risk for infection by zoonotic parasites. Veterinary parasitologists play a key role in human health by determining the source of infection, monitoring the prevalence of parasites and devising control measures that lower the risk of zoonotic infection. Some of the measures that are commonly used to reduce the transmission of parasites include improved hygiene practices, regular deworming and methods for controlling the transmission of vectors. In addition, meat, milk and other animal products contaminated with parasites have the

potential to compromise food safety and threaten consumer health. Because of these reasons, veterinary parasitology has a significant impact not only on animal health, but also on protecting humans from diseases caused by parasitic organisms. The collaboration of veterinary and medical disciplines will continue to strengthen the efforts to control zoonotic parasites and improve the health standards of entire communities throughout the world (Urquhart et al., 1996)

In order to sustain productivity and profitability, modern livestock production systems use effective parasite control as a major component of their operation. Parasites lead to decreased feed efficiency, compromised immune systems and increased susceptibility to other viral and bacterial diseases in animals. Young animals are especially at risk for parasitic infection, and untreated infections can result in stunted growth and death. Knowledge gained through veterinary parasitology has played an important role in diagnosing, treating and preventing parasites found in livestock. Advances in laboratory testing such as fecal examinations, serology and molecular diagnostic testing have improved the ability of veterinarians to identify parasitic infections earlier and administer targeted treatment for specific parasites. Proper parasite control also helps to prevent the overuse of drugs and slow the development of resistant parasite populations. Farmers are increasingly using integrated control measures including improved sanitation, grazing management, selective use of anthelmintics to better manage parasite populations. This results in improved animal health and overall productivity on the farm and reduced economic losses from parasitic diseases in the commercial production of livestock (Kaufmann, 1996)

The veterinary field focuses on the health of non-human animals and how their health is affected by the environment. Many wild animals are known reservoirs for parasitic organisms and can transmit these parasites to domestic animals and humans. Changes to the environment (in particular, deforestation, climate change, and habitat destruction) can alter the spatial distribution of parasites and give rise to newly emergent parasitic diseases. By researching the relationships between parasites, their hosts, and surrounding ecosystems, veterinary parasitologists help to understand how environmental factors affect disease transmission.As the use of chemical antiparasitic drugs increases, so does the potential for these products to cause environmental contamination and harm to non-target organisms; as such, veterinary parasitologists are focusing their attention on developing sustainable parasite control options, such as biological control methods and environmentally-friendly treatments that will mitigate the negative impacts of chemical antiparasitic drugs on the environment. Veterinary parasitologists are also helping to promote environmentally responsible management of parasites, thus contributing to the preservation of biodiversity and ecological balance. Ultimately, these activities promote long-term health of animals and support more sustainable agricultural and environmentally friendly practices on a global scale (Wall & Shearer, 2001)

Recent technological advances have enhanced the range and effectiveness of veterinary parasitology. The use of molecular biology, genomics and bioinformatics are allowing researchers to better comprehend the genetics of parasites, how they interact with their hosts, and how they develop resistance to drugs. With these technologies, parasitologists are now able to rapidly diagnose parasites with a high degree of accuracy, enabling veterinarians to provide patients with timely and effective treatment plans. In addition, there is a growing body of work related to vaccines for use in animal health, which has the ability to prevent parasitic disease in animals for an extended period of time. Furthermore, digital technologies and machine learning are providing the ability to accurately predict outbreaks of parasites and improve disease surveillance systems. Veterinary professionals are also providing educational programs and awareness initiatives to assist farmers and pet owners in understanding the significance of preventing parasites and providing appropriate animal care. Advancing veterinary parasitology will continue to be a critical aspect of improving the health of animals globally, ensuring adequate food supply, and protecting human health from emerging parasitic threats during times of increasing global interconnectedness.(Foreyt, 2001)

Economic impact of parasitic diseases

Livestock production and productivity can be severely affected by economic losses due to parasitic disease. Parasitic infections contribute to reducing livestock production through a number of mechanisms, including; weight loss and decreased weight gain, poor feed efficiency, anemia, decreased fertility, decreased milk production, and decreased meat production in animals infected by parasites. Livestock infected with parasites typically incur significant costs for treatment, veterinary costs, and other preventative costs, thus placing a financial burden on the livestock producer/operator. In extreme cases of human/animal neglect due to lack of proper parasite management or control practices, the animals can die and create an immediate loss of money to the livestock producer/operator and decrease the overall profitability of the entire farm. Developing nations are impacted even more severely than developed nations, as livestock production is directly related to the survival of rural families and the availability of food within their communities. In most rural communities in developing countries, poor farmers typically do not have access to adequate veterinary care; nor do they have access to adequate pasture management or parasite control resources to reduce infection rates; thus, parasites can spread rapidly among the livestock in rural communities. The economic impact of parasitic disease on the agricultural industry is not only directly detrimental to livestock producers, but is also indirectly detrimental to national agriculture productivity and livestock product trade. Therefore, effective parasite management is crucial to achieve a sustainable livestock production system, as well as for maintaining economic stability in the livestock sector in the agricultural industry.(Perry & Randolph, 1999)

Globally, gastrointestinal parasites are one of the main causes of financial losses due to infection in animal husbandry. Parasites (e.g., nematodes), as well as other parasites of the intestines, result in a reduced ability to absorb nutritional components. Poor growth performance and low weight gain of the animal adversely affect both young and adult livestock. The immune system of young animals is significantly weaker than that of adult animals; heavy parasite burdens would have the potential to limit their immune system and make them more likely to develop secondary infections. As a result of decreased milk production and quality in dairy cows, these infections may result in significant losses to dairymen. Similarly, meat producing species (e.g., lambs, kids) are also negatively impacted by parasitic infections and disease; these infections and diseases result in poor carcass evaluations and decreased market values. Farmers frequently spend substantial sums for medications to treat parasites, for nutritional supplements that support infected animals, and other professional services (e.g., veterinary consultations) to aid in managing parasite infections. If antiparasitic medications are not used appropriately, the parasites that are treated can develop resistance to the medication, and the treatments would require even more money, and the success of future treatment efforts would decrease. Therefore, continuous monitoring of livestock and timely treatment of gastrointestinal parasites is critical for minimizing production losses as a result of gastrointestinal parasite infections in livestock production around the world.(Sykes, 2010)

Ticks, mites, lice and flies (the ectoparasites) are responsible for significant losses for the animal production industry financially. These ectoparasites cause both skin irritations (scratches and rubbing), as well as blood loss and stress to the affected animal which leads to decreased productivity. Ticks are particularly harmful because they may transmit serious diseases such as babesiosis and anaplasmosis to livestock, and these diseases too can lead to illness/death of livestock. Poultry production like chickens is also affected by mite and lice infestations, which result in fewer eggs being produced and negatively impacts the growth rate of birds and hence, profits from commercial production. Additionally, pests/ectoparasites can result in the loss of the market value of animal hides and wool due to damage done to the skin. The impact of vector-borne parasitic diseases due to pests/ectoparasites in the warmer climate of tropical/subtropical regions normally has a severe financial impact for the producers as environmental conditions allow rapid reproduction and spread of the pest/ectoparasite. Therefore, many produce invest thousands of dollars into insecticides, acaricides, and control

programs to control pests/ectoparasites and to contain disease outbreaks from infectious pathogens. Unfortunately, as evidenced by the reoccurrence of pest/ectoparasite infestation outbreaks, many livestock producers globally face substantial ongoing financial difficulties managing their livestock and the health systems developed by veterinarians worldwide.(Jongejan&Uilenberg, 2004)

Parasitic illnesses have an impact on trade and food security around the world because they lower the quality and safety of animal products. High levels of parasitic infestations in a country can cause restrictions on the export of livestock and other animal products due to health and safety concerns. Products which are found to be infested with parasitic cysts or larvae will often be rejected when inspected by inspectors. As a result of this, producers and exporters suffer economic losses. Parasitic illness also reduces the availability of high quality protein sources—such as meat, milk, and eggs—therefore leading to nutritional deficiencies among human populations. Meanwhile, in developing countries, where there are already limitations to livestock production due to poor veterinary infrastructures and disease management practices, food insecurity is exacerbated. Because of this, governments and agricultural organisations spend an enormous amount of money on the surveillance of parasites, vaccination programmes for livestock, and public awareness campaigns about the need to control parasites in order to protect livestock industries and create better standards in food safety. As a result of these investments in surveillance, vaccination, and public awareness efforts, many people are working hard to improve parasite control in order to improve global food supply chains and economic development.(FAO, 2020)

Veterinary advancements and improved strategies for managing parasites sustainably reduce the economic impact of parasitic infections and disease. Integrated programs combining better nutritional practices, proper pasture management, selective animal treatment, and the use of biological control methods have all contributed to the success of integrated parasite control programs in livestock production. In addition, current diagnostic technologies allow for early detection of parasitic infections, which provides timely intervention opportunities for veterinarians and farmers before economic impacts from parasites occur. Additionally, research is continuing on vaccine development and genetic resistance to parasites, providing significant long-term solutions for controlling parasites. Educational programs for farmers promote responsible use of drugs and prevent further development of antiparasitic resistance. International collaborations between researchers, veterinary professionals, and agricultural organizations have improved the prevention and control of diseases caused by parasites through improved monitoring and management of parasites on an international scale. Although there are still many challenges due to parasitic diseases, utilizing sustainable and scientifically based methods of parasite control in the future will lead to greater animal productivity, more profitable farms, and increased global food security.(Zajac&Conboy, 2012)

Zoonotic parasites and public health

Zoonotic parasites refer to those that can infect both animals and humans and pose significant risks to public health on a global scale. They include protozoa, helminths, and ectoparasites that infect domestic animals and wildlife, as well as humans directly through contact or indirectly via contaminated food and water, as well as through vectors. Examples of zoonotic parasitic diseases include toxoplasmosis, giardiasis, leishmaniasis, and echinococcosis, which affect millions of people around the world, particularly in areas that have poor sanitation and lack adequate veterinary services. Animals can act as reservoirs of infection for these parasites, allowing them to persist and continue to spread within the community. Therefore, human populations that live in close proximity to livestock, pets, and wildlife are at an increased risk of acquiring a zoonotic infection. Additionally, children, older adults, and individuals who are immunocompromised, are at a greater risk for experiencing serious complications from these diseases. Veterinary parasitology is critical to understanding the transmission dynamics of zoonotic parasites and developing effective methods to prevent and control zoonotic parasites. Public awareness, good hygiene practices, and routine monitoring of animal health will all play key roles in reducing the incidence of zoonotic parasites and protecting

both animal and human populations around the world.(Robertson et al., 2014)

Foodborne zoonotic parasites pose serious risks to public health because they can be transmitted to humans through contaminated animal products such as meat, dairy, seafood, and produce. Many parasites (e.g., Taeniasolium, Toxoplasma gondii, and Trichinellaspiralis) are often associated with cooking or food contamination. Ingesting contaminated animal products can lead to serious health complications like neurological diseases, gastrointestinal disorders, and long-term illness. In many developing nations, the proliferation of foodborne parasite diseases are partly driven by unsanitary practices at slaughter facilities, insufficient food safety oversight, and an absence of awareness among citizens. The incidence of waterborne parasites, like Cryptosporidium and Giardia, is compounded by fecal contamination of drinking water with animal waste. Public health officials work with veterinarians to enhance meat safety standards, promote proper cooking methods, and monitor the health of food-producing animals to protect the public from zoonotic transmission. Efficient monitoring and occasional inspections of food items are essential in limiting the extent of transmission of foodborne parasites, and assuring the protection of consumers both domestically and internationally.(Torgerson& Macpherson, 2011)

Vector-borne zoonotic parasites pose a serious risk to human health, especially in the tropics and sub-tropics. Zoonotic diseases caused by parasites spread by mosquitoes, fleas, ticks, and sandflies have high morbidity and mortality rates in humans and animals alike. Examples of community-based vector-borne diseases include malaria, babesiosis, and leishmaniasis - diseases that continue to afflict millions of people worldwide. Due to climate change, urbanization, and increased international travel, New vectors have expanded their geographical range along with the associated diseases; this increases the risk of disease outbreaks in places that formerly had no cases of the disease. Domestic animals and wildlife also act as a reservoir for vector-borne parasites and thus provide continual cycles of transmission between the vectors and the reservoir hosts. Controlling populations of these vectors using environmental management, insecticides, and public awareness is extremely important in reducing the transmission of parasitic diseases. Veterinary and medical professionals work closely together to monitor the density of vector populations to identify emerging threats and to develop integrated control strategies. Increasing the effectiveness of vector surveillance and the level of community participation will provide protective measures against zoonotic parasites transmitted by vectors.(Gubler, 2009)

Zoonotic parasitic diseases impose a heavy economic and social toll on low- and middle-income countries. However, these diseases lead to decreased productivity in workers, higher health costs, and decreased quality of life for people who are economically affected by disease. Zoonotic diseases also lead to decreased productivity or to animals that are no longer suitable for sale/consumption resulting in loss of income to the farmer and/or livestock owner. Zoonoses tend to negatively impact tourism in the affected area and strain the public health system. Rural communities are also more susceptible to parasitic infections due to limited access to healthcare, veterinary care, and clean water. Therefore, it is critical that education programs addressing sanitation, safe animal handling, and prevention of zoonotic diseases be established in order to help minimize instances of zoonotic infections. There continue to be substantial investments by governments and international organizations in disease surveillance systems, animal vaccinations and parasite control programs to improve overall health of the community, as well as stability in terms of their economy. It is important that there is a strong working relationship among veterinary, medical, and environmental professions to help protect public health over the long-term from zoonotic parasitic diseases.(Hotez et al., 2008)

The One Health concept is now playing a major role in controlling zoonotic parasites and enhancing worldwide public health outcomes. The One Health concept recognizes the interconnectedness between human health, animal health, and environmental health. Veterinarians who treat parasites, medical practitioners, ecologists, and public health officials collaborate to track diseases as they emerge and determine which factors increase the

likelihood of jumping from one species to another, and develop strategies to avoid disease transmission among species using an integrated approach. Newer diagnostic methods, such as molecular diagnostics and genetic analysis, now provide much quicker identification of zoonotic parasites, allowing for a rapid response to outbreaks. Continued research into new vaccines, enhanced sanitation systems, and sustainable methods of vector control will strengthen global activities to control parasitic diseases. Public education campaigns encourage the responsible ownership of companion animals, safe food handling practices, and maintenance of a clean environment which reduces the risk of exposure to zoonotic parasites. Global cooperation and the exchange of information are critical in containing emerging zoonotic threats due to the increasingly interconnected nature of our world. With the coordination of One Health activities, veterinary parasitology continues to be a critical partner in promoting public health and in supporting positive and safer relationships between our planet and all of the creatures that call it home.(Mackenzie &Jeggo, 2019)

Climate change and parasite distribution

As a result of climate change, the distribution and transmission of parasitic diseases among animals and people around the world has been significantly influenced. The rise in global mean temperature, changes in the amount and type of precipitation (rainfall, snow), and increased levels of humidity have also created suitable environmental conditions for the survival and reproduction of many different types of parasites and the organisms that transmit them (i.e. vectors). Climatic changes affect the life histories of many types of parasites and enable them to expand into new geographical regions that were previously outside of the parasites' distribution areas. Because of this, there is a greater emphasis on understanding the impact of environmental changes on parasite ecology and the epidemiology of parasitic diseases within the field of veterinary parasitology. In general, parasites that thrive in warm climates develop faster, and many parasites and their intermediate hosts can survive for longer periods during the winter months. These changes have resulted in an increased intensity and duration of parasitic infections in both livestock and wildlife populations and have created new challenges for farmers and veterinary practitioners in controlling the spread of diseases to areas that have previously been considered to be at low risk for disease transmission. In order to develop effective strategies to control/parasitic diseases so that they do not negatively impact animal health and agricultural productivity, it is essential to gain more knowledge about how climate-related variables (e.g. temperature, rainfall) impact the biology of parasites.(Patz et al., 2005)

The Expansion of Vector-Borne Diseases Due to Climate Change - One of the major consequences of climate change to the distribution of parasitic organisms is the growing trend of vector-borne diseases. Vectors (e.g., ticks, mosquitoes, and other types of insects) have a high sensitivity to environmental factors, and thus their populations respond greatly to alterations in temperature and precipitation patterns. As global temperatures continue to increase, many of Comet's vectors have shifted to ascend upwards in elevation and migrate northward in latitude, resulting in the introduction of parasitic diseases into areas of the world that have historically been free of these types of infections. For example, tick- borne illnesses have been documented in livestock in geographic regions that have not previously reported such disease patterns. The introduction of these parasite species to populations of animals that lack or have developed minimal immunity against the introduced organisms presents a substantial risk to the health of those animal populations. Climate change may also influence the seasonality of transmission of vector-borne diseases, with changing seasonality resulting in increased number of vector transmission cycles per year, thereby increasing overall transmission rates. Therefore, veterinary practitioners must continually assess the ecology and geographic distributions of vector-borne diseases and implement adaptive control strategies to reduce the risk of transmitting disease. Overall, climate change effects upon the ecology of vectors establishes the need for a comprehensive surveillance system that utilizes environmental parameter data in conjunction with data from veterinary epidemiology.(Sutherst, 2004)

Climate change also impacts the survival and growth of parasite eggs, larvae, and intermediate hosts in the structure of the environment that

cannot support their survival throughout the various stages of their life cycle as they transition through these conditions, (depending on their habitat) in order to complete their life cycle. The increase in rainfall due to climate change will also lead to the creation of moist conditions which will support the survival of parasite larvae that have been contaminated with their larvae in that environment, (for example soil or water), whereas the decrease in rainfall from climate change will cause animals to have to gather together at areas of limited water, due to drought conditions, which will increase the risk of parasite transmission. Depending upon the species, parasite development will be accelerated or decelerated, depending upon the temperature increases or decreases per a change in the seasons, as per weather conditions, in comparison to their normal parasite development times (insects or protozoans). Such environmental changes will cause the normal pattern of parasite infection and transmission to be disrupted and, make control measures impossible to implement predictably, or at all. Livestock grazing systems are especially vulnerable, as animals are exposed to contaminated pastures on a continual basis. Studies of the environmental interactions and the use of data collected from studies conducted by veterinary parasitologists will assist in creating predictive models related to parasite infection risk under different climate scenarios; this data is crucial when developing a parasite control program that is designed specifically for a region that changes as a result of the different effects of climate change on the environment.(Morgan & Wall, 2009

Climate change is having an effect on the distribution of parasites that will have an impact on the economy and food security. The spread of parasitic diseases into new geographic areas is causing livestock to be less productive; this means that animals are growing at a slower rate, producing less milk and meat, and dying at a higher rate. As a result of this decline in livestock productivity, farmers will need to spend more money on veterinary care, treatment, and prevention, leading to increased overall production costs. The impact will be particularly acute in developing countries because agriculture is so heavily dependent on systems that are sensitive to climate. Changes caused by climate change will have a disastrous impact on people's livelihoods in rural areas and on their access to food. Additionally, the introduction of new parasitic diseases into regions that have never experienced them will disrupt both the domestic livestock trade and export markets. Governments and agriculture organizations need to invest in more research, better surveillance, and adaptation strategies to minimize the amount of economic losses associated with parasite expansion driven by climate. Improving veterinary infrastructure and educating farmers will be two critical components to reducing the vulnerability of livestock systems to climate change. Sustainable parasite control methods will play a pivotal role in helping to maintain food security throughout a changing global climate.(Bett et al., 2017)

A multidisciplinary, global approach is needed to address how climate change impacts how parasites are distributed throughout the world. The combined efforts of veterinary science, climatology, ecology, and epidemiology will be needed to fully understand and manage these complicated interactions. Many modern technologies will aid in mapping the distribution of parasites as well as predicting and forecasting when these diseases will be present in the future. These technologies include geographic information systems (GIS), remote sensing and predictive modelling to assist veterinary and public health officials in creating intervention strategies tailored specifically for individual cases, as well as improve allocation of limited resources. The One Health approach to climate sensitive parasitic diseases also represents an important strategy as it fosters collaborative efforts among human health, animal health and environmental sectors. International cooperation will be necessary to identify new or evolving threats and provide appropriate preventative measures or treatment internationally. With combined scientific research and sustainable resource management, it will be possible to reduce the effects that climate change has on the distribution of parasites and subsequently protect both animal and human health long term.(Ostfeld& Brunner, 2015)

Emerging parasitic infections

The emergence of parasitic diseases is a growing concern for both animal and human health. Changes in our climate, environment and global

animal movement have led to the emergence of new or increasing incidence of new parasitic diseases in both veterinary and human medicine. Emerging parasitic infections occur as a result of climate change, urbanization, deforestation and international trade. Emerging parasitic infections can decrease productivity of livestock, impact the health of wild animals and increase risk to food safety. Animals can serve as reservoirs for novel or previously rare parasites, which will eventually infect humans and lead to zoonotic disease outbreaks. Emerging parasitic infections highlight the need for continued surveillance and early detection systems. Veterinarians and researchers play an important role in identifying new parasitic threats, and determining how they are transmitted. Early detection of emerging infections is important to reduce the risk of widespread disease outbreaks, reducing the impact of emerging infections on animal food production systems and public health.(Daszak et al., 2000)

Increased incidence of new parasitic infections can be attributed largely to increased interaction of wildlife, domestic animals, and humans. Because more human populations are encroaching on wildlife habitats, these individuals are being exposed to novel, previously wildlife-associated parasites. Expansion of livestock farming operations, furthermore, has created greater density of animals susceptible to parasitic transmission and mutation. Animal movement by trade and transport also promotes the cross-regional and inter-regional spread of parasites. Parasites that were once restricted to specific climates have also begun to spread to new areas as a result of ecological disturbances. As a result of these factors, there is an increased risk for outbreaks in both animals and humans. Veterinary surveillance systems will be increasingly critical for identifying the earliest signs of emerging infections and preventing their establishment in new populations. Understanding the relevant ecological and epidemiological factors will therefore be critical for controlling the spread of emerging parasitic diseases.(Jones et al., 2008)

The rise of parasitic infections is closely linked with climate change altering the life cycle, distribution and survival of the vector (hosts) and parasite. The increase in average temperature and changes in rainfall typically enables parasites to survive in areas that had previously been unsuitable, thus permitting them to expand into new areas of transmission, resulting in an increase in the incidence of diseases such as leishmaniasis, babesiosis, and other vector-borne parasitic infections. In addition, seasonal changes in climate often lead to multiple transmission cycles being present at any one time which also contributes to an increased incidence of disease in any 1 year and in particular in wildlife and livestock populations due to their exposure to rapidly changing environmental conditions. Thus the need for continuous monitoring and predictive modelling of environmental changes will be necessary to project the risk of future diseases as a result of climate change. Thus, there is increasing interest by veterinary parasitologists in using climatological data to investigate the effects of climate change on the emergence of parasites; such research is crucial for development of successful control and prevention strategies in the face of a dynamically changing and unstable global climate.(Lafferty, 2009)

The rise of drug-resistance among parasitic organisms makes controlling parasitic diseases more difficult than ever before. Due to overuse and misuse of anti-parasite medications on livestock animals, many of the standard treatments are becoming less effective, especially for parasites that are able to survive exposure to these medicines. As a result, parasites that survive treatment are able to continue multiplying and spreading; thus, making it more difficult to control these infections. Resistance can raise treatment costs and lower production of livestock animals. In addition, previously common parasites have been identified again as major threats because they have developed resistance to treatment. This demonstrates the need for integrated parasite management strategies which will utilize all available control options (chemical, biological, and ecological) for the control of these parasites, monitoring resistance patterns, and educating about appropriate use of anti-parasite medications. Veterinary researchers are also looking for means of reducing the amount of chemical use in the treatment of afflictions caused by parasites. These alternatives may include the use of vaccines and natural substances.(Kaplan &Vidyashankar, 2012)

To effectively manage emerging parasitic diseases, action must be taken from multiple angles, globally and cooperatively, by veterinary medicine, public health, and environmental science. Advances in diagnostics such as molecular diagnostic testing, PCR, and genomic sequencing have greatly improved our ability to quickly identify both new parasites as well as the genetic characteristics associated with them. These advances provide enhanced capacity for disease surveillance and assist with the understanding of transmission routes. The One Health paradigm is critical to the mitigation of emerging parasitic diseases through the implementation of a single strategy that incorporates human, animal and environmental health. Therefore, if cooperation at an international level is maintained, new parasites can be closely monitored through the sharing of information about disease outbreaks and the establishment of global contingency plans. Educating and creating awareness among farmers, veterinarians, and the public about reducing the potential for the spread of infection is also essential. Ultimately, through the integration of current best practice research, surveillance systems, and sustainable parasite management techniques, the global burden of emerging parasitic diseases can be reduced while safeguarding both human and animal health worldwide.(Woolhouse et al., 2005)

Anthelmintic drug resistance

Anthelmintic resistance is an increasing and significant issue within the field of veterinary parasitology, which is effecting the ability to manage parasitic worms in livestock across the globe. This form of resistance refers to the ability of helminth parasites (including nematodes, trematodes and cestodes) to survive doses of anthelmintic drugs that were once considered effective. Consequently, this form of resistance has a direct effect on the efficacy of commonly used anthelmintics therefore increasing the complexity, cost and uncertainty associated with controlling parasitic worms. Livestock will be mostly impacted by the development of anthelmintic resistance due to their regular exposure to gastrointestinal parasites; species including sheep, goats, cattle and horses will be the most susceptible. The emergence of resistance is viewed as a major threat to the health of animals, the productivity of livestock, and the availability of food for the world's population. Farmers may see decreased growth and milk production and/or higher mortality rates in treated infected animals. Veterinary parasitologists acknowledge the need to identify and understand the mechanisms of resistance in addition to improving control strategies. In addition, if anthelmintic drugs are not appropriately managed, anthelmintic resistance may spread rapidly within and/or between farms, rendering numerous drugs ineffective and limiting future treatment options for livestock-related diseases.(Prichard et al., 2012)

The primary reason for the development of anthelmintic drug resistance in livestock is due to the regular and inappropriate use of antiparasitic drugs. The reliance on mass medication of livestock without a basis of diagnosis and the lack of a systematic way of rotating between classes of drugs exert a strong selection pressure on parasitic populations that allow for the survival and reproduction of parasites that are resistant to the drugs used. Eventually, the resistant populations of parasites will become the dominant populations in the parasite community. In addition to the repeated use of the same class of drug for mass deworming, other factors such as under-dosing, improper drug administration and/or poor quality antiparasitic products also play a large role in the development of resistance. Many producers routinely deworm their livestock based upon a pre-established deworming schedule rather than in response to the amount of parasites present in the animal or the identification of the parasite species involved. This type of misuse of anthelmintics serves to accelerate the rate of resistance development and consequently diminish the effectiveness of currently available treatments. In addition to all of the above challenges, there is a lack of understanding by many producers on the correct use of antiparasitic drugs and proper management of parasites, which creates an additional burden on farmers in controlling the development of parasite resistance. Targeted selective treatment of the animals based upon diagnostic criteria, as recommended by veterinary professionals, will aid in reducing the amount of non-infected animals exposed to antiparasitic drugs and consequently, slow the rate of

resistance development in the parasitic populations.(Kaplan, 2004)

Anthelmintic resistance is a common problem among gastrointestinal nematodes like Haemonchuscontortus, Teladorsagiacircumcincta, and Trichostrongylus species which result in high economic losses due to decreased productivity and increased mortality of small ruminant animals. Resistant parasites have been shown to be able to survive multiple classes of antidhelmintics that were formally useful including macrolides, benzimidazoles and imidazothiazoles. The inability to use these different classes of drugs creates limitations for treatment options and increase the challenge with controlling parasites. In some locations farmers have reported total failure in treatment due to the presence of highly resistant worms. Movement of animals, use of common grazing land and poor biosecurity practices will continue to facilitate the spread of resistant worms. Veterinary researchers have begun to search for genes and biological pathways that will be responsible for development of resistance in helminths so that new drugs can be developed and improvements can be made to current treatment strategies. If no effective intervention occurs, anthelmintic resistance will ultimately result in a significant decrease in livestock production systems around the world.(Sangster et al., 2009)

Farmers of all sizes and types suffer severe economic consequences from anthelmintic drug resistance. These include increased treatment frequency, the high cost of drugs, and decreased production by the animals. The combination of these three factors can cause farmers to experience significant economic losses. To help offset the loss, many farmers will need to invest in alternative control methods, including improving pasture quality, providing nutritional supplements, and conducting diagnostic tests. This creates additional production costs for the farmer. Resistant infections may also cause decreased quality of meat and milk produced from infected animals, therefore lowering both the market value and export potential of those products. In developing countries, where livestock is critical to the livelihoods of many families, the burden of economic losses from drug resistance is even greater. Access to advanced veterinary services and diagnostic facilities is limited, making it difficult for farmers to manage drug resistance effectively. Many governments and agricultural organizations are currently involved in creating awareness and learning programs to educate farmers about the appropriate use of anthelmintics. To limit economic losses and ensure the long-term productivity of livestock in light of increasing levels of drug resistance, effective sustainable parasite control programs must be implemented.(Van Wyk et al., 2006)

The management of anthelmintic drug resistance will involve both integrated and sustainable methods to reduce reliance on chemical means for treatment. Many approaches toward this goal are currently gaining traction such as: rotational grazing; biological control; selecting for resistant animals through breeding; and the use of alternative therapies. In addition to these integrated parasite management strategies, regular monitoring of the parasite load via diagnostic methodologies allows for the most appropriate treatment decisions and minimizing the development of resistance by utilizing combination drug therapies with proper dosage. Molecular biology advancements have provided a platform for identifying resistant genes in normal parasite populations which will help to identify and implement early intervention measures. A critical part of this process is utilizing veterinary extension services to educate producers about parasite control best practices. Lastly, developing new anthelmintic compounds and sustainable management programs will also require international cooperation/collaboration and research. To successfully combat the development of resistance will require a coordinated One Health approach that involves veterinarians, researchers and producers. Implementing integrated parasite management systems will allow for the sustainability and effectiveness of the current anthelmintics in controlling helminth infestations in livestock worldwide. (Taylor et al., 2010)

Conclusion

The veterinary parasitology field is rapidly evolving, and the emergence of new trends in this area will continue to grow in importance globally concerning animal health, food security, and public health protection. The effects of climate

change, along with increasing globalization and intensive animal farming systems, have combined to create conditions in which parasitic diseases are spreading more quickly than ever before, making it extremely difficult for veterinarians to control parasites in their practices. The second factor contributing to the evolution of the veterinary parasitology field is the huge problem caused by anthelmintic drug resistance. The ever-growing prevalence of parasitic infection and widespread use of anthelmintics have led to a dramatic decline in the efficacy of good old-fashioned anthelmintic treatments; therefore, it has become increasingly complex and expensive to manage parasites using traditional treatment. Therefore, the veterinary community has responded to these challenges by shifting towards more sustainable and integrated methods of parasite control, such as biocontrol, vaccines, herbal medicine, and precision-based treatment approaches. Additionally, the rapid advancement and availability of molecular diagnostics, genomics, and digital technologies will help create earlier detection of parasitic infections and enable more targeted/efficient intervention. Finally, the development of the One Health approach will further enhance collaboration among veterinary, medical, and environmental professionals in controlling zoonotic and new/unidentified parasitic diseases.

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