Chapter

Impacts of Environmental Parameters on the Infectivity of Freshwater Snail

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Abstract

The successful transmission of the infective stage of the parasite (miracidia) depends on different factors. These free-living stages miracidia rely on their own stored energy and are directly exposed to environmental factors including disturbance resulting from pollution and human activities. There are different environmental factors that affect the cercarial infection of the snail. These include pH, temperature, salinity, dissolved oxygen, water hardness, habitat conditions, presence of predators and competitors, etc. Each of these factors may increase or decrease the freshwater snail's infectivity. The more hydrogen ion concentration in the aquatic habitat could have an effect on the maturation and physiology of the parasitic stage (miracidia), leading to impaired survival and reduced infectivity. In contrast, high temperature increases snail infectivity. While low dissolved oxygen in the aquatic environment results in low snail infectivity. Regarding the presence of predators can result in low snail infectivity by consuming the schistosome egg and the snails themselves. Total hardness also had a negative impact on the prevalence of snail infection. The hardness of the water results in the shell hardening of snails subsequently leads to low infection of snail by miracidia.

Keywords: environmental factors, freshwater snails, snail infectivity

1. Introduction

Snails belong to phylum – Mollusca and class – Gastropoda, which accounts for a large and highly diverse group of invertebrates. Many freshwater snails serve as an intermediate host for different digenetic trematodes that cause schistosomiasis, fascioliasis and other snail-borne diseases of humans and animals [1, 2]. Trematodes are a group of flatworms and utilize parasitism as a way of life. The development of larval digenean trematodes is a complex and multi-stage life cycle process that typically uses invertebrates as intermediate hosts and vertebrates as definitive hosts [3].

The eggs of the digenetic trematodes enter into the environment through feces or urine of the definitive host. Upon reaching to freshwater bodies, the eggs will hatch and release the first free-swimming larva of digenetic trematodes (miracidia) infecting a freshwater snail host. The larval developmental stages, such as sporocysts, rediae, and cercariae are completed in the freshwater snails. The infected snails shed thousands of the second-stage free-swimming larva called cercaria into the water. Then the cercaria enters into mammalian hosts through direct penetration of skin during contact with water bodies contaminated with human excreta containing parasite eggs. Adult parasites live in different sites of their definitive hosts, like the digestive system, circulatory system, respiratory, urinary, and reproductive systems [3–6]. The infection with digenetic trematodes cercaria gives rise to a disease for mammalian hosts. Understanding the trematodes lifecycle and transmission mechanism between freshwater vector snails and mammalian hosts is important to the control and elimination of the diseases [4, 6].

The miracidium is the first free-swimming larvae in a digenetic trematode's life cycle and is a main component in the transmission from vertebrates to molluscan hosts. However, different species of digenetic trematodes are known to have actively infecting free-swimming miracidia that quickly swim through water bodies searching out a suitable molluscan freshwater intermediate host [7].

Once the first free-swimming larvae hatch from the egg, different intrinsic and extrinsic parameters affect whether a successful freshwater snail penetration is achieved. Furthermore, eggs that take longer to embryonated may produce free-swimming larvae miracidia that are more sensitive to these environmental conditions [3].

The ability of free-swimming larvae miracidia to search its intermediate host is the primary stage in initiating a successful infection. Modification of different abiotic and biotic environmental conditions influences miracidia behavior [3, 8].

2. Environmental factors

Environmental condition change will lead to both direct (i.e.; physiological) and indirect (i.e.; interspecific interactions) influences on parasite transmission, some of which man increases disease while others will reduce infection [5]. In the transmission of digeneans, eggs and the free-living larvae that hatch from eggs, known as miracidia, play a crucial role. The eggs and miracidia are exposed to the environment, whether it is the host or the watery external habitat. To establish a suitable molluscan host, transmission stages must be able to detect a suitable molluscan host and ensure larval survival and infectivity. Actively infecting miracidia develop from eggs in the environment and swim actively to locate and penetrate the molluscan host (e.g., *Fasciolidae*, *Echinostomatidae*, *Philophthalmidae*, *Schistosomatidae*), whereas passively infecting miracidia hatch in the intestine of a suitable mollusk host (e.g., *Plagiorchiida*, *Hemiuroidea*, *Brachylaimoidea*) [9]. Miracidia hatch quickly upon adequate stimuli if eggs are fully embryonated (intrauterine development within adult parasite), or after a maturation period in the external environment if eggs are not fully embryonated (intrauterine development within adult parasite) [10].

The attachment to the freshwater snail surface and passage into tissue is thought to be the two steps of miracidium penetration into the host. This procedure is aided by the terebratorium, whose muscles aid penetration into the snail, and is likely accomplished in tandem with the histolytic secretion of the miracidia glands. Once located in the intermediate freshwater snail host, the miracidium has to be capable to penetrate the tissue [10].

Variations in environmental factors or physiological status could potentially account for some of the differences in infectivity in freshwater snail infectivity. Water quality and composition were shown to have a significant impact on snail infectivity [11]. Environmental factors both abiotic and biotic factors were the major determinant factor for snail infectivity [12].

The successful transmission of the infective stage of the parasite (miracidia) depends on different factors. These free-living stages miracidia rely on their own stored energy and are directly exposed to environmental factors including disturbance resulting from pollution and human activities. Among different environmental factors: temperature, pH, salinity, biological oxygen demand, dissolved oxygen, rainfall, hardness of water, predators and competitors are the most important determinants for snail infectivity [13].

2.1 Abiotic environmental factors

2.1.1 Temperature

Environmental factors frequently influence the outcomes of host–parasite interactions and, as a result, disease dynamics [14, 15]. Particularly as ambient temperature has a significant impact on these dynamics [16, 17]. Understanding such effects is becoming increasingly relevant as a result of anthropogenic climate change, as climate change leads to an increase in average air temperature and more frequent occurrence of extreme weather events, such as summer heatwaves [18, 19]. High temperatures are thought to affect host–parasite interactions by lowering host resistance to infections as a result of a poor immunological function [20, 21]. This is because the immune system is commonly thought to be the primary physiological barrier against parasites [22]. It can be difficult to predict the effects of temperature on host–parasite interactions based just on the information of host immune defense. This is because parasite infection methods, as well as host traits other than immune function, can play a role in how interactions turn out [23]. Temperature, for example, can have a direct impact on parasite infective stages (e.g., survival l, movement), altering infection success [7, 24]. Furthermore, temperature influences the metabolism of ectothermic species and may alter their physiological characteristics [25].

In the two experimental laboratory setup, freshwater snails kept at 25°C had higher parasite infection success than snails kept at 15°C over the long term. In the short-term treatment, maintaining a temperature of 25°C prior to parasite contact resulted in fewer infections than maintaining a temperature of 15°C. The experimental snails were assigned randomly in to one of the two temperature (15°C and 25°C) [23]. The other study also shows when the average temperature was 30.5°C, the average relative humidity was 73 percent, rainfall was 145.7 mm, and pan evaporation was 4.0 mm, the highest infection occurred. The infection of snails and meteorological parameters (temperature, relative humidity, and rainfall) were found to have a positive relationship [26].

At low and high temperatures, the rate of infectivity drop is the fastest. Elevated temperatures had a deleterious impact on hatching success and infection rates, corroborating our results of morphological degradation and motility patterns (**Figure 1**). Because the lower hatching and infection rates associated with higher temperatures suggest that temperature has a direct impact on trematode biological integrity during its "free-living" stages, and ultimately transmission success, independent of temperature-mediated snail susceptibility [27].

While higher temperatures were linked to higher infection rates, these findings reflect the influence of temperature on ectothermic snails, including their feeding behavior, rather than the long-term effects of temperature on parasite physiology. Environmental conditions alter miracidia and their snail hosts, creating complexity through nonlinear temperature-dependent processes and time-dependent metabolic trade-offs that favor particular and restricted transmission windows. This

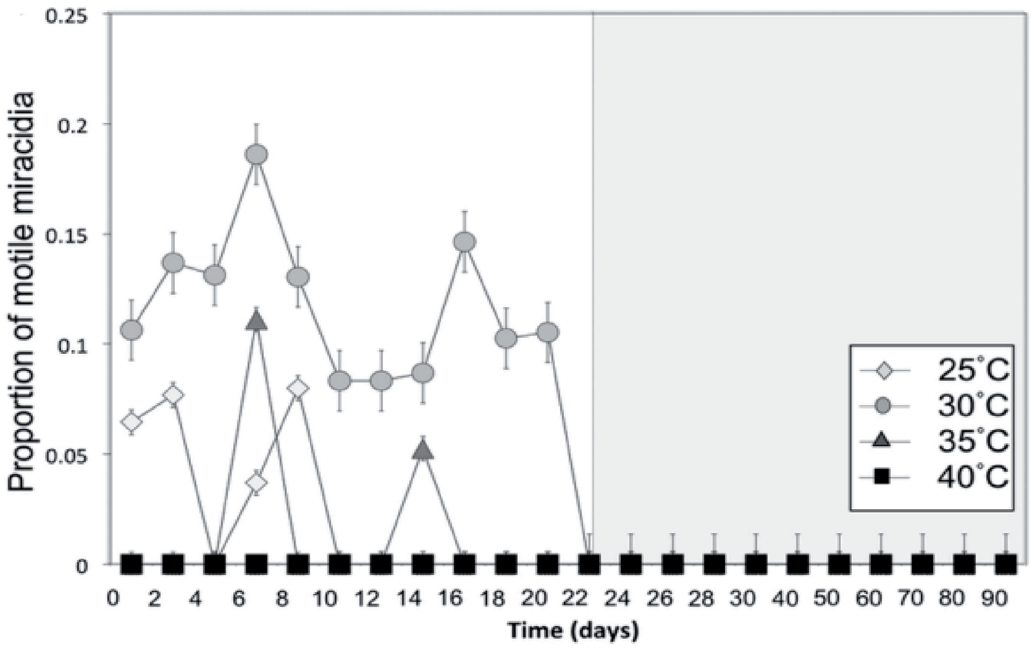

Figure 1.
Proportion of motile miracidia over time and across temperatures [27].

experiment is done in randomly distributed snails in five replication per temperature treatment (**Figure 2**) [27].

Although comparative investigations of different species have so far been limited to cercariae, trematodes in particular appear to have a complicated and variable relationship with temperature [28, 29]. High snail infection was obtained in the temperature ranges between 22.16°C to 24.66°C. Temperature is one of the most important parameters for snail and trematode larval growth [30], hence these temperature ranges are ideal for trematode larva infection in host snails [5].

With respect to different larval stages (sporocyst, redia, and cercaria) of the trematode in freshwater snail host, direct involvement of metabolic energy usage

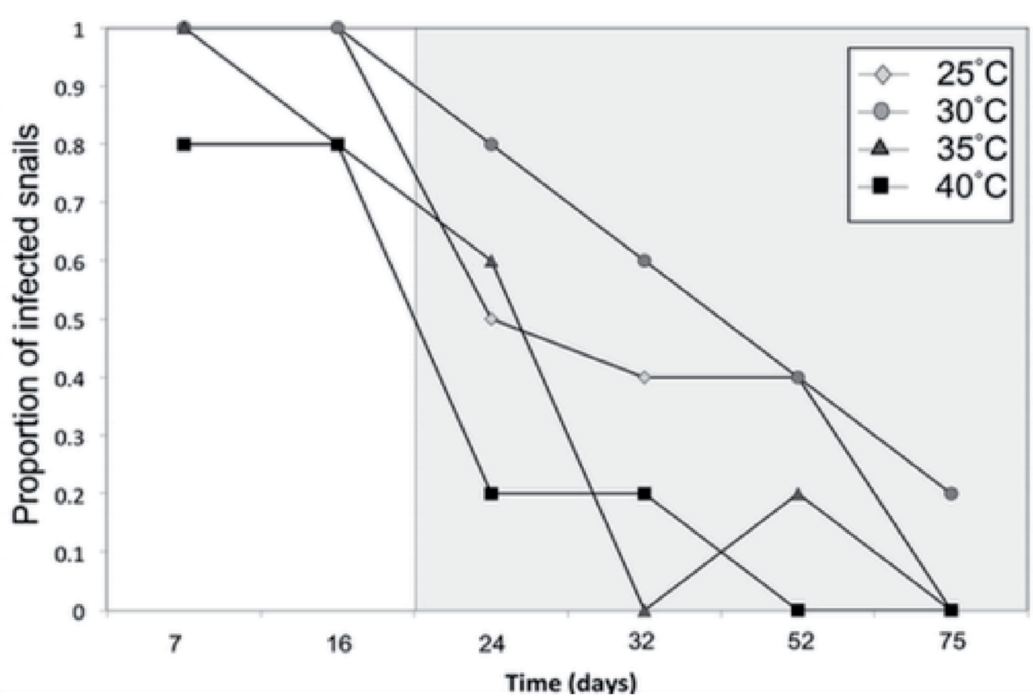

Figure 2.
Proportion of snails infected over time and across temperatures [27].

(i.e., oxygen consumption rate), as well as abiotic environmental parameters such as temperature, pH, oxygen, and free carbon dioxide, is required [5].

Because of its impact on the parasite and its host, the effect of temperature on vector-borne diseases such as schistosomiasis is well-known. Snail hosts' ability to survive and reproduce is temperature sensitive and varies between species [31]. The temperature has an effect on parasite viability, as evidenced by the reduced infectivity of cercariae emerging from sporocysts in snails kept at temperatures of 23–25°C. As the snail maintenance temperatures are dropped, the pre-patent period tends to be lengthened [32].

Temperature is one of the most important environmental elements governing miracidia life span, and it can have a big impact on transmission viability. It has a direct impact on activity, with larger amounts of movement occurring when the temperature rises. Understanding the thermal biology of trematodes is crucial for predicting parasite population dynamics in the face of climate change. The effects of the climate on both hosts and parasites can alter the extent and intensity of parasitism, with the temperature being a particularly important role [7, 33].

2.1.2 Rainfall

The impact of rainfall patterns on the density of intermediate snail populations and infection rates, stressing how the presence and seasonal vigor of breeding sites and foci dictate the periodicity of schistosomiasis transmission in a specific area. Snail infection rates were high until the dry season began when population density began to fall. The initial captures following rains delivered adult snails that were already infected, demonstrating that they may maintain *S. mansoni* infection during aestivation and are capable of shedding cercariae and transmitting the disease as long as weather conditions permit life in the breeding site [34].

According to the studies, there is no infected freshwater snails found between November 2013 and March 2014 except December; but staring in April, infected snails were found coinciding with the rainy season (**Figure 3**) [35].

2.1.3 Salinity and pH

High electrical conductivity and chloride in water bodies indicated that the total dissolved salts in the water were high [36]. The vulnerability of miracidium to salinity is of course strongly related to whether a parasite inhabits a freshwater habitat. The miracidium can withstand slight salt concentrations without affecting their survival [13]. The freshwater that has high salinity may lead to a reduction of miracidium infectivity, subsequently, it results in low infection in snails [37].

Regarding the pH, it had a negative association with freshwater snail infection. The more hydrogen ion concentration in the aquatic habitat could have an effect on the maturation and physiology of the first free-swimming stage (miracidia), leading to impaired survival and reduced infectivity [5, 13].

The study shows freshwater snails and the parasites are well-adapted to high-salinity and alkaline coastal habitats (**Figures 4** and **5**) [34]. The trematode life cycle, including embryonic development, is influenced by environmental conditions like pH. The impact of pH on trematode larvae hatchability in aquatic settings is important. Environmental factors influence distinct stages of parasitic fluke life cycles and, as a result, their epidemiology [38, 39].

Different researchers have found that the maximum hatching rate of miracidia occurs at a neutral pH level [38]. At a pH of 5–10, the hatchability of eggs is

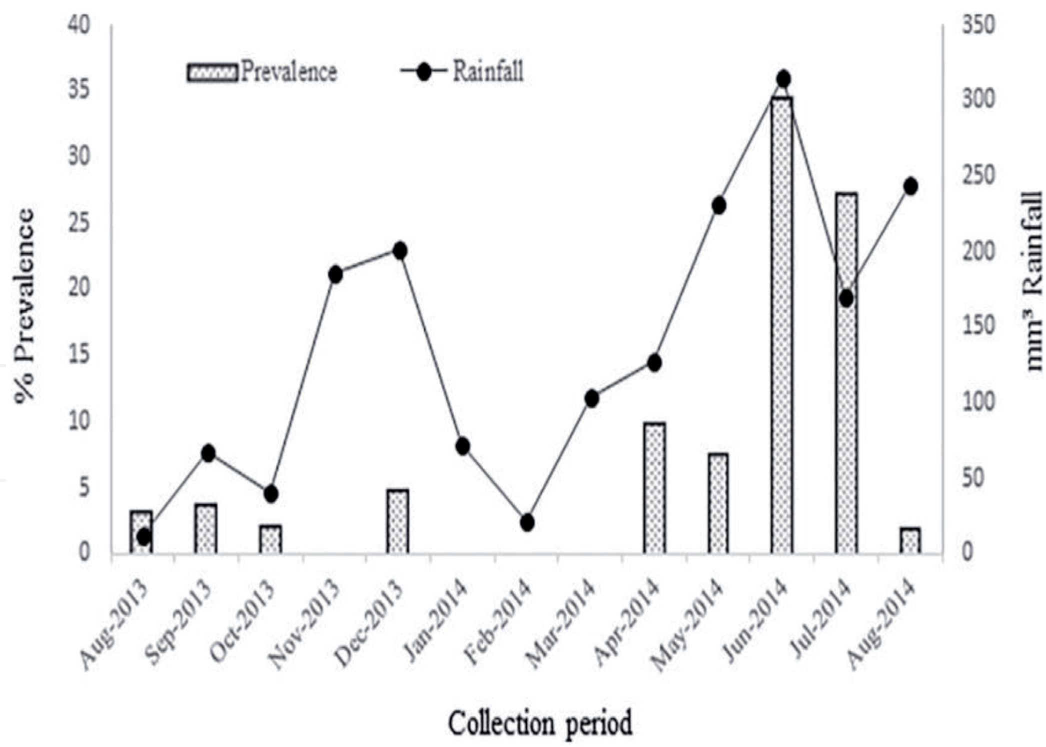

Figure 3.
Correlation between snail infection and rainfall [35].

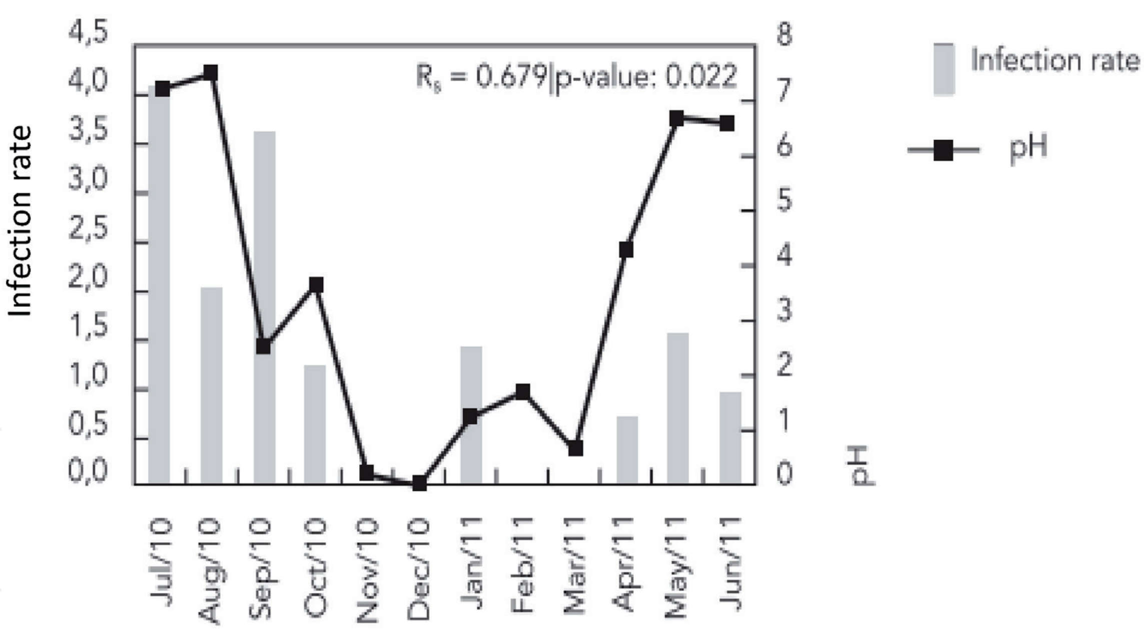

Figure 4.
Relationship between snail infection and pH [34].

decreased. The proliferation of miracidia in trematode eggs was impacted by pH variations. Subsequently, it minimizes the infection rate of intermediate snail hosts. Several studies have demonstrated that higher and lower pH levels affect the time it takes for trematodes to hatch and the number of sterile eggs they produce. [38, 39].

The influence of water pH on the toxicity of heavy metals can have an indirect impact on the life cycle and multiplication of parasitic trematodes [40]. pH has an impact on the life cycle of trematodes as well as their intermediate hosts, such as snails, from an epidemiological perspective. Freshwater snail distribution is influenced by water quality, notably pH [41]. The pH range of 7.2–7.5 is ideal for snail activity and population propagation [42]. Snails living in freshwater may be

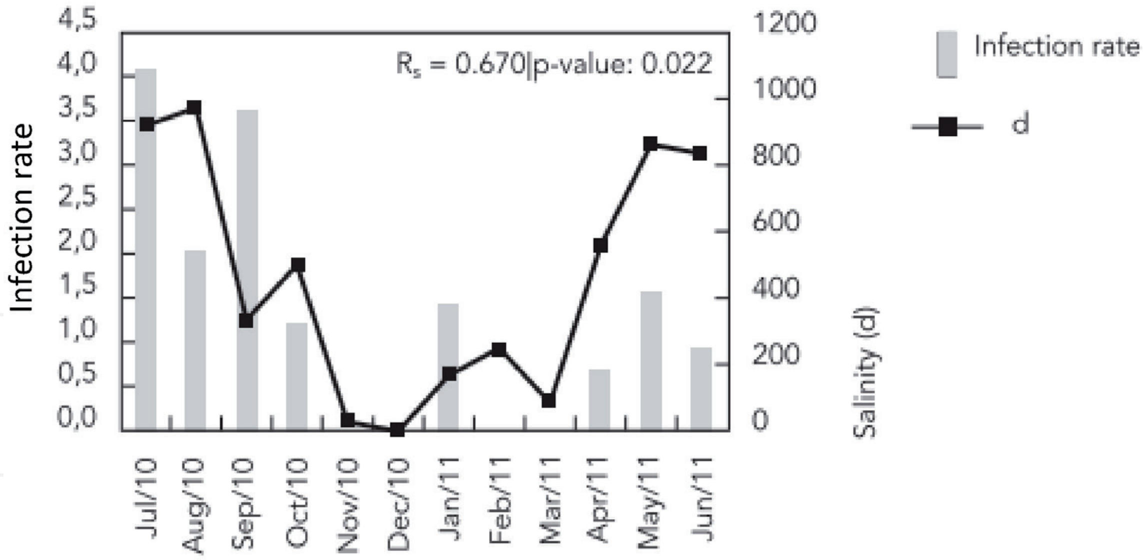

Figure 5.
Relationship between snail infection and salinity [34].

killed by low pH levels. This reduces freshwater snail abundance and subsequently results in low snail infection. This is due to the high abundance of freshwater snails that could promote cercaria transmission as the access distance for the miracidia is reduced as a result more snails get infected, which could be because why the area with lowest freshwater snails abundance had the lowest infection in snail [37]. The alkaline pH of about eight is ideal for the multiplication of freshwater snails [41].

2.1.4 Dissolved oxygen and BOD_5

The BOD5 had a positive relationship with the freshwater snail infection. These might be due to the presence of organic pollution which increases BOD5 and subsequently increases the infection of freshwater snails. Whereas dissolved oxygen concentration had a negative relationship with snail infectivity. The low dissolved oxygen was an indication of the presence of organic pollution in the aquatic environment [43]. This organic pollution is beneficial and expands the habitat of freshwater snail hosts and subsequently, more snails might be present. And also, it might have a trematode egg in the waste. With the high availability of freshwater snail hosts and trematode eggs, the probability of a miracidium searching and infecting a snail is higher. As a result, the cercarial infection in the freshwater snail host could be increased [44].

2.1.5 Hardness of water

Freshwater snails need calcium for shell hardening, egg production and are unable to get it in the water with less than 2 mg/l calcium. The ratio of calcium to magnesium is significant for calcium uptake by the snails. The freshwater snail that lives in the water with a low concentration of calcium was highly infected than in high concentration calcium [45].

2.2 Biotic environmental factors

2.2.1 Predators

The prevalence of freshwater snail infection is also affected by biological factors. The predators including Belostomatidae, Naucoridae, Nepidae, Gomphidae, and

Gyrinidae were prey on the freshwater snail and consume trematode larva miracidia [46, 47]. As a result, the prevalence of freshwater snail infection with trematode might be reduced. And also, the snail infectivity might be indirectly influenced by competitors like Thiaridae, Physidae, and Lymnaeidae [46, 48]. This results in an abundance of infected snails were decreased in the presence of predators and competitors [49].

Furthermore, biotic factors such as toxins produced by hosts, non-hosts, predators, or decoy organisms may act in concert with abiotic factors to expose free-living endohelminth stages to a diverse range of hazards on their way to the next host, further modulating transmission dynamics and infection patterns in a host population [27, 50].

The functioning of aquatic relationships is influenced by predatory and competitive forces. Predators often cause trophic cascades in which resource dynamics and energy balances in the environment are affected [51]. Such trophic cascades could be detected in Zambia [52] and Malawi [53] as a general reduction in aquatic biodiversity due to strong fishing pressure. Overfishing has reduced the predation pressure on snails, and fish mortality from metals, pesticides, and other chemical pollutants has reduced the top-down regulation of trophic interactions [32]. These all conditions reduce the abundance of snails in the aquatic environment and subsequently results in low snail infection. This is due to the high abundance of freshwater snails that could promote cercaria transmission as the access distance for the miracidia is reduced as a result more snails get infected, which could be because why the area with the lowest freshwater snails abundance had a low infection in snail [37].

2.2.2 Competitors

The non-host snail had the most significant influence on miracidia, causing them to enhance their host-finding behavior and penetration attempts. They discovered that failed penetration attempts resulted in severe mage and tiredness, making infecting the host snail more difficult. In addition, failed attempts caused them to shed penetration glands, making infection more difficult. When the media was infected with sew, the rate of miracidial infection in host snails decreased. This could be because of the fact that the sew contained a harmful material discharged by the none host snails, triggering a host snails regulatory response [3].

Snail introductions produce comparable outcomes, as they can infest wide regions of new suitable habitat and establish dominance. These have both bad and positive consequences since they cause economic damage and disruption to the biodiversity of the area in question, as well as positive results as a result of their competitive and predatory behaviors against hosts of dangerous parasites like schistosomes [32, 54].

2.3 Habitat conditions

Some habitat conditions like silt, organic, chlorophyll-a, canopy cover, riparian vegetation and freshwater snail abundance have an association with snail infectivity. These factors may be contributing to the development of the hotspot include the vulnerability of snails to infection, probability of interaction with viable trematode eggs, and suitability of snail habitat [55]. This study shows the habitat with silt, organic, shadow, and muddy grass-grown highly favored by the snails and the majority of infected snails were found in silt substrates, and greater than 50% riparian vegetation. The high abundance of snails that could promote cercaria transmission as the access distance for the miracidia is reduced as a result more snails get infected, which could be because of why the site with lowest snail abundance had a low infection in snail [37].

3. Snail borne diseases

There are different intermediate host snail species in the world freshwater bodies which cause snail borne parasitic diseases like schistosomiasis, paragonimiasis, fascioliasis, fasciolopsiasis, angiostrongyliasis, clonorchiasis, and opisthorchiasis. These diseases are the most important parasitic disease which remains crucial to public health issues worldwide, mainly in developing countries. Millions of people in 90 countries have suffered from snail borne disease, in which snails are intermediate hosts and transmitting vectors. These diseases also resulting in extensive socioeconomic burdens in many tropical and sub-tropical countries [1].

Specifically, human schistosomiasis is one of the most prevalent parasitic infections in the world and found in 52 countries. A report from WHO indicated that 219.9 million people worldwide are estimated to be affected by schistosomiasis, of which it is estimated that at least 90.4% of those requiring treatment for schistosomiasis live in Africa. This disease caused a loss of 2.5 million disability-adjusted life years (DALYs) [6]. It is the second most widespread parasitic disease after malaria and killing an estimated 300,000 people each year in the African region alone and 163 million population need treatment in sub-Saharan Africa [56, 57].

Schistosomiasis is caused by six species of trematodes from the genus *Schistosoma*: *Schistosoma mansoni*, *S. haematobium*, *S. japonicum*, *S. intercalatum*, *S. guineensis* and *S. mekongi*. The predominant causes of disease are *S. mansoni* and *S. haematobium* in tropical and subtropical regions, particularly in sub-Saharan Africa [6]. *Schistosoma mansoni* and *S. haematobium* trematodes are transmitted by two primary snail species of the genus *Biomphalaria* and *Bulinus* respectively, which are widely distributed throughout African countries [58].

Environmental and endogenous variables influence the development of *Schistosoma mansoni*'s life cycle in its intermediate host [58]. Mollusk infections occur in freshwater bodies contaminated by schistosome-infected people's feces. The existence of the Biomphalaria mollusk, as well as lack of or inadequate sanitation, human cultural habits, and the parasite's life cycle, all contribute to the parasite's persistence and, as a result, the disease's geographic spread [59–61].

The complete spectrum of direct and indirect effects on host and parasite life histories determines the impact of abiotic environmental factors on infectious disease dynamics. Importantly, these effects will go beyond a simple shift in host or parasite geographic distribution to involve a considerable modification in the physiological and temporal interaction between host and parasites, thereby altering disease dynamics in natural populations [62].

4. Conclusion

Environmental changes along the borders of water bodies aimed at diminishing snail habitats are one method of snail control. In both snail and parasite intervention during control operations, knowledge of the environmental factors in snail infectivity in endemic areas is vital. It will be feasible to take efforts toward preventing and regulating the harmful impacts of parasitic trematode outbreaks by knowing the ecological drivers of their infection, growth and propagation. As a result, it may cause overt harm to humans and livestock, as well as economic losses in the future. In man-made systems, where the design phase includes proper technical activities, environmental change may be optimal. Control techniques must be tailored to the ecology of the host snails as well as the social characteristics of the affected group, and executed on an individual basis.

Conflict of interest

The author declares no conflict of interest.

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