Expert Views

The relevance of climate change for life and health insurance

Part 3 – The Epidemiologist's View

SCOR
The Art & Science of Risk

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Climate change is a trend that has highly complex and interconnected impacts, and understanding the relevance for life and health insurance requires expertise and a broad perspective. This series of papers by SCOR's internal experts aims to support the readers in gaining a solid understanding of the key elements of the impact of climate change and enable them to draw conclusions for their own company and situation. Parts one and two, giving the risk manager's view and the medical director's view, can be found at scor.com.

In this third part of the series, with SCOR's experts Dr. Gabriela Buffet, infectious disease specialist, and Xiao Gao, epidemiologist, we will examine existing and emerging infectious diseases and analyze their interplay with climate change and health. Changes in ecosystems, such as higher temperatures, rainfall variability, storms, droughts, floods, forest fires and heat waves, trigger changes in the epidemiology of many diseases.

The fourth part of the series will focus on mental health. The negative impact of climate change on human emotional and psychological wellbeing, while currently still largely underestimated and under-researched, might become a major concern.

The pathways of interaction between climate change and diseases

Infectious diseases are not only a risk for humans. They are also, or possibly even more so, threats to other animals, both domesticated and wild, and to the flora on which all life eventually depends. In this paper, we will mainly use the term "host" for organisms affected by a pathogen, but we will also use it to simply refer to humans, as our focus here is life and health insurance.

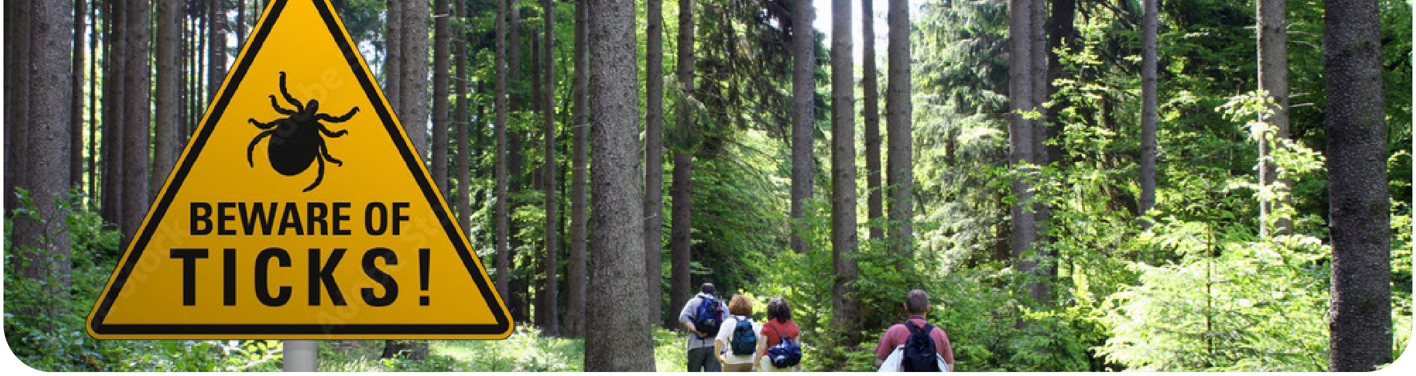
Infectious diseases are caused by pathogens, mainly by viruses, bacteria, fungi, and parasites. Some spread directly from host to host, using transmission channels such as bodily fluids, air, water, or food. Others are transmitted by an intermediate host, a so-called "vector", such as a mosquito or a tick. Each pathogen is adapted to the specific environmental conditions in which it develops, including temperature, humidity, and geographical location.

The impacts of climate change, already observed in the recent past and projected to increase in the future, modify the equilibrium of different ecological niches that had been stable for very long periods of time. Disrupting those conditions can influence infectious diseases in several ways, including increased incidence and increased severity[1].

Changes in spatiotemporal distribution

The survival of key vectors for disease transmission, such as mosquitoes, fleas, ticks, birds, rodents and various other mammals, is entirely dependent on the right ecological conditions. Therefore, alterations in average and extreme temperatures, humidity, and vegetation quality, as well as large-scale animal and human movements will be inexorably accompanied by changes in the distribution patterns of vectors and the diseases transmitted by them.

An overall warmer world with shorter and milder winters due to climate change allows more vectors and pathogens to survive at higher latitudes and, at the same time, favors their extension to other latitudes and higher altitudes. This increases the geographic distribution of infections, the duration of the transmission season as well as its intensity. However, although "warmer is better" for vectors in general, the relationships between temperature and vector survival, abundance, and feeding are often complex. For instance, malaria transmission increases with temperature, peaks at a specific temperature, and then decreases. Therefore, climate change could worsen malaria transmission in the short term and mitigate it in the long term if global temperatures continue to rise.



The distribution of mosquitoes is driven by global climate change but also by other factors such as urbanization, changes in land use and human mobility. Studies have shown that the geographic distribution of Anopheles and Aedes mosquitoes is expected to expand dramatically over the next century, as previously inhospitable habitats become favorable, posing significant public health challenges. Both species have now successfully spread around the world, partly due to their close association with humans but also due to their physiological plasticity: the ability to survive in tropical and temperate conditions, laying winter- and desiccation-resistant eggs and a wide range of breeding habitats. Interestingly, according to literature[2], climate change will not be directly the main driver behind the increase in the distribution of these mosquitoes, but it is expected to be mainly driven by urbanization and human mobility.

With rising temperatures, however, some regions of the world will actually become less favorable for certain vectors as their survival conditions will be challenged. Examples include the plague, which is transmitted optimally only at temperatures below 27°C, and human sleeping sickness, which is transmitted by the tsetse fly whose juveniles are also sensitive to high temperatures. In addition, the typical seasonal epidemics of air-borne influenza (winter flu) and respiratory syncytial virus, which are responsible for bronchiolitis in children, are predicted to become shorter in duration and thus lower in overall impact with warmer and briefer winters.

Changes in pathogen and vector lifecycle

Climate change indirectly affects pathogens and vectors by providing conditions where they often have a broader geographical range and an extended timespan regarding where and when they can thrive. But it also can have a direct and physical effect, as illustrated by the example of mosquitos: Temperature affects the dynamics of mosquito physiology, life cycle, behavior and competence for disease transmission. Mosquitoes depend on the ambient temperature for biting rate, fecundity, development and longevity. Temperature, humidity and rainfall influence both the mosquitoes and the parasites within their bodies.

Considering the example of the Chikungunya-transmitting Aedes mosquito, this relates to the four stages in its lifecycle: embryo, larva, pupa and adult. The duration of the embryonic state, i.e., the time between laying and hatching, reduces from around 40 days at 15°C to around five days at 30° C for tropical mosquito strains. Similarly, the larva stage drops from 35 days to five days over the same temperature range, and the pupa stage duration decreases from eight days to two days. Only the adult stage is extended with lower temperatures, with a consensus that mortality rises above 27°C and temperatures above 40°C are generally accepted as the limit for adult survival[3].

This means that with higher (but not too high) temperatures, mosquitos can reach maturation faster, leading to more generations and thereby higher total number of disease-carrying vectors. At the same time, the proliferation of the pathogens themselves is affected. In the case of the malaria-causing *Plasmodium* parasite, it enters the female mosquito's gut via ingested blood and then goes through various development stages inside the mosquito until it reaches the salivary glands and is ready to be transmitted to the next human. The duration of this so-called "extrinsic incubation period" also seems to be a function of temperature, with higher temperatures speeding up the process and making infected mosquitos faster in becoming infectious.

Studies also show that elevated temperatures could increase mosquitoes' resistance to insecticides, thus lowering the effectiveness of vector control measures.

However, not only tropical or neglected diseases are favored by climate change, but some common infectious diseases are also expected to be impacted, among them pathogens such as *Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, Streptococcus pneumoniae*, and *non-typhoidal Salmonella*. This is due to bacterial metabolism being closely linked to temperature. An overall warmer environment increases bacterial growth rates and horizontal gene transfer, the latter a key mechanism for the acquisition of antibiotic resistance. The result is a "double whammy" of more bacterial spread and infections together with more resistance to antibiotics: researchers have found that when comparing the minimum temperature across various US regions, a 10°C temperature difference was associated with observed antibiotic resistance being higher by 4.2%, 2.2% and 2.7% for *E. coli, K. pneumoniae*, and *S. aureus respectively*[4].

Changes in human-host interactions

Environmental changes are causing increased physical proximity of pathogens, vectors, and humans. For example, heat drives mice to seek shelter near human habitations, leading to increased cases of mouse-borne illnesses. Drought forces any animals, including mosquitoes and birds, to concentrate around remaining water sources, intensifying interactions and favoring the transmission of pathogens such as West Nile fever or avian flu, among others. Floods and storms are associated with sewage overflow and interruption in water infrastructure, favoring foodborne illnesses caused by contaminated agricultural products and waterborne diseases. In tropical areas, heavy rainfall and flooding increase the risk of leptospirosis infections, which can have a fatality of 5%-10%. Wider adoption of air-conditioning can increase the transmission of diseases such as tuberculosis and legionellosis.

Droughts, floods, storms, and other events that reduce food availability and cause failing harvests can put pressure on people to forage in a wider area, bringing them more frequently in contact with wildlife and thus increasing the risk of zoonoses. These are diseases that move from animal hosts to humans, with notable past examples being HIV and MERS. In addition, dry periods concentrate animals around water sources, increasing the rate of infection and consequently the probability of human infection. Other trends that increase the interaction between humans and potential vectors and pathogens are the cutting of new roads across forests, damming of rivers, and the growing consumption of non-domesticated animals.

Global warming is also causing the permafrost in the Artic region to thaw and ice covers to melt, exposing buried and frozen known pathogens such as Anthrax spores, and possibly also undocumented pathogens. How viable and how virulent they are under today's conditions remains to be seen.

Changes in human vulnerability

At the same time as influencing the optimal conditions for pathogens, climate change can also amplify vulnerabilities and exposure of their targets. According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability is defined as "the propensity or predisposition to be adversely

affected by infectious disease or a susceptibility to harm and lack of capacity to cope and adaptation". Vulnerability factors for health impacts can be categorized into biomedical (including having co-morbidities, being malnourished or obese, immunocompromised), demographic (including age and occupation), geographic (including living in areas prone to flooding and forest fires), socioeconomic (including poverty and level of education), and sociopolitical (including instability and corruption).

Climate change can lead to changes in vector habitat as well as human habitat. Among the downstream factors that are impacted are the type and standard of buildings people are able to construct, the availability of protective gear, access to health care, education, food quality and availability, and workplace conditions (e.g., timing and duration of outdoor work, availability of breaks, water and shade). Economic strain typically also means lower access to prevention, creating a higher infection risk, and lower access to treatment, resulting in a poorer disease outcome. As explained in the previous paper, climate change is expected to have a heavy toll on the human body, including the vascular, respiratory and immune system. The burden from heat and humidity will be more difficult to bear when combined with problems regarding food security and water availability and quality.

Extreme weather events create favorable conditions for the spread of diseases, especially when they also lead to population displacements. For example, overcrowded conditions in emergency shelters favor infections and challenges the provision of health services. This can also have cascaded or indirect effects. For example, in Latin America, a number of hurricanes disrupted anti-malaria vector control programs and resulted in a resurgence of *P. falciparum* in the 1980s and 1990s. Drought and floods are linked to increased risk rates for digestive bacterial and virus infections. Droughts could force people to consume water from unsafe sources and reduce their hygiene standards, while heavy rains and floods can contaminate drinking water.

A further aspect of vulnerability is migration. Human movements can transport diseases into new regions. In Brazil, for example, periodic epidemic waves of the parasitic disease visceral leishmaniasis have been associated with migrations to urban areas after long periods of drought. Likewise, migrants moving into new regions might not be immunized against diseases established in these regions.

As an upside, humans co-evolve with the diseases they encounter and beneficial gene variants can spread in a population, helping to increase resistance. One example is a mutation of the CCR5 receptor in the human immune system, which seems to have arisen in Northern Europe around 1000-2000 years ago under positive selection from the bubonic plague. Similarly, the Duffy antigen provides resistance to malaria.

Project Wolbachia in Singapore

Controlling vector populations to reduce infectious diseases can be achieved in multiple ways, including very innovative and environmentally friendly methods. One example is Project Wolbachia in Singapore, which is about the release into the wild of male mosquitoes that have intentionally been infected with Wolbachia bacteria. Wolbachia are naturally occurring bacteria present in more than 60% of insects but not in Aedes aegypti, the primary dengue-transmitting vector. When female mosquitoes mate with these released males that carry Wolbachia, their eggs do not hatch. As the National Environment Agency reports[8], populations at study sites are reduced by up to 98%. Correspondingly, the core areas of the study sites with at least one year of releases saw up to 88% fewer dengue cases, compared to areas without releases.

The relevance for Life and Health insurance

From the above it is evident that there will be, in general, more infectious diseases. Some will have a broader geographic range and affect larger parts of the population, while at the same time, the human population will become more vulnerable. Some researchers predict a higher frequency of pandemics driven by the increasing rates of diseases emerging from animal reservoirs[5].

From an insurance perspective, it can be useful to distinguish between morbidity risk and mortality risk. Regarding the latter, many of the known infectious diseases seem dangerous, because they have significant fatality rates. However, one needs to consider that this high fatality is influenced by a lack of access to healthcare in developing countries where they are endemic and by affecting vulnerable sub-populations. For instance, according to the WHO, 95% of malaria cases and 96% of malaria deaths in 2021 were in the African Region, and children under 5 accounted for the majority of these deaths. The same diseases will have far lower fatalities if they occur in other parts of the world such the Global North, for reasons such as:

- Effective surveillance systems and quick case identification can stop disease transmission early enough to prevent epidemics.
- Isolating infected individuals can lower the probability of vectors feeding on an infected person and of direct transmission, thus reducing the reproduction rate and the number of new cases.
- Early treatment and access to healthcare can reduce severity and mortality.
- Healthcare is more widely available (e.g., distance to the next hospital, relative number of medical professionals, ICU beds, equipment and medication infrastructure).
- Large parts of the population have a lower vulnerability due to better nutrition and access to clean drinking water and sanitation.
- As evidenced during the COVID-19 pandemic, vaccines are more broadly available and reach a larger part of the population. There are already vaccines for dengue, malaria and tick-borne encephalitis, with several new ones in clinical trials.
- It can be expected that more research will be directed toward currently neglected diseases once they become a higher threat to affluent societies.

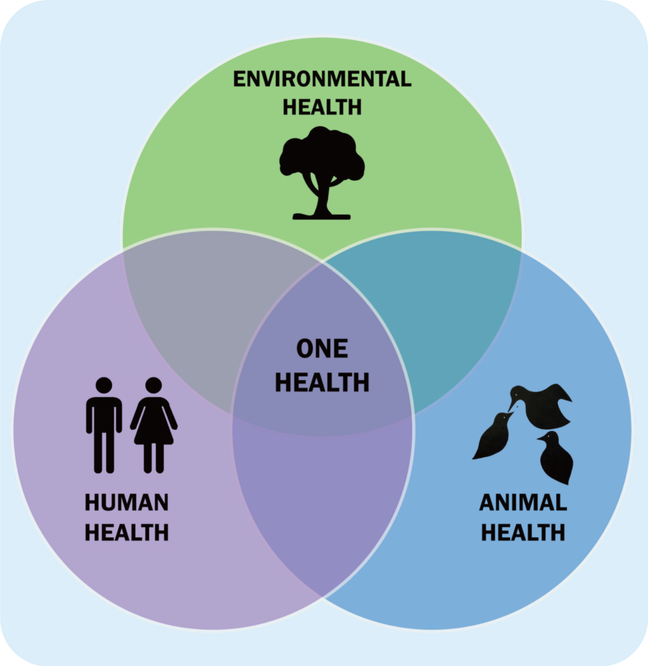
Mosquito-borne tropical diseases are expected to become endemic in Europe and North America. Studies predict malaria transmission for up to six months per year after 2050, particularly in southern and southeastern Europe, and even Scotland is expected to be climatically suitable for malaria transmission by 2080. However, the influence on mortality is predicted to be small. In 2014, the WHO published a report estimating additional deaths attributable to climate change in 2030 and 2050 by region[6]. Results showed that excess deaths from malaria and dengue were close to zero in high-income countries. For the UK, a separate study predicts that climate change may lead to 280-480 extra deaths per year from malaria, tick-borne encephalitis and dengue fever combined.

By contrast, the impact of the increase in infectious diseases caused by climate change on morbidity could be significant due to their high treatment costs and durations, as well as possible long-term disability outcomes from some infections. According to US figures[7], the mean cost per hospitalized malaria patient was USD 27,642, and USD 1,177 for non-hospitalized patients. Many survivors of cerebral malaria (severe malaria with coma) sustain brain injury, and a quarter has long-term neurologic and cognitive deficits. Severe dengue cases can lead to internal bleeding and lasting organ damage. In conclusion, regarding insurance products, is likely that those covering medical expenses, disability and long-term care could experience more frequent claims due to climate change-driven infectious diseases.

Intervention avenues

Governments and health authorities are studying interventions to reduce the impacts of climate change on health in the short, medium, and long term. In the short and medium term, it is crucial to take a two-pronged approach and reduce vulnerabilities and exposure at the same time. For example, comorbidities, which are known to lead to more severe outcomes of infections, can be targeted through campaigns focused on the prevention of obesity, smoking, etc. Exposure can be reduced through health education campaigns regarding the prevention of infectious (such as checking for ticks after each walk) and parasite control measures (such as not leaving stagnant water sources outside). Finally, it is essential to combat deprivation and improve access to health services. The WHO predicts that in the short and medium term, the impacts of climate change on health will mainly be determined by the vulnerability of populations, their capacity for resilience and their rate of adaptation.

In the longer term, the WHO estimates that the effects of climate change will largely depend on measures and policies to reduce the magnitude of impact and avoid the tipping point towards irreversible changes. This means that durable and global solutions must be put in place. One of these solutions is to consider the interconnectedness of human, animal, and environmental health and their interactions by creating an integrated approach: One Health. This concept was introduced in the early 2000s and brings together physicians, veterinarians, and experts from agriculture with the aim of promoting a multidisciplinary and global approach to health problems and identifying effective and sustainable solutions to shared complex health problems.



One example is the overuse of antibiotics in animal husbandry, which contributed to the increase in antibiotic resistance and is now being tackled worldwide. Another example of the close interdependency between human and environmental health is the recent spreading of aggressive types of the fungus *Puccinia graminis*, which causes stem rust in wheat and poses a major threat to global wheat production and, thus human food security.

In the fight against infectious diseases, various actors will have distinct roles to play:

- Healthcare systems: prepare drugs, equipment, procedures, etc., to treat emerging infectious diseases and provide training to doctors, nurses and other health professionals on diagnosis and treatment.
- Governments: operate robust disease surveillance systems, ensure fast responses to health emergencies, increase public awareness, and invest in research on vaccines and treatments.
- Insurance companies: offer suitable and affordable products that provide cover for treatment and long-term impacts in severe cases.
- Individuals: adopt prevention measures, be informed about diseases and their symptoms, seek treatment as early as possible and avoid infecting others.

Spotlight on selected diseases

- **Dengue** – Dengue fever is the most important mosquito-borne viral disease affecting humans. Dengue is caused by an arbovirus with four different serotypes and is transmitted by Aedes mosquitoes. Infection by one serotype induces immunity against this serotype but not against the other three, so repeated infections are possible. While the disease is asymptomatic in most cases, it can cause fever associated with pain and a rash. In rare cases, serious and sometimes fatal complications can occur. Around 0.5 milllion people with severe dengue require hospitalization each year.

  The coexistence of dengue outbreaks with the COVID-19 pandemic led to aggravated pressure on health systems, misdiagnosis, and difficulties in management of both diseases in many regions of South America, Asia, and Africa.

- **Chikungunya** – Chikungunya virus is an arbovirus from the family *Togaviridae* and is transmitted by *Aedes* mosquitos. In the last 50 years, it has spread from Africa and Asia to Europe and the Americas and from the tropics and subtropics to temperate regions. Chikungunya is causing approximately 1 million infections each year, leading to joint pains that can become chronic.

- **West Nile fever** – West Nile fever is caused by West Nile virus, a virus of the *Flaviviridae* family that infects mainly birds and, infrequently, humans through the bite of an infected *Culex* mosquito. 80% of cases are asymptomatic; however, West Nile virus can cause neurological damage (meningitis, encephalitis, and meningoencephalitis). These neuro-invasive forms are more common in the elderly and can lead to sequelae and even be fatal in humans.

- **Rift valley fever** – Rift Valley fever is a viral zoonosis caused by a member of the *Phlebovirus* genus. Several different species of mosquito can act as vectors for transmission. Uncomplicated human Rift Valley fever manifests as an acute influenza-like illness. The severe form of the disease is a hemorrhagic diathesis with hepatitis which can lead to death. Complications include retinitis and encephalitis; 50% of cases suffer from permanent loss of central vision. The case fatality rate is generally low, but full recovery can be long, and long-term neurological complications have been reported.

- **Tick-borne diseases** – Lyme disease is a bacterial infection caused by the *Borrelia burgdorferi* bacteria that can be spread to humans by infected ticks of the species *Ixodes*. Deer ticks are the predominant vectors in the USA. Their expanding geographic distribution poses an impending public health problem. Over the past 30 years, the incidence of Lyme diseases has increased in Europe, the USA, and Canada. If not treated, Lyme disease may cause neurologic and rheumatic manifestations weeks or months later. Almost half a million cases of Lyme disease are diagnosed in the United States annually. According to the CDC, the economic burden of Lyme disease is between $345 million and $968 million each year. The average patient cost was approximately $1200.

  In addition to Lyme disease, other tick-borne diseases have started to emerge and are likely to increase with climate change: Anaplasmosis, Babesiosis, infections with Powassan virus (which have a case fatality rate of 10% - 15%), and with *Heartland virus*.

- **Cholera** – Cholera is responsible for more than 95 000 deaths annually. Although inadequate sanitation is the main enabler, climate conditions are increasingly favouring the survival of *Vibrio cholerae* in natural waters, keeping an environmental reservoir and favouring its spread.

  Low rainfall and high temperatures in the warmer months favour *V. cholerae* replication as well as increase bacterial concentrations in groundwater. And heavy rains and floods favour the contamination of drinking water sources.

- **Vibriosis** – Non-cholera *Vibrio* bacteria can cause septicaemia with a case fatality rate of ~50% and necrotizing wound infections. *V. vulnificus* thrives in saline and brackish waters and can cause gastroenteritis if ingested via contaminated food such as shellfish and crabs.

  The incidence of vibriosis has been increasing during the last decades and cases are occurring in regions where environmental conditions in the past had been considered unfavourable for the *Vibrio* pathogen. Rising seawater temperatures as a result of climate change have been identified as one of the main drivers, particularly in high-latitude locations. For instance, the area of coastline suitable for *Vibrio* increased from 30% to 57% in the US northeast.

  In addition, past outbreaks were associated with swimming/bathing in coastal waters during heat waves, when humans increasingly seek cooling. As climate change will lead to more extreme heat, such vibriosis-outbreaks are likely to increase in frequency and intensity.

- **Schistosomiasis** – This disease, also known as bilharzia, is caused by parasitic flatworms that are released into freshwater by snails. Chronic infections can lead to liver and kidney damage, and to developmental issues in children. Transmission might decrease in tropical regions when temperatures exceed the critical maximum for snails but is expected to increase in other geographic regions with sufficient water resources where temperatures are currently too low for snail development. Likewise, flooding may favor the spread of snails and cause outbreaks of schistosomiasis in or near endemic areas.

- **Fungal diseases** – Although generally of lower clinical relevance, fungal infections such as caused by *Candida auris* or *Cryptococcus deuterogattii* can be expected to become a risk for immunosuppressed or otherwise weakened patients. Global warming has been proposed as a contributing cause for the emergence of different strains of *Candida auris* on different continents. It possibly became pathogenic for humans due to thermal adaptation in response to climate change. In parallel, fungi are becoming less susceptible to current antifungals, which poses a therapeutic problem.

- **Seasonal Influenza** – The El Nino Southern Oscillation (ENSO) is a major, irregular, periodic global climatic phenomenon that results from thermal inversion in the Pacific Ocean. It has profound effects on weather and climate worldwide and causes regional surges in rainfall and temperatures in the United States. Studies have confirmed an influence of ENSO on the timing, magnitude, and severity of epidemic influenza activity due to changing local weather patterns. Climate change is expected to influence ENSO activity, which will have impacts on seasonal influenza in ways that are difficult to predict.

- **Pandemic influenza** – Analysis of data from ENSO and influenza pandemics of the past century suggests that the likelihood of an influenza pandemic emerging is greatest during La Niña events. The most plausible biological explanation involves ENSO-mediated changes in bird migration. In fact, the effect of ENSO on the health and behaviour of migratory birds may be one of the ways in which the environment alters the likelihood of influenza virus reassortment events and interbreeding with human hosts.

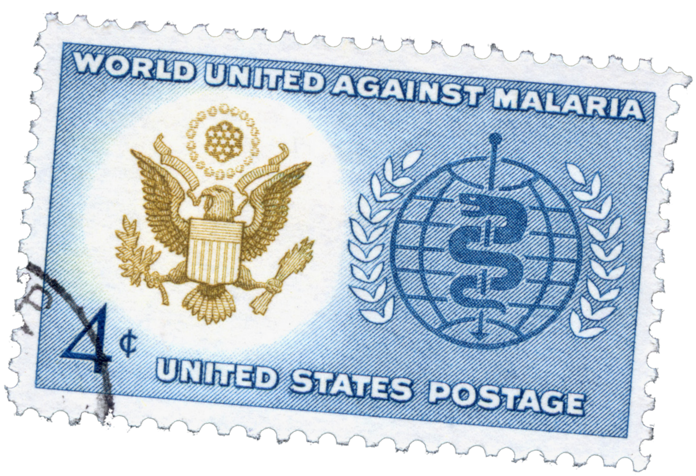
  Potential mechanisms are changes in (i) bird number, (ii) bird fitness/viral shedding, (iii) bird stopover time (more time in residence equals more mixing with bird local population), (iv) bird species composition, and (v) changes in water habitat type and abundance that facilitate fecal-oral avian and swine infections, multiple infections, and virus reassortments.[10]

Closing remarks

At SCOR, we see it as imperative to partner with our clients to better understand emerging trends and risks, and to develop tailored insurance solutions that help people to remain resilient in this evolving risk landscape. This series aims to contribute to a deeper understanding of the relevance of climate change for Life and Health insurance and to facilitate the development of suitable actions.

As shown in this paper, the relationship between infectious diseases and climate change is more complex than given credit for in the discussions so far. A differentiated approach is needed to properly understand the relevance for mortality, morbidity and the consequences for insurance. The contributing factors vary across geographies and types of disease as well as populations affected. Adaptation, public health initiatives and research into prevention and treatment are elements that will have a major impact but are difficult to predict, as they are highly complex and heavily depend on the future economic situation and political priorities. This is related to the "transition risk," where the exact path to decarbonization will play a role in shaping conditions that influence the risk of infectious diseases.

As a global independent reinsurance company, SCOR contributes to the welfare, resilience, and sustainable development of society by bridging the protection gap, increasing insurance reach, helping to protect insureds against the risks they face, pushing back the frontiers of insurability, and acting as a responsible investor.



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