

Effects of Climate Change on Parasitic Adaptations

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Introduction

Contemporarily, the earth's temperature is fast increasing due to increased warming. ~~It is demonstrated through~~ global warming that has resulted in the melting of ice sheets and modification of precipitation patterns. Swiftly shifting climates will go down in the annals of history as critical contributors to the extermination of organisms. Climate change is expected to ~~partake~~ ^{have} irreversible implications on the ecosystem, and this will affect organisms. Parasitic adaptations will be significantly affected. For instance, the geographical boundaries and the ecosystem of ectoparasites may be susceptible to aridity, elevation, and cold and salt spray. On the other hand, endoparasites' existence may be compromised by soil type, temperature ^{and} ~~a~~ alongside precipitation. This is because an altering climate modifies the accessibility of parasite niche space leading to habitat loss and shifting of ranges reducing their population growth and reproduction rates. ~~The paper's~~ ^{is} thesis seeks to explain the consequences of climate change on parasitic adaptations.

Over the past 20 years, extreme weather events have increased significantly due to rising global temperatures and additional climatic changes, per the United Nations report. ^(Ref?) Some prevalent extreme weather events include drought, hurricanes, tornadoes, floods, and blizzards, to name a few. ^(?) Furthermore, the report by the United Nations outlines that between 2000 and 2019, 7348 major natural disasters took place globally. Consequently, these extreme events have significantly disrupted the life cycles of many parasites, either positively or negatively. ^(ref) In the contemporary world, incidences of extreme weather events have increased astronomically. This has been attributed to climate change. Human activity has been considered a primary cause of rapid changes in climate across the world. For instance, non-renewable energies such as fossil

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fuels ~~and coal~~ that emit toxic greenhouse gases into the atmosphere are immensely utilized in homesteads and industries as sources of energy. This has resulted in an amplified occurrence of extreme weather happenings in the world today. (ref)

In the world today, three major components of climate change are evident and continue to escalate in magnitude and significance. They include warming, altered patterns of precipitation as well as the amplified occurrence of extreme climatic events. The components mentioned earlier have significantly impacted the structure and functions of ecosystems, thereby affecting various parasitic adaptations. Climate change affects parasitic adaptations in myriad ways:

Temperature-Dependent Escalation of Effects on Hosts'

Some parasites can adapt ^{to} in increasing temperatures, an adjustment that enables them to thrive in warm climates. Warmer temperatures increase ectotherm^{ic} hosts' organismal metabolism. Hence parasites of ectothermic hosts can live and cause infections on their hosts. Also, climate change affects endo-parasites via the somatic location in the hosts. When faced with extreme weather events, hosts that can adapt to different temperatures can overcome infections of parasites, and the new ecosystem may be unfavorable for the parasite to live (Carlson et al., 2017). ^{how?}

However, warming caused by climate change may adversely affect eutrophic parasites that live in the aquatic environment. Increased warming of the water sources reduced the amount of oxygen. Low oxygen is a leading environmental stressor that can weaken hosts and worsen disease impacts. During summer, shallow-water environments have low oxygen that can sustain eutrophics organisms while the parasites can thrive. Usually, temperature increases parasite

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metabolism, thereby increasing their feeding and replication within a host. Also, the host usually experiences amplified environmental stress that deteriorates its resistance to disease-causing parasites. It is demonstrated in *Hyalophysa lynii* that is a recently recognized apistome ciliate parasitizing penaeid shrimp within the southeastern US. The parasite has been found to live within the shrimp's gills and initiates an immune response that leads shrimp's gill tissue to develop melanized nodules. The nodules hamper the exchange of oxygen and lessen physical endurance along with escape responses equated to shrimp having no nodules. The physical impairment intensifies on the host as oxygen concentration drops with increasing temperature.

Adaptations of Parasitic Nematodes Due to Incidences of Climate Change

In the face of extreme weather events, parasites have adopted adaptations to help them survive extreme ^{conditions} and environmental unpredictability. Climate change is gradually and constantly escalating weather changeability, resulting in further intense, recurrent, and lengthier extreme happenings such as severe famines, erratic rainfall, high heat, and cold waves. Under these unpredictable conditions, the parasites' performance and host-parasite associations are directly impacted by the capability of parasites to deal with extreme weather events by adapting to the new conditions. For example, parasitic nematodes cope with extreme weather conditions by developing structural, behavioral, and ecological characteristics to persevere and acclimatize to the transitioning ecological conditions (Aleuy, & Kutz, 2020). In the Arctic, temperature changes are significantly increasing since climate change is happening quickly and more rapidly. Parasitic nematodes have resistant anatomic structures that allow them to develop structural and behavioral adaptations to survive life-threatening conditions and the shifting environments. During warm temperatures, eggshell adaptations ensure that the egg is protected from

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desiccation. Also, the egg fluids can be appropriately maintained in a liquid state when exposed to freezing temperatures (Dobson et al., 2015). Freeze tolerance of eggs is a necessary adaptation that allows *Marshallagia marshall* (abomasal nematode) to survive in very arid and cold conditions.

Also, the free-living stages of parasitic nematodes have embraced various adaptations – behavioral and physiological mechanisms – that help them delay, prevent or survive when exposed to risky weather conditions. The unhatched infective stage larvae of parasitic nematodes can be dominant in the egg until appropriate hatching conditions occur. Environmental stresses such as changes in temperatures and desiccation can trigger this quiescent state. This is demonstrated in *the Nematodirus battus* that normally attains its growth from egg cell to L3 afore shading. Hence, eggs with L3 are capable of remaining in an inactive condition until the temperatures attain a defined extent, usually 11.50C as well as 170C, to enable hatching to occur. Thus when the eggs become exposed earlier to cold temperatures of winter, the rate of shading ^{speeding} increases dramatically (Utaaker et al., 2015).

Dormancy can increase the survival of the parasitic nematodes when inhabiting their intermediate hosts. The parasites' life cycle is a crucial contributing factor to extreme weather events on host-parasite relations. A predominant concept is that parasites having ancillary life cycles are likely to go through significant danger of extermination under incidents of extreme weather circumstances matched to parasites having uninterrupted life cycles. Typically, parasites with ancillary life cycles need several exact and coerced exchanges to transpire to attain effective spread (Polley et al., 2010). However, the changes may be disrupted within a changing environment. Intermediate hosts are usually more efficient in migrating to microhabitats that

moderate ambient climatic conditions than free-living parasites. This ensures that parasites can be protected from temperature extremes as they are positioned inside the host. (Ref)

Factors That Covary with Change in Temperature Disturb Host-Parasite Systems

Increasing global warming results in high salinity of water bodies. Also, global climate change has affected the patterns of precipitation. A balance between precipitation and evaporation defines the sea surface salinity; hence salinity varies spatially. In evaporation-dominated mid-latitude areas, higher salinities are distinguished. Thus certain parasites like the dinoflagellate *Hematodinium* can thrive and parasitize blue crabs (*Callinectes sapidus*) all through the Atlantic coast of the US estuaries (Singh et al., 2011). Infection of the blue crabs is more pronounced when the salinity of the water is exacerbated due to an increase in global temperatures. However, in low salinities, the transmission of infection by the *Hematodinium* sp. is reduced. This indicates that the disease does not thrive in low saline aquatic environments. In this essence, many blue crabs migrate up-estuary to freshwater, where the parasite cannot live. In the early 2000s, severe droughts in the southeastern US resulted in increased temperatures, precipitation, and decreased stream inflow that significantly increased salinity in estuaries. This led to increased incidences of infection of blue crabs because *the Hematodinium* parasite was able to grow in large amounts. (Ref)

Besides, climate change has been exacerbated by the increased emission of carbon dioxide into the atmosphere. Oceans are carbon sinks that absorb the majority of the emitted carbon dioxide. Ocean acidification (OA) has myriad effects on parasitic adaptations (Van Dijk et al., 2010). For instance, parasites exposed to ocean acidification face different problems like other organisms, like reduced abilities to control ions and perform calcification. The primary

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experimental studies done have mainly concentrated on trematodes and highlighted that introduction to significant carbon dioxide water bodies decreases the chances of trematode cercariae and outward metacercarial cysts. Considerable mortality rates of a trematode's cercarial stage are distinguished below low pH circumstances. This explains the reason why more infections associated with amphipods take place at low pH.

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Moreover, severe droughts caused by climate change have provided ample climates for some parasites to grow and multiply. Typically, parasites are more diverse and several compared to their hosts – they control population dynamics. Hence they play a vital role in impacting the grazing conduct of animals. An example is depicted in the southern US salt marshes where drought interrelates synergistically with underpinning grazing to develop broad ecosystem die-off (Morgan, & Wall, 2009). Trematode parasites can resist drought and cause field manipulations due to salt stress within the sediments. This suppresses the feeding activity of grazers that overfeed their animals on drought-stressed plants. Experimental studies reveal that parasitism is more pronounced in animals grazed in die-off borders. Hence farmers may opt to relocate with their animals to others areas where the parasite may be avoided.

(Ref)

What does this mean?

Are you talking about grazing cattle etc?

Additionally, climate change influences the living of parasites. *Trichostrongyles* such as *Ostertagia gruehneri* and *Teladorsagia boreoarcticus* are renowned non-zoonotic nematodes parasitizing the guts of animals' adults. These parasites have uninterrupted life cycles encompassing eggs' development put in the fecal matter to free-living, virulent maggots within the environs. Typically, contamination by hosts of ungulates is through consumption of the infective bugs. However, hosts' positive and negative effects of climate change can change patterns of growth for the free-living periods of the parasites (Polley, & Thompson, 2009). When

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sufficient moisture and longer warmer summers would increase the chances of survival for the free-living phases resulting in reduced generation intervals along with large infectious larvae, animals would record an increase in the rate of diseases. On the other hand, changed summer transmission aspects and drop climate can modify the arrangements of larval restraint within the gastrointestinal mucosa, resulting in a reduced rate of diseases caused by the parasite. (Ref)

Furthermore, flooding is an extreme weather event that gives many parasites conducive breeding grounds, such as *Posthodiplostomum cuticola* and snails. Flooding is regarded as a significant contributor to the increased growth and development of these parasites. Areas that have been highly flooded report increased cases of fish infection as a result of the *Posthodiplostomum cuticola* parasite. Also, snail fever is increasingly reported in areas where flooding occurs since snails' population increases. (Ref)

Predictors of Parasite Vulnerability

Geographic distributions and the size of the population are considered the most outstanding dependable forecasters of climate-induced extermination peril for several Red Listed free-living species shortlisted in the IUCN. (Ref) Conversely, the statistics for many species of parasites are lacking. The biological traits of parasites that affect their success when faced with climate change are myriad. Foremost, the metabolic ecology of the parasites plays fundamental roles in determining whether they will thrive or suffer during the incidence of climate change events. Parasites less cushioned from erratic ambient temperature fluxes by poikilothermic hosts are more vulnerable to extreme weather events (Cizauskas et al., 2017). Secondly, the host body size is a critical factor to be considered. Parasites on larger hosts are expected to be more disposed to elimination due to amplified co-extinction jeopardy and the subsequent loss of a significant

extent of parasite slots along with the diversity of parasites. Typically, hosts with larger bodies form breeding grounds for many parasites. Thus the host is faced with problems resulting from climate change, and the parasites will also be under threat. For example, ticks are parasites that live on cattle. When cows die due to severe droughts, the ticks are likely to succumb. (Ref)


Thirdly, host-specific^{ity} and host switching are factors that explain the ability of a parasite to thrive on a host or not. Host-specific parasites are faced with overall more significant risks of co-extinction (Pozio, 2020). For example, foodborne parasites face a greater risk of extinction when farmers ~~reintroduce~~ new crops instead of the ideal crops vulnerable to the parasites. Nevertheless, unseen plasticity allowing the switching of hosts can lessen certain risks a parasite is exposed to. Fourthly, transmission and persistence of the parasites determine their ability to succeed or agonize when exposed to climate change. Its status of the ecological niche may brand? every independent phase within the life cycle of a parasite. (Ref)

Conclusion

Climate change is a scourge that has had a considerable impact on parasitic adaptations. It has led to shifting ecosystems and improved the living conditions optimal for parasites to live and multiply. Various experimental studies have indicated that climate change has resulted in elevated warming, changed precipitation patterns, and amplified climatic changes such as floods, droughts, and many more. Extreme weather events have been on the rise in the current world. Per the new report done by the United Nations, the increasing occurrence of extreme weather changes is linked to global warming. For instance, from 1980 to 1999, major floods have doubled, and severe storms have increased, heat waves have also elevated. However, the challenge brought about by the high rate of global warming is that animals – hosts – have been adversely

affected by the increasing population of parasites. Some parasites such as trematode have resisted the harsh climatic conditions of severe droughts and suppress the feeding activity of grazers.

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