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Climatic change: possible impacts on human health

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Abstract

This paper addresses a number of problems relating climatic change and human health. Following an introduction that outlines the over-arching issues, a short summary is given on climatic change and its anthropogenic causes. The rest of the paper then focuses on the direct and indirect impacts of global climatic change on health. Direct effects comprise changes in the hygrothermal stress response of humans, atmospheric pollution, water quality and availability; indirect effects include the potential for the spread of vector-borne diseases outside of their current range. The paper concludes with some comments on possible response strategies aimed at alleviating the adverse effects of climatic change on human health.

1. Introduction

Over coming decades, humankind is likely to be subjected to the impacts of rapid environmental change that has been, at least in part, triggered as a result of human activities. While the balance between humans and their resource-base has always been delicate, the accelerated changes resulting from industrialization and significant global population increase over the last century has resulted in definite and sometimes irreversible damage and loss of resources. According to Myers and Tickel (2001), there have been more changes in the environment in the last 200 years than in the last 2,000, and more changes in the last 20 years than in the last 200. The rate of species extinction is now well beyond the natural rate, in what is sometimes referred to today as the “biotic holocaust”.

Global environmental change can be defined as a series of stress factors on the physical and biological systems of the planet (e.g., Beniston, 2000). The Earth's environment has in the past been continuously subjected to various stresses through natural processes and, more recently, through human interference. Whether the global environment is capable of withstanding natural and anthropogenic stresses is a matter of constant debate, however, and examples of irreversible degradation have provided arguments to those who believe that environmental impacts are cumulative and difficult to reverse.

The root causes of environmental mismanagement are often to be found in economic policies and political options, and include:

- severe depletion of resources such as water and food availability;
- loss of territory following sea-level rise, for example;

- changes in the sanitary situation of many populations as a result of the expansion of vector-borne diseases;
- changes in extreme events; natural hazards related to extreme weather events are those that exert the greatest damage to the environment and infrastructure, and take the heaviest toll on life.

This paper will thus provide a brief overview of these inter-related factors and the manner in which they can impact upon human health in different parts of the world.

2. Climatic change: possible trends in the 21st Century

The so-called "Greenhouse Gases" (GHG) are minor gaseous constituents which have radiation properties capable of warming the atmosphere. A fraction of the solar energy which is intercepted at the top of the atmosphere reaches the ground and warms the surface. The extent of direct solar heating depends on a number of factors, such as the reflectivity of the surface, the quantity of clouds or the amount of dust in the atmosphere. The interaction between the different major components of the Earth system, namely the atmosphere, the oceans, the cryosphere (snow and ice) and the biosphere (terrestrial and oceanic) are also important determinants on the manner in which energy is distributed around the globe.

In order to avoid continuously absorbing energy and overheating, the earth emits part of the absorbed solar energy back to space in the form of infrared radiation. GHGs absorb infrared radiation in certain wave bands of the infrared electromagnetic spectrum, and re-emit this heat energy in all directions, i.e., including the atmosphere and the earth's surface. In doing so, GHGs maintain low-level atmospheric temperatures at a level 35°C higher than would otherwise be the case. In the absence of trace gases such as carbon dioxide, the Earth would be about –18°C on average. Greenhouse gases are therefore life-sustaining; they represent less than 3% of the gaseous composition of the atmosphere. In other words, the gases which are climatically-relevant paradoxically make up a very modest proportion of the atmosphere (e.g., Beniston, 1997).

Human activity, through industry, agriculture, energy generation and transportation, has released significant amounts of GHGs into the atmosphere since the beginning of the industrial era, and there is concern that this may be inadvertently modifying the global climate through an enhancement of the natural greenhouse effect. According to the Intergovernmental Panel on Climate Change (IPCC, 1996; 2001), global mean temperatures could increase by 1.5 to 5.8°C by the end of the next century in response to this additional radiative forcing. While this may appear to be a minor warming when compared to diurnal or seasonal amplitudes of the temperature cycle, it should be emphasized that this is a warming unprecedented in the last 10,000 years. It is not only the amplitude of change but also the rate of warming which is generating concern in the scientific community, especially in terms of the vulnerability and response of environmental and socio-economic systems to climatic change.

Changes in planetary temperatures will be accompanied by shifts in the distribution of precipitation patterns and seasonalities. In addition, a greater frequency and intensity of extreme climatic events may emerge as climate continues to change in the next decades. Because of the sensitivity of ecosystems, water quality and quantity, agriculture and air quality to weather and climate, any significant and long-lasting changes in the climate

system will impact upon human well-being, which has subtle dependencies on climate, food security, water quality, and environmental health.

3. The possible impacts of climatic change on human health

It is often difficult to associate any particular change in the incidence of a particular disease with a given change in a single environmental factor. It is necessary to place the environment-related health hazards in a population context, such as age, hygiene practices, socio-economic level (access to adequate clothing and shelter), and medical and agricultural traditions (McMichaels and Kovats, 2000). Forecasting the climate change impacts on health is complex, because populations have different vulnerabilities to change and susceptibility to disease.

There are numerous side-effects of environmental change that can impact upon health and well-being, including hygrothermal stress and enhanced levels of air pollution, the modification of natural ecosystems which may have repercussions on such aspects as food production and water quality. These in turn may affect the geographical distribution and celerity of propagation of vector-borne diseases, as well as the equilibrium between a number of other infectious and non-infectious diseases (McMichaels and Kovats, 2000). In addition, if climatic change were indeed to be accompanied by an increase in the intensity of certain forms of natural hazards, such as cyclones, floods, or drought, these would compound the effects on human health. Moreover, such catastrophes can generate large refugee and population movements, with a need for resettlement in what are often already densely populated areas (Pebley, 1998).

The impacts of climatic change on human health are likely to be two-fold, namely direct effects related to the physiological effects of heat and cold, and indirect effects such as the spread of vector-borne pathogens into areas where disease currently does not exist or was eradicated in the past.

3.1 Direct effects of climatic change on health

The physiological effects of temperature on the human body are well-known, because extreme conditions of heat or cold can be detrimental to many body functions, both directly and in terms of the water stress imposed by high temperatures. In a recent survey of mortality, Keatinge et al. (2000) have reported that deaths in countries of the mid- and high-latitudes occur most frequently during conditions of extreme cold or extreme heat, as illustrated schematically in Figure 1. Between the two extremes, there exists a physio-climatic “optimum” where mortality is at a minimum. The profile given in this figure is identical for many different parts of the world, although the temperature scale will vary from one location to another. This is because the physiological response to heat and cold stress will be vastly different for inhabitants in Helsinki and Athens, for example, because they are acclimatized to a particular range of temperatures under current climatic conditions; it is when temperatures begin to come out of the current range that health impacts may become significant.

Insert Figure 1 here

Associated with heat waves, particularly in large urban areas, are episodes of strong pollution often linked to the formation of tropospheric ozone, a gas that is formed by chemical transformation of nitrogen oxides and other "precursor" gases released during the combustion of fossil fuels. Ozone is a highly corrosive gas that can irritate or damage lung tissues in addition to provoking eye irritation. The "Los Angeles smog" has long been a persistent feature of southern California, as a result of optimal socio-economic and meteorological conditions for ozone formation, but today the very large cities in the south, such as Mexico City, New Delhi, or Cairo, are also severely affected by such pollution.

The probable increase in heat waves in a generally warmer climate, and the concomitant effects of heat on atmospheric pollution, will lead to greater mortality overall, even taking into account the probable reduction in cold-related deaths in many parts of the mid- and high-latitude countries. Studies conducted by the WHO (2001) show, for example, that mortality from both cardio-vascular disease and respiratory disease may increase in cities like Athens; in Amsterdam, on the other hand, deaths resulting from cardio-vascular disease may decrease, while respiratory-related mortality may increase. This is because, following the "Keatinge curve" illustrated in Figure 1, population in Athens would find itself at the high end of the temperature curve and would be subjected to both high levels of heat stress and air pollution. Dutch populations, however, would find themselves in the relative optimum region of the curve, resulting in less mortality from cardio-vascular disease, while at the same time experiencing higher levels of pollution linked to generally warmer conditions – thus leading to greater risk of mortality resulting from respiratory ailments.

Water quality and quantity are also likely to change in the future, as precipitation patterns change and warmer conditions adversely affect the potential levels of aquatic-borne pathogens and water pollution. The United Nations currently consider the availability of 1,000 m^3 of water per capita and per annum as a minimum for well-being; this includes the use of water for agriculture, industry, and domestic water supply. Currently, 50% of the world population do not reach this level, and close to 350 million people in 20 countries do not have access to potable water. In a changing climate, and especially in a world whose population will continue to increase considerably in the developing world, estimates point to reductions in water availability almost worldwide (Shiklomanov, 2001). In addition, water quality issues will become even more crucial than today, with possibly over 1 billion people in more than 30 countries without access to clean water supply. The potential for disease is thus enhanced in the poorer nations of the world.

Shifts in temperature and precipitation patterns can also impact upon agriculture and therefore affect food security in many parts of the world. Of all human activities, agriculture is probably the most sensitive to weather and climate. The IPCC (2001) suggests that, while *global* food supply may be maintained through to the middle of the 21st century, there will be many regions of the world that will experience adverse effects of heat waves, droughts, and excessive moisture on crops. In particular, the developing countries are likely to experience shortfalls of up to 30% of current food production, implying that they will need to import basic foodstuffs from producer countries such as the United States and the European Union.

The combined effects of poorer water quality, enhanced air pollution, uncertain food security, and hygrothermal stress will impact populations of the developing world in particular, but also increasingly in the countries of the North. Poor people are often

exposed to greater health and environmental risks, and in countries with growing populations, these risks will increase in the future. In terms of the distribution of wealth, the gap between the rich and the poor (both within individual nations and between rich and poor countries) has widened steadily since the 1960s (Miller, 1996). 85% of the world's economic wealth is in the hands of 20% of the world's population, and this gap is likely to widen in the future, because 95% of the projected increase in world population will take place in the developing countries. The people of the "South" are thus likely to bear the biggest burden of impacts related to climatic change.

3.2 Indirect effects of climatic change on health: the particular case of malaria

The occurrence of vector-borne diseases such as malaria is determined by the abundance of vectors and intermediate and reservoir hosts, the prevalence of disease-causing parasites and pathogens suitably adapted to the vectors, and the human or animal hosts and their resilience in the face of the disease (McMichaels and Haines, 1997). Local climatic conditions, especially temperature and moisture, are also determinant factors for the establishment and reproduction of the *Anopheles* mosquito (Epstein et al., 1998). The possible development of the disease in mountain regions thus has relevance, because populations in uplands where the disease is currently not endemic may face a new threat to their health and well-being as malaria progressively invades new regions under climatic conditions favorable to its development. (Martens et al., 1999).

The occurrence of vector-borne diseases is widespread, ranging from the tropics and subtropics to the temperate climate zones. With few exceptions, they do not occur in the cold climates of the world, and are absent above certain altitudes even in mountain regions of the tropical and equatorial belt (WHO, 2001). At elevations above 1,300 – 1,500 m in Africa and tropical Asia, the *Anopheles* mosquito can currently neither breed nor survive; as a result, malaria is almost totally absent from many highlands of the tropical zone (Craig et al., 1999).

Vectors require specific ecosystems for survival and reproduction. These ecosystems are influenced by numerous factors, many of which are climatically-controlled. Changes in any of these factors will affect the survival and hence the distribution of vectors (Kay, 1989). Global climatic change projected by the IPCC (2001) may have a considerable impact on the distribution of vector-borne diseases. A permanent change in one of the abiotic factors may lead to an alteration in the equilibrium of the ecosystem, resulting in the creation of either more or less favorable vector habitats. At the present limits of vector distribution, the projected increase in average temperature is likely to create more favorable conditions, both in terms of latitude and altitude for the vectors, which may then breed in larger numbers and invade formerly inhospitable areas.

The infection rate for malaria is an exponential function of temperature (WHO, 1990); small increases in temperature can lead to a sharp reduction in the number of days of incubation. Regions at higher altitudes or latitudes may thus become hospitable to the vectors; disease-free highlands that are today found in parts of Ethiopia and Kenya, for example, may be invaded by vectors as a result of an increase in the annual temperature. If this were to occur, then the number of persons infected by malaria would increase sharply, because many live in the uplands of the East African zone.

Insert Figure 2 here

Lindsay and Martens (1998) and Martens et al. (1999) have investigated the possible changes in the distribution of malaria. Increases in temperature and rainfall would most probably allow malaria vectors to survive in areas immediately surrounding their current distribution limits. How far these areas will extend both in terms of altitude and latitude depends upon the extent of warming. The IPCC (1998) has published maps of increases in the incidence rate of malaria in Africa, as given in Figure 2 for a modest warming scenario of +1°C. It is seen that the regions with the sharpest rise in the rate of infection are those which lie above 1,000 m (as given in the inset map). In these highland regions, even a modest rise in temperature may lead to a spread of the disease into hitherto disease-free regions. Figure 3 illustrates that the trend may already be discernible in a number of highland regions of Africa, such as Zambia and Rwanda (Loevinsohn, 1994). It is seen here that there is a quasi-exponential increase in the incidence of malaria, which is, at least in part, consecutive to changing climatic conditions for the period 1975-1990.

Insert Figure 3 here

This conclusion is in apparent contradiction to a number of studies that attempt to play down any clearly discernible link between observed climatic change and increases in malaria in the East African highlands. One recent study by Hay et al. (2002) concludes that, at least for Kenyan uplands, there have been no climatic trends of sufficient importance for transmission of the disease during the 20th century. The authors furthermore state that because of the high spatial and temporal variability of East African climate, "*claimed associations between local malaria resurgences and regional changes in climate are overly simplistic"*. While this may indeed be a logical conclusion for the relatively modest changes in climate observed in the region, it may not hold when changes are of greater amplitude. A particular example is the intensification of malaria in Colombia during episodes of El Niño, whereby mean temperatures increase and mean precipitation decreases with respect to normal conditions (Poveda et al., 2001). Such links between abrupt but significant changes in climate and the annual cycle of malaria development and transmission may help further our understanding of cause-to-effect relationships between environmental and epidemiological factors, both on the short term (El Niño/Southern Oscillation cycles) and the longer term (climatic change).

Africa is not the only continent to be affected by the increase in vector-borne diseases; in certain countries where the disease has been eradicated in the second half of the 20th Century, particular strains of malaria are resurging. There are reports from various low to medium elevation upland sites in Turkey, Tajikistan, Uzbekistan, Turkmenistan and the Urals that malaria is being transmitted in rural populations. Wilson et al. (2001) report that the spread of malaria in the south-eastern sector of Anatolia, Turkey, is currently reaching close to epidemic proportions.

3.3 Other vector-borne diseases

Table 1 summarizes some of the possible impacts of climatic change on a range of other major vector-borne diseases that are likely to affect increasing numbers of persons, particularly in the tropical zone, on the basis of information provided by both the IPCC (2001) Third Assessment Report and the WHO (2001).

Insert Table 1 here

4. Conclusions

Human health impacts of climatic change will depend on many factors, in particular existing infrastructure, financial resources, technology, access to adequate health care facilities and equity across different countries and regions. Climatic change will be one among many exacerbating factors, but possibilities do exist to adapt to global warming, through policy, economic, social and legislative action in the context of the United Nations Framework Convention on Climate Change (UN – FCCC).

Climatic change presents the decision-maker with numerous sets of challenges, however. In a set of issues in which there are considerable uncertainties, the policy maker needs to take into account the potential for irreversible damages or costs and the long time frames involved, i.e., decades to centuries. He must also be aware of the long time lags between greenhouse-gas emissions and the response of the Earth system to higher levels of these gases in the atmosphere, and the fact that there will be substantial regional variations in impacts.

In order to come to terms with global warming, international cooperation is essential but this is by no means trivial because of the wide range of conflicting interests and the extremely heterogeneous income levels in the nations of the world. Economic growth, social development and environmental protection are interdependent and mutually reinforcing components of sustainable development, which is the framework for international efforts to achieve a higher quality of life worldwide. Responses to environmental change should be coordinated with social and economic development in an integrated manner. Any policy decision should aim at averting the adverse impacts of change, taking into full account the legitimate priority needs of developing countries for the achievement of sustainable development and the eradication of poverty.

The measures required to reduce the health-related impacts of climatic change are not necessarily of an advanced, “technological nature” but are more in the realm of “common sense”. Indeed, if advanced technologies were necessary to face up to health issues in a changing climate, then a majority of countries would not have the financial resources to implement such measures. The WHO (2001) has suggested a portfolio of recommendations that, if followed, would allow to alleviate some of the negative effects of climatic change on human health. Recommendations include:

- Increasing the flexibility of managed systems, by allowing incremental adjustments to be made, reversing practices that encourage deforestation, desertification, loss of agriculturally-viable soils, and enhancing the adaptability of natural systems.
- Reversing trends that increase vulnerability, such as avoiding settlement and economic activity in high-risk area like floodplains, coastal zones or landslide zones.
- Improving societal awareness and preparedness, in particular information on risks associated with climate change and health, early-warning systems and public education programs.

Indeed, the rising awareness of populations at risk that may be the most efficient manner by which the health-related risks associated with climatic change may be reduced. As the WHO (2001) states:

"*Capacity building will certainly be an important step for adapting to climatic change, enabling people to take well-informed decisions for the long-term benefit of society*".

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Table and Figure Captions

<u>Table 1</u>: Climatic factors influencing the range and propagation of vector-borne and water-borne diseases, and the probable human impacts of these diseases as a result of climatic change by 2050 (adapted from WHO, 2001).

<u>Figure 1</u>: Schematic relation between mortality and atmospheric temperatures, adapted from Keatinge et al. (2000).

<u>Figure 2</u>: Changes in the incidence rate of malaria in Africa, following a modest 1°C average temperature increase. Gray scale denotes invasion of the vector into currently malaria-free regions. Inset map highlights African highland regions above 1,000 m; note that the spread of malaria is likely to occur because these upland regions will become increasingly hospitable to the *Anopheles* mosquito as climate warms (IPCC, 1998).

<u>Figure 3</u>: Infection rate in two African highland countries (Rwanda and Zambia), 1975–1990, according to Loevinsohn (1994).

Disease	*Environmental conditions*	**Persons at risk by 2050 (millions)**
Malaria	Temperature and moisture dependency, water availability	2,200
Dengue and Haemorragic Fever	Temperature and moisture dependency	2'500
Schistosomiasis	Temperature dependency of snail reproduction and growth	600
African Trypanosomiasis ("Sleeping Sickness")	Temperature and moisture dependency of tsetse fly's reproductive range	55
American Trypanosomiasis ("Chagas Disease")	Temperature and moisture dependency of triatomine bug's reproductive range	100
Leishmaniasis	Temperature and moisture dependency of phlebotomine sandfly's reproductive range	350
Onchocerciasis ("River Blindness")	Dependency of the blackfly's reproductive range on water availability	120

Table 1

FIGURE 1

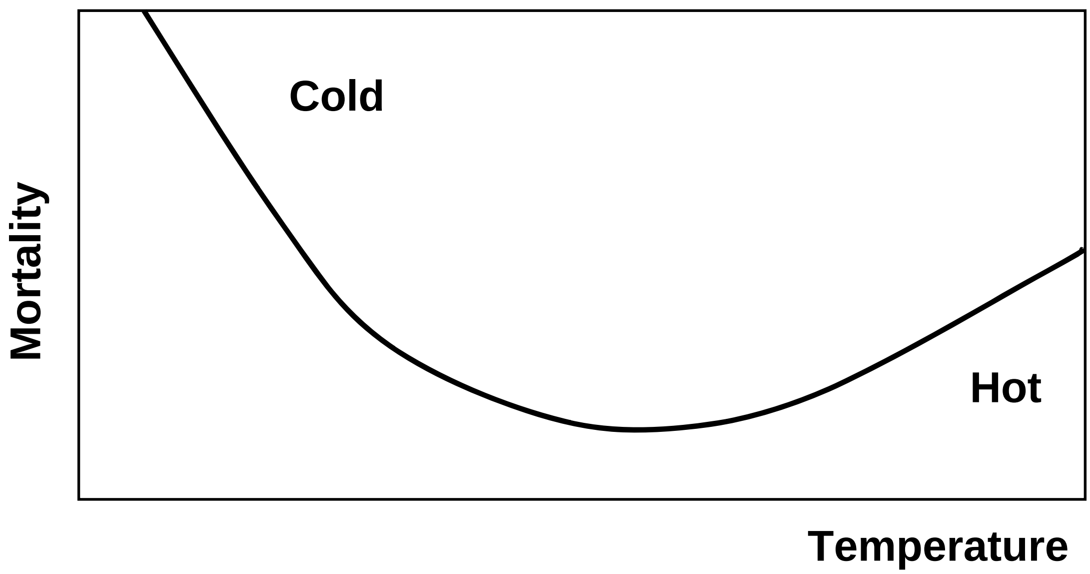


FIGURE 2

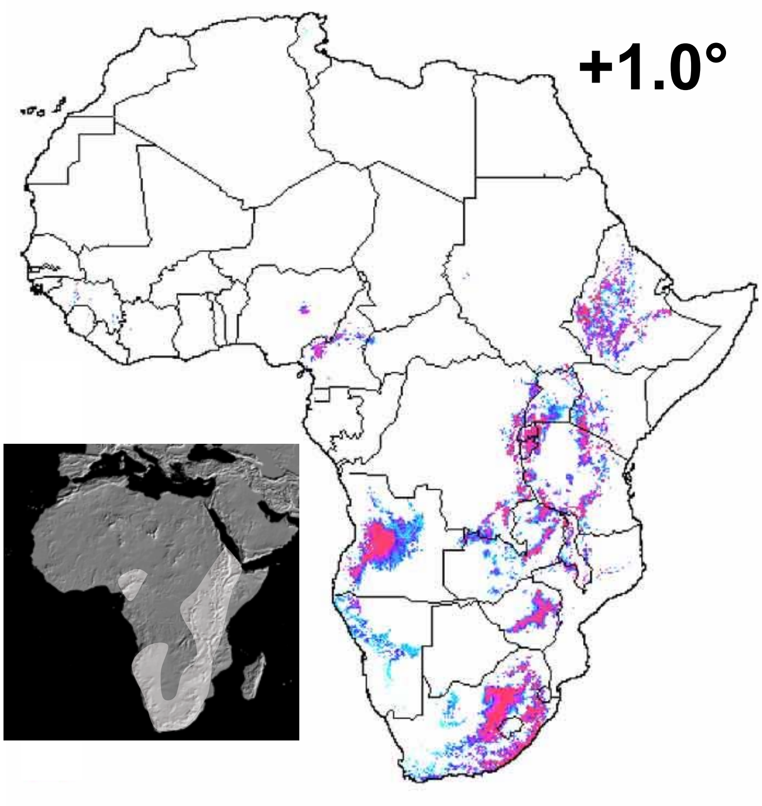
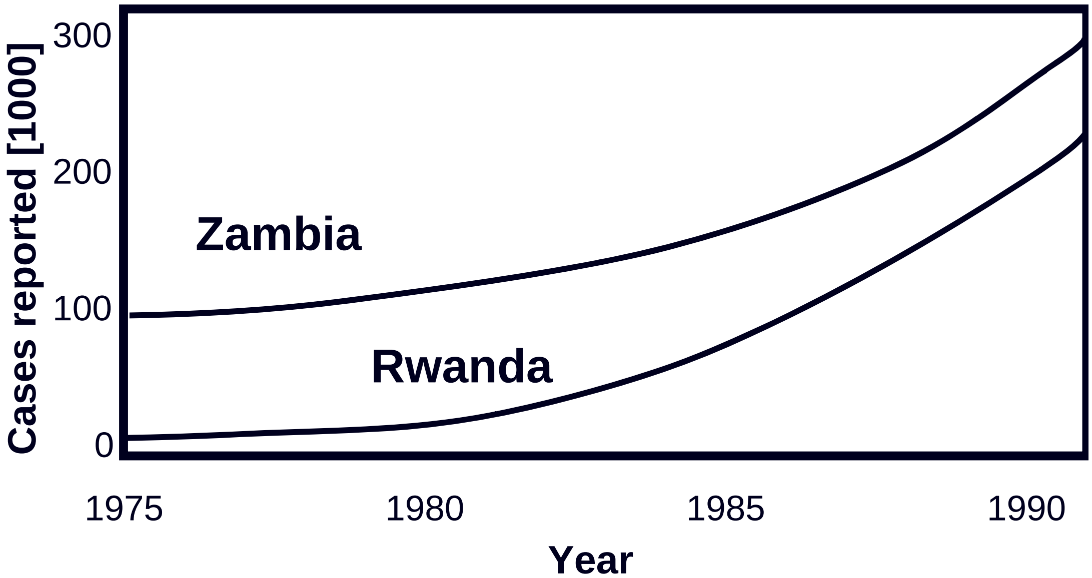


FIGURE 3



300
200
100
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Cases reported [1000]
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Rwanda
1975
1980
1985
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Year