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Human Health

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EXECUTIVE SUMMARY

In this chapter, potential adverse health impacts of scenario-drived climatic changes in Portugal were assessed and adaptation measures to avoid/reduce these impacts were suggested. This study also reviews the existing literature on: the current health status in Portugal, populations most sensitive to changes in weather, health issues influenced by global climate change, recent global initiatives on climate change and human health assessment, and methods that are currently available to study climate change impacts on human health.

Following an extensive literature review, several health impacts were identified that may be adversely affected by climate change. Key findings regarding the impacts assessed are summarised below.

Heat-related deaths occur following heatwave periods in Portugal. Climate change scenarios for Lisbon indicate that heatwaves will become more frequent and more intense. Under these scenarios, heat-related deaths are expected to increase under all assumptions. For the 2020s, the most conservative approach (HadRM2 model results and assuming acclimatization) shows a 7% increase in heat-related deaths, compared to the present heat-related death rate of 6 deaths per 100,000 individuals per year. If the least conserative approach (PROMES model results and assuming no acclimatization) is used, heat-related deaths are expected to increase six-fold relative to the present. Planned adaptation measures such as a national early warning system, urban planning to reduce the "heat island" effect in urban areas, and the use of air conditioning are suggested to reduce population vulnerability to anticipated heatwaves.

Ambient *air quality* often reaches levels hazardous to public health. If the climate becomes warmer and more variable, as suggested by climate change models, ambient levels of tropospheric ozone and aeroallergens such as pollen may increase. Higher ambient air levels of these pollutants may exacerbate asthma and other respiratory diseases, which currently are significant public health concerns. Improved pollution control measures and a national air quality warning system are two of the adaptation measures required to reduce current and anticipated air pollution-related health outcomes.

Flood and drought are reccurring events in Portugal that result in significant economic and health outcomes. Climate change is likely to increase the frequency and intensity of both. Adaptation measures such as early warming systems and improved zoning and building codes are suggested in order to reduce population vulnerability.

Water quality and food-borne disease outbreaks are current significant public health concerns in Portugal. If precipitation variability and temperature increase as climate scenarios indicate, *water and food-borne disease* transmission risk may increase as these climatic changes favour pathogen survival and biotoxin production. Population vulnerability to water and food-borne disease transmission risk may be reduced if current water and waste management systems are improved and environmental and disease surveillance initiatives are strengthened. Deterioration of current public health infrastructures will undoubtedly lead to increased disease transmission risks, regardless of climatic changes.

Increases in temperature and precipitation variability may also increase the potential risks of *vector and rodent-borne diseases* such as Lyme disease, Leishmaniasis, and Leptospirosis. Insufficient information precluded any conclusions as to how climate change may affect Mediterranean spotted fever. Improved disease, vector, and pathogen monitoring and surveillance is necessary to better understand vector and rodent-borne disease transmission. In addition, improvements to current basic public health infrastructures were also suggested to reduce population vulnerability.

The scarcity of health and environmental data in Portugal and the significant number of knowledge gaps on the relationship between health and climate have resulted in many uncertainties being incorporated into the assessment. Consequently, no definite conclusions could be reached on the magnitude of change on potential climate change health impacts. These research gaps need to be urgently addressed in order to conduct more profound national assessments on public health vulnerabilities to anticipated climatic changes.

8. Human Health

8.1 INTRODUCTION

The World Health Organisation's (WHO) definition of human health (box 8.1) clearly indicates that human health incorporates many aspects of human welfare and encompasses much more than simply the absence of disease. Health can thus be regarded as an index that reflects the state of natural and socio-economic environments (box 8.1). Human health is therefore a particularly compelling reason to study the effects of environmental change.

BOX 8.1

> *Human health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity*
>
> (WHO definition of health)
>
> *Good health and well-being require a clean and harmonious environment in which physical, psychological, social and aesthetic factors are all given their due importance. The environment should be regarded as a resource for improving living conditions and increasing well-being*
>
> (European Charter for Environment and Health, 1989)

Historically, environmental health concerns centred on the adverse effects of exposure to specific physical and chemical agents in the local environment. In recent years, unprecedented changes to the global environment have begun to impinge upon human health (McMichael 1993). Global environmental changes that may adversely affect human health include:

- Global climate change
- Stratospheric ozone depletion
- Loss of biodiversity
- Desertification
- Chemical pollution

In this chapter we discuss the potential impacts of global climate change on human health in Portugal.

8.1.1 OVERVIEW OF CURRENT HEALTH STATUS

The past three decades have seen significant improvements in the overall population health. These improvements can be attributed to general improvements in economic and social conditions such as housing, education, sanitation, communication and transport infrastructures, and, to a lesser extent, increased human, material and financial resources devoted to health care. In this section, traditional health indicators are used to assess the current national health status in Portugal.

In 1998, the life expectancy for Portuguese males and females was 72 and 79 years respectively (WHO 1999a). By mid 1998 continental Portugal had a population of 9,474,070 with mortality and fertility rates of 10.7 and 11.4 per 1,000 individuals respectively (INE 1998a; INE 1998b).

Chronic diseases are the major causes of death, accounting for more than 60% of deaths. The leading causes of death are related to circulatory and respiratory disorders and cancer. Given the growing number of smokers (Azevedo et al. 1999), a decrease in chronic disease incidence rates is not likely in the near future.

Over the last two decades, the profile of infectious diseases has changed significantly. In the 1980's, the majority of the infectious disease cases reported were from measles, chicken pox, meningitis, pneumonia, tuberculosis (TB), gastro-enteritis, typhoid fever, rickettsial infections, tetanus, and hepatitis A. Children under the age of ten were the age group most affected by infectious diseases during this period (Lecour 1988). A more recent analysis of hospital admissions indicates that most infectious diseases in the late 1990's occurred in adults in the 21–35 age group. This is mostly due to an increased number of acquired immune deficiency syndrome (AIDS) cases and AIDS/HIV related infections observed during this period (Castro et al. 1996; Pereira et al. 1999). In 1998, infectious diseases contributed to 2% of deaths. AIDS, TB and septicaemia were the leading causes of deaths in this category (INE 1998b).

The current national health system (NHS) was created in 1979 with the idea that it would provide free, universal and comprehensive health cover to all citizens. Although universal coverage has been achived, a number of key challenges remain before an equitable, efficient and quality health service is attained. The public health care delivery system is composed of the traditional primary, secondary, and tertiary health care sectors. General practitioners (GP) in health centres provide primary health care services, while secondary and tertiary care is mainly provided by hospitals. Although the number of health centres and health posts have continued to grow over the last two decades, long waiting times for access to diagnostic facilities continue to be a problem. Inequitable distribution of health care resources and shortage of qualified staff in health centres are at the heart of this problem (EOHCS 1999). This problem is further aggravated by the lack of funding available for primary health care programmes and other preventative medicine initiatives (Calheiros 2001).

Accessibility to basic public health infrastructures such as water, sanitation and electricity contribute towards good public health. Despite significant improvements during the past two decades, data presented in table 8.1 shows that accessibility to these infrastructures vary between regions (INE 1998e).

8.1.2 EFFECT OF WEATHER ON HUMAN HEALTH IN PORTUGAL

Historical records indicate that the effects of weather on public health in Portugal have concerned scientists, medical doctors and politicians for more than three hundred years. As far back as the 19th century, scientists like Frazini, expressed concerns for public health during "extreme heat episodes". Some documented health outcomes linked to meteorological conditions in Portugal are briefly described below.

A study done on the monthly mortality in Lisbon from 1845–1997 shows changes in seasonal mortality patterns. These results show that during the mid 1800's most of the deaths occurred in August. The increased number of deaths in August and other summer months were attributed to gastrointestinal infections and malaria. By the late 1800's to mid 1900, distinct seasonal death patterns were not evident. During the last three decades of the 20th century, most deaths occurred in winter, and were mostly due to circulatory and respiratory illnesses. During the period of analysis, life expectancy and quality of life improved significantly (Alcoforado et al. 1999). This clear shift in seasonal mortality patterns may be attributed to society's adaptation to the underlying health hazards (warmer temperatures are more conducive to infectious disease transmissions) and adequate management of these hazards within the medical and technological capabilities of the period.

Analysis of unusually high ambient temperatures experienced in June 1981 established an excess of

Table 8.1 – Household type and infrastructure accessibility in Portugal, 1997 (source INE 1998e)

	Continental Portugal (%)	Northern Region (%)	Central Region (%)	LVT (%)	Alentejo (%)	Algarve (%)
Household type						
House	59.6	65.5	79.4	30.1	86.2	70.5
Apartments	38.7	32.2	19.7	68.1	13.7	27.9
Others	1.7	2.2	0.9	1.8	0.1	1.6
Households with						
Electricity	99.3	99.4	99.4	99.7	98.6	98.2
Tap water (indoors)	92.7	93.0	92.0	94.4	90.8	89.6
Tap water (outdoors)	4.9	4.2	4.9	5.0	5.9	5.9
Without tap water	2.4	2.8	3.1	0.6	3.3	4.5
Sewage connection to public grid	62.8	44.9	41.2	88.4	83.4	65.7
Septic tank	33.5	52.0	52.4	10.6	10.6	26.4
Without sewage removal	3.7	3.1	6.4	1.0	6.0	7.9
Air conditioners	1.7	0.8	0.9	2.7	2.7	2.3

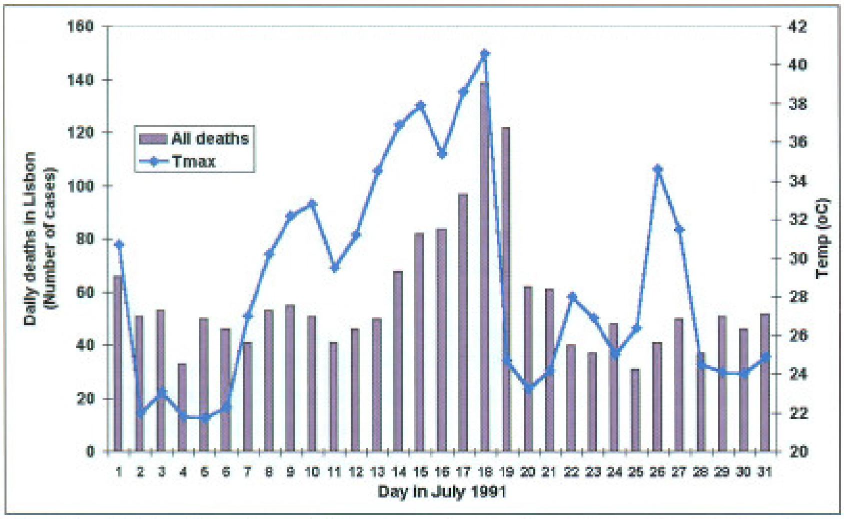

Figure 8.1 – Relationship between daily maximum temperature and mortality in Lisbon during the July 1991 heatwave (data from INE 2000 & IM 2000).

1,900 deaths during a period of nine days (Garcia et al. 1999). A decade later, another heatwave also resulted in unusally high daily mortalities (figure 8.1).

Though seasonal variations of infectious diseases are still evident, thanks to improved health care infrastructures, disease transmission is greatly reduced and fatalities are relatively low due to medical and technological advances. Infectious diseases that currently show seasonal patterns include; Mediterranean spotted fever (tick-bite fever), salmonellosis and other gastrointestinal disorders (DGS 1999; IGIF 2000). Although local transmission of cholera, malaria, and yellow fever no longer occur (DGS 1999), historical records demonstrated seasonal epidemics of these diseases (Calheiros 2001).

Studies have established a link between meteorological conditions and asthma and allergic disorders (Bastos et al. 1993; Pinto & de Almeida 1999). Relationships between air pollution levels and meteorological conditions in Lisbon have also been documented (Andrade 1996; Queiróz et al. 1998). Health outcomes such as premature death, asthma and other respiratory illness associated with air pollution are well documented in the international literature (WHO 2000).

Extreme weather episodes have also been associated with significant acute impacts on public health, perhaps the most noticeable of which are the health impacts of floods. Health effects known to be associated with flooding in Portugal include drowning, physical injuries, mental distress, and possible increases in rodent-borne diseases such as leptospirosis, as well as water and food borne diseases.

8.1.2.1 Population Vulnerability to Weather

Medical records indicate that the poor, the elderly, the very young, and people with compromised immune systems as more likely to develop illnesses due to exposure to environmental stresses. Immigrant populations were identified in this study as an additional population-subgroup whose health is likely to be adversely affected by global environmental changes.

8.1.2.1.1 The poor

The relationship between health and poverty is well established. People in low-income groups are more vulnerable to illness; this is particularity true for acute health risks such as infectious diseases, heat-stress, and the adverse health effects of poor air quality. Current and future trends in poverty in Portugal are discussed in chapter 3.

8.1.2.1.2 The elderly

The elderly are a vulnerable population group for various reasons. Firstly, ageing is often accompanied by multiple chronic illnesses that could lead to greater vulnerability to acute environmental stresses like heatwaves, air pollution and infections. Secondly, the economic status of the elderly generally declines with time. Financial resources available for help with housekeeping, nutrition, and personal hygiene are often reduced. Finally, social isolation endangers the mental health of elderly individuals living alone.

The number of individuals over 65 years of age has increased significantly. In 1998, 15.2% of the population was 65 years or older (INE 1998c). This number is expected to increase as life expectancy increases. Data presented in table 8.2 also shows that regional distribution of the elderly is not uniform.

Table 8.2 – Population demographics for Portugal, 1998 (source INE 1998c)

Region	Population size	Population <15 years (%)	Population 15-64 years (%)	Population 65 + years (%)
Portugal	9 979 450	16.8	67.9	15.2
North	3 578 310	18.4	68.8	12.7
Centre	1 710 330	15.7	66.1	18.1
LVT	3 326 460	15.6	68.9	15.4
Alentejo	510 320	14.3	64.1	21.5
Algarve	348 650	16.0	65.3	18.6

The state is the major health care provider for the elderly. Some social services for the aged are provided in each region through the Ministry of Social Security. However, *Misericórdias,* which are independent charitable organisations, are the key providers of social services.

Residential care for the aged, provided by the public sector, is very limited and lacks sufficient resources. The majority of old age homes are privately owned and very expensive. Overcrowding and insufficient staff is a common problem in these establishments. It is thus not surprising that in Portugal the elderly often live alone in rural areas or with relatives in urban areas.

8.1.2.1.3 The young

Children are more vulnerable to contaminants than adults for various reasons. Firstly, they ingest more food and liquids relative to their body size than adults do. Secondly, they have higher breathing rates than adults, and thus breathe in more pollutants relative to their body size. Thirdly, they have behavioural patterns that expose them more to environmental contaminants (i.e. more soil exposure). And finally, their bodies are still developing and thus their organs are not as effective at metabolising and excreting contaminants (Landrigan et al. 1999).

In 1998, 16.8% of the population were under the age of 15 years (table 8.2). If the current national decline trend in fertility rate is assumed, the proportion of individuals in this age group is not expected to increase significantly in the next few decades.

Child health has improved significantly during the past four decades, dropping from an infant mortality rate of 77.5 in the 1960's to one of 6.0 (per 1,000 individuals) in 1998 (INE 1998c). Compliance with childhood vaccination is over 95% (WHO 1997). Current childhood public health concerns include asthma, acute gastric and respiratory infectious diseases, and accidents.

Recent epidemiological studies indicate a cumulative asthma prevalence of 10% and a general rhinitis of 27% in city children. Children between the ages of 13–14 reported a higher prevalence rate of both disorders (Allergonet 2000). Asthma and rhinitis sufferers are most vulnerable to pollen and other air pollutants.

8.1.2.1.4 The immunocompromised

Immmunocompromised individuals are more vulnerable to infectious agents, air and water pollutants, and thermal and physical stresses. These individuals are probably the most vulnerable to climate changes. AIDS/HIV individuals are not the only immunocompromised individuals within society; the elderly and people undergoing certain medical treatments (such as cancer therapy) are also in this population group.

The proportion of the population that is immunocompromised is difficult to determine correctly due to the lack of data. However, it is anticipated that the proportion of immunocompromised individuals is likely to increase in the future given the ageing population, increased cancer incidence, and longer survival rates of AIDS/HIV and cancer patients.

8.1.2.1.5 Immigrant populations

Immigrant populations are defined in this study as all groups of individuals that previously lived in a foreign country but now reside in Portugal. These individuals are vulnerable to health risks associated with both countries.

Since 1990, the growth of legal foreign residents present in Portugal has increased by an average annual rate of 7.2% (Baganha et al. 2000). By the end of 1998, there were 177,774 legally resident foreigners. This represents 1.78% of the total population in Portugal. The majority of which were from Africa (46.4%), followed by Europe (29.3%) and the Americas (19.7%). These individuals reside predominantly in the Lisbon, Faro, Setubal and Porto districts (INE 1998c). If the socio-economic scenarios described in chapter 3 are assumed, this population group is anticipated to increase by 7-13% per annum.

Most immigrants reside in the poorer areas of the larger cities. Such living conditions are often conducive to community diseases (Baganha et al. 2000). Some immigrants can have specific disease patterns and health needs due to genetic and behavioural factors and exposure to different environments in their countries of origin. Access to health care that can meet such specific needs is not always available. Illegal immigrants in particular may have restricted access to health care services.

8.2 METHODOLOGY

Few climate change assessments address the impacts on human health. This is mostly attributable to the fact that the field of climate change health impact assessment is yet in its infancy. Thus, it is particularly important to understand the particular methodology used in any given assessment. Here, various possible methodologies are reviewed.

8.2.1 DESCRIPTION OF ASSESSMENT APPROACH

Forecasting the potential impact of climate change on human health can not be determined using conventional human health risk assessment methodologies that focus on locally generated chemicals and physical exposures (NRC 1994). With climate change, the environmental "exposure" is complex and less immediate relative to conventional exposures. In addition, most of the climate change-induced "exposures" of concern lies in the future. This means that forecasting the potential impact of climate change on human health calls for the development of risk assessment methods based on scenarios rather than an estimation of risks based on past realities (McMichael & Kovats 1998). Recent developments in this field are described below.

8.2.1.1 State of the Art

Concern for the potential health impacts of climate change have stimulated several investigations. The most comprehensive of which have been the reviews produced by; the United Nation's Intergovernmental Panel on Climate Change (IPCC) (McMichael 1996; McMichael & Githeko 2001), the World Health Organisation (WHO), World Meteorological Organisation (WMO) and United Nations Environmental Programme (UNEP) Task Group on health impacts of climate change (WHO/WMO/ /UNEP 1996), and several WHO communications (Kovats et al. 2000a; Kovats et al. 2000b).

The UNEP has produced a Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies. However, this handbook does not recommend any well-developed methodologies to assess human health impacts of climate change. Instead, a suggested approach to performing a qualitative impact assessment for human health is described. This approach focuses on identifying current national health problems that may intensify with predicted climate changes (Balbus et al. 1998).

The WHO, Health Canada and UNEP are currently involved in a joint project with the aim of producing a guideline document to assist countries assess the potential impacts of climate variability and change on human health (WHO/Health Canada/UNEP 2001).

To date, the most comprehensive national assessments on potential climate change impacts on human health have come from Canada (Duncan et al. 1999), the UK (DH 2001), and the USA (Patz et al. 2000). As the effect of climate change on a given population's health reflects the conditions of its ecological and social environments, health impacts will naturally differ between countries and regions. To our knowledge, the present study is the first national assessment done on the potential health impacts of climate change in any southern European country.

8.2.1.2 Options for Assessing Impacts on Human Health

The study of the impacts of climate on human health is an emerging research area. Most of the currently published work in this field has been review articles on probable health impacts based on expert judgement. Predictive modelling for health impacts of climate change are limited, firstly because most aspects of human systems are not readily amenable to modelling and, secondly, because of insufficient long-term data series on health outcomes. Conclusions regarding health outcomes in populations living in currently unknown circumstances many decades into the future are thus difficult to formulate and are subject to a considerable level of uncertainty.

Research methods by which climate-health interactions have been studied can be grouped into four general categories: expert judgement, analogue studies, direct studies of early effects, and predictive models (McMichael & Kovats 2000a). Ecological risk assessment is an additional approach that can be used to evaluate potential climate health impacts (Balbus et al. 1998; Bernard & Ebi 2001).

8.2.1.2.1 Choice of assessment methodology

The linkage of climate and health data offers considerable benefits but also poses many dangers if not carefully carried out. The choice of the most appropriate assessment method depends on several factors such as the purpose of the study and the type of data available.

Important issues that need careful consideration in detecting and quantifying the influences of climate change upon human health include (Kovats et al. 2000b):

- Most diseases have multiple causes,
- Great diversity in possible disease types, for example, acute and chronic, physical injury and mental health disorders,
- Many uncertainties regarding the biological and physical process by which climate affects health, as well as the many environmental assumptions,
- Long-term nature of the changes involved, and
- Most epidemiological studies have been done on a local basis, making application on a wider scale difficult.

The advantages and disadvantages of the assessment methods listed above are summarised in table 8.3. These facts have to be carefully considered so that the most suitable method is used. For example, while predictive modelling methods are the most desirable assessment methodology to study health impacts of climate change, the extensive resources and large amounts of additional data that these models require make them impractical when such requirements are limited. In practice, such requirements cannot always be met by most countries, including many developed countries, leaving researchers with no alternatives but to use less data intensive assessment methods. Results of the latter assessment types can still be accepted as a basis for action provided that they were conducted in a scientifically credible manner and the results obtained are consistent with those obtained from more detailed studies for which the statistical precision was established. Moreover, the results from these less complex assessment methodologies are useful in highlighting areas or issues requiring further, or more detailed investigation.

8.2.1.2.2 Uncertainties inherent in climate change health impact assessments

Assessments of the impacts of climate change have been overwhelmed by large uncertainties at each step of the process. The health impact assessment is no exception. Uncertainty accumulates throughout the process of climate change prediction and impact assessment creating a "cascade of uncertainty". This occurs due to the uncertainties of future emissions of greenhouse gases, modeling of the climate system, climate-health relationships. In our assessment we explored the uncertainty range of potential health outcomes through scenarios that represent plausible and internally consistent futures.

Broadly speaking, uncertainties arise from two different sources: 'incomplete' knowledge and 'unknowable' knowledge. Incomplete knowledge affects much of our model design whether they be climate models (e.g., poorly understood cloud

Table 8.3 – Advantages and disadvantages of study methods

Study Method/Approach	Advantage	Disadvantage
Expert judgement	• Inexpensive & rapid • Integration of multiple factors possible (very basic level) • Stakeholder involvement possible • Not very data intensive	• Only qualitative results possible • Imprecise, may be subjective
Analogue studies	• Qualitative and quantitative assessments possible • Relatively inexpensive & rapid • Visual representation of important information possible • Simpler computation than predictive modelling	• Dependent on secondary health and environment data availability and quality • Unable to integrate numerous factors & dynamic interactions • Limited applications to population with vulnerabilities different to historical reference population
Early effects	• Quantitative • Visual representation of important information possible • Rapid identification of disease endemic areas and new outbreaks, allowing for rapid intervention	• Relatively data intensive • Dependent on health and environmental indicator trends • Low predictive power • Requires on going data collection
Predictive Modelling	• Quantitative • Integration of numerous factors & dynamic interactions possible	• Very data intensive • Complex with many uncertainties • Most expensive and time consuming • Resource intensive • Dependent on secondary health and environment data availability and quality
Ecological risk assessment	• Draws on expertise from various study fields • Qualitative & quantitative assessments possible • Relatively rapid • Assessment complexity flexible • Uncertainties discussed • End result useful for decision-makers & public.	• Dependent on secondary health and environment data availability and quality • May be subjective • Ecosystem health associations not always fully understood • Integration of other health determinants (e.g. socio-economic factors) not always possible

physics) or impact models (e.g., poorly known dose-response effect of thermal stress and cardiovascular health outcomes). Unknowable knowledge arises from the inherent indeterminacy of future human society and of the climate system (Hulme & Carter 1999). Examples include the cultural adjustments in time that may have an impact on the relationship between thermal stress and mortality rates, for example, improvements in housing conditions (Martens 1998); or the climate system, as a complex non-linear dynamic system, is indeterminate and even with perfect models and unlimited power, for a given forcing scenario a range of future climates will always be simulated.

8.2.1.3 Description of Assessment Methodology Used in Present Study

The assessment methodology used in the present study drew on the UNEP recommendations (Balbus et al. 1998) as well as several assessment techniques used in the Canadian, UK, and US national assessments (Duncan et al. 1999; DH 2001; Patz et al. 2000). The present assessment used the following approach:

1. Assessing current health status in Portugal

2. Identifying populations most vulnerable to climate change

3. Understaning the manner in which scenario-derived climate changes may affect human health

4. Assessing the manner in which potential climate change health impacts may be avoided/reduced.

5. Identifying knowledge gaps that need to be investigated further to fully understand the possible impacts of climate change on human health in Portugal.

Due to the difficulties in obtaining reliable and timely data, quantitative modelling of future impacts was not possible for most health outcomes assessed. Potential climate change health impact "projections" made in the present study are therefore mostly qualitative. Results of the work done on the first two points listed in the assessment approach above are presented in section 8.1, while the remaining three points are discussed in sections 8.3, 8.4, and 8.5 respectively. Assessment of all five points was based on expert judgement and national data collection. However, determination of the manner in which expected climate changes may affect human health in Portugal (point 3) required a more in-depth analysis. The methodology followed is briefly described below.

Following an extensive literature review, several health impacts were identified that may be adversely affected due to climate change in Portugal. The present study focused on the following health outcomes:

- Heat-related mortality,
- Air pollution-related health effects,
- Health effects associated with floods and drought,
- Water and food-borne diseases, and
- Vector and rodent-borne diseases.

Potential health outcomes that were not anticipated to be *adversely* affected due to climate change in Portugal were not assessed in depth. Health outcomes were assessed for continental Portugal only. Assessment of potential health outcomes due to international travel was not included in the present study.

During the assessment of each health outcome, the following points were considered:

- Is the health outcome currently a problem in Portugal?
- Are there historical records to indicate that the health outcome was a problem in Portugal in the past?
- What is the climate-health relationship for the health outcome?
- Assuming the above climate-health relationship is valid for all climate change scenarios for Portugal, what health changes are anticipated to occur?

The manner in which each potential climate change health outcome was studied is summarised below.

8.2.1.3.1 Heat-related mortality

An empirical-statistical predictive modelling approach was used to assess the impacts of climate change on heat-related mortality in Lisbon. This modelling approach was based on a dose-response relationship derived from daily maximum temperature and excess mortality during the summer months of 1980-1998 observations.

The climate-mortality association was estimated using an observed-expected analysis similar to the method applied by Guest et al. (1999). Two approaches were used to calculate expected deaths during summer months in order to account for the uncertainty in estimating this variable:

- A fixed mean of daily mortality for each summer month for the entire period 1980-98 (these were: 50.5 in June, 49.9 in July and 47.6 in August);

- A 30-day running mean (from mid-May to mid-September) for the whole period, but selecting only the summer values (thus having a different value for each summer day).

In each case, daily excess deaths were calculated by subtracting the expected values by the observed daily values. In the fixed mean approach that meant subtracting every observed daily death of June by 50.5, every observed daily death of July by 49.9 and so on. In the 30-day running mean method each observed daily death was subtracted by its corresponding expected value. Heat-related deaths were defined as the number of deaths occurring in excess of the number that would have been expected for that population in the absence of stressful weather (McMichael 1996). Each summer day for the 1980-98 period had an excess death value and a corresponding maximum temperature. We then aggregated excess deaths into 1°C intervals and summed them up to determine at what temperatures the heat effect was more pronounced. Our analysis showed that heat-related deaths were not discernible below 29°C (Figure 8.2).

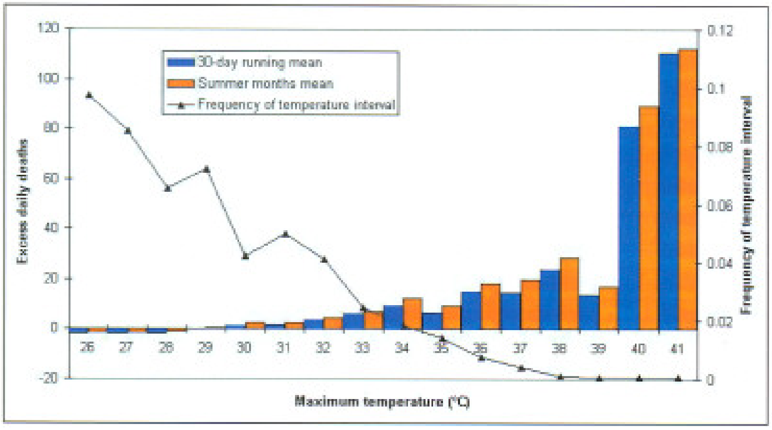

Figure 8.2 – Excess heat-related daily deaths in Lisbon during the summers of 1980-98. Added difference between observed and expected number of deaths, according to temperature intervals of 1°C, using a 30-day running mean and a summer months mean as expected values. The black line represents the frequency of occurrence of the temperature interval during the period. (data from INE 2000 & IM 2000).

A non-linear regression showed a strong relationship between maximum temperature and excess deaths (using two approaches to calculate expected deaths: a 30-day running mean and a fixed summer months mean) in Lisbon for the period in study (Dessai 2001).

Table 8.4 – Observed and modelled mortality under two variants of the model (a summer months mean and a 30-day running mean approach). Mortality rates per year are given under brackets using the average population throughout the period

	Summer months mean	30-day running mean
Observed	2425 (6.2)	1903 (4.9)
Modelled	2338 (6.0)	2108 (5.4)

Observed and modelled mortality using these two variants is summarised in table 8.4. Under the fixed mean approach total annual heat-related mortality was around 6 per 100,000 or 128 deaths per year for the population of Lisbon, during the period 1980-98. This relationship (under the two approaches) was used to assess potential heat-related deaths in Lisbon under various climate change scenarios. These scenarios are described in section 8.2.2.

A climate impact assessment exercise entails many uncertainties either due to incomplete or unknowable knowledge. Due to this fact, many assumptions have to be made about the future because:

1. Temperatures above 29°C have a higher frequency that the period 1980-98, and often occur outside summer.
2. Temperatures will go well beyond previously experienced conditions where the dose-response relationship is no longer valid.
3. People will acclimatize/adapt to future climates.

To deal with these problems of epistemic uncertainty (i.e. incomplete knowledge of processes that influence events) a set of assumptions were made to provide, in our opinion, a wider picture of the possible impacts.

With respect to point one, the model used here (Dessai 2002) is only valid for summer months, but taking into account that heat waves could extend their period (outside summer) in the future we assumed the relationship holds outside summer (considered a high estimate and called hereafter *Year-round*). We also only selected future summer daily temperatures to calculate future mortality. This was considered a low estimate and designated *Summer (JJA)* hereafter.

As for the second point, we took two approaches. In the first approach, we allowed the extension of the dose-response curves into *unobserved temperatures* (i.e. temperature outside the demonstrated range of the model) assuming the association holds its characteristics for temperatures higher than those observed (considered a high estimate). However, we did set a limit to avoid unrealistic results. We only considered valid those results that contemplated less than 0.5 days per year of unobserved temperatures, which is roughly saying that the model holds an extra 2°C outside its proven-valid range.

In the second approach, which takes into account point three at the same time, we assume people will *acclimatize/adapt* with time. This approach is centred on the possibility that people may acclimatize over long periods. It is known that initial physiological acclimatisation to hot environments can occur over a few days but complete acclimatisation may take several years (McMichael 1996). "How many years" is still an unanswered question due to the lack of long-term studies on climate and human health. We assumed complete acclimatization to an extra 1°C (compared to the present) is reached after three decades, making the dose-response relationship work from 30-42°C in the 2020s, 31-43°C in the 2050s, and 32-44°C in the 2080s (as compared to 29-41°C in the present). This approach reduced considerably the number of unobserved temperatures because it artificially changed the range of the dose-response curves in the future.

8.2.1.3.2 Air pollution-related health effects

Recent studies on global climate change and air pollution-related health effects indicate that health effects of concern are most likely to be those associated to tropospheric ozone (O_3) and aeroallogens (i.e. pollen) exposures (Patz et al. 2000; Kovats et al. 2000a). Ambient air levels of these pollutants were obtained (DGA 2000a; EPI 2001) for Portugal and the health effects likely to be associated with these air pollutant levels assessed.

Since ambient levels of these pollutants are influenced by factors including pollutant emission sources and local weather conditions, information on these factors was compiled. Data on O_3 precursor emission trends for Portugal was thus collected (UNECE/CLRTAP 2000; DGA 2000b) as well as information on the plants responsible for most pollinosis in Portugal (EPI 2001).

Analogue studies were used to determine the effect of climate variables on the levels of nitrogen dioxide (NO2), O_3 and pollen in Lisbon. The climate-NO_2 relationship was established based on daily windspeeds and minimum temperature in Lisbon in relation to NO_2 levels (Andrade 1996). The climate-O_3 relationship was achieved based on daily windspeeds and maximum temperature in relation to O_3 levels. Airborne pollen levels in Lisbon were found to increase by increases in daily maximum temperatures during the flowering period, cumulative rain-free days, and windspeeds (Queiróz et al. 1998).

The climate-pollutant relationships established above were used to determine potential changes in the intensity and dispersion of these pollutants in Lisbon under different climate scenarios. Results from two regional climate models (see chapter 2), PROMES and HadRM2, were used to construct the climate scenarios. Potential changes in health effects of climate-related changes in air pollution were qualitatively assessed based on these scenarios. In-depth quantification of potential health outcomes was not possible, as reliable quantification data on future pollutant levels was not available.

8.2.1.3.3 Health effects associated with floods and drought

An international literature review was conducted in order to ascertain the health impact of natural disasters such as floods and drought. Results indicated that indirect health effects of floods and drought are far greater than direct health outcomes.

The indirect effects of potential climate change alterations in floods and droughts, such as waterborne diseases and vector and rodent-borne diseases were investigated as described in the three sections that follow.

8.2.1.3.4 Water and food-borne diseases

The available literature was reviewed to ascertain current and historical disease prevalence (and outbreaks) of water and foodborne diseases. Health outcomes associated with coastal and marine issues such as seafood poisonings were also included in the definition of water and food-borne diseases and thus also assessed in this section. Potential pathogen contamination routes of these diseases are discussed.

Since water quality has a critical role in the transmission of all diseases assessed in this section, data on drinking water, recreational freshwater and coastal water quality was studied based on official water quality records (DGA 2000c; INAG 1996; INAG 2000). Information on population accessibility to basic health infrastructures such as drinking water and sanitation were also compiled (INE 1998e). Collectively, this information was used to determine population groups currently most at risk of contracting water and foodborne diseases. Although climate change may affect water supplies in terms of quality, quantity and availablity, only potential health impacts associated with the former were assessed here.

Climate variables known to influence water and food-borne disease transmission were identified based on international studies (Rose et al., 2000; WHO 1999b; INAG 1996; Lacey 1993; Baird-Parker 1994). Changes in these climate variables in Portugal were assessed based on results from the HadRM2 climate model (see chapters 2 & 5). These facts allowed for a qualitative assessment of the potential changes in water and foodborne disease transmission. Quantification of risks in the transmission of these diseases was not possible because of limited health data availablity.

8.2.1.3.5 Vector-borne diseases

Vector-borne diseases of possible public health concern due to climate change were identified based on expert judgement from review studies (Kovats et al. 2000a; Parry 2000; Patz et al. 2000) as well as consultations with key national vector biologists.

Information on current and historical data pertaining to disease, vector, and parasite prevalence was compiled. Where possible, disease prevalence was collected for various population sub-groups in order to identify populations most at risk. Information on each disease's clinical manifestations and transmission dynamics was obtained based on available literature. Special attention was given to temperature threshold limits required for pathogen and vector survival.

These temperature threshold limits were used together with results from the climate change models PROMES and HadRM2 in order to determine potential temperature favourable periods for pathogen and vector survival for five regions in Portugal. Two climate scenarios were used from each model, one representative of a $1xCO_2$ concentration (model-baseline climate scenario) and the other representative of a $2xCO_2$ concentration (model-future climate scenario).

Vector and pathogen survival potentials were used as indicators of vector abundance and pathogen prevalence potential. Potential disease risks were assessed based on vector abundance and pathogen prevalence potential relative to the scenarios listed in table 8.5. The qualitative risk levels used in this assessment were categorised as summarised in table 8.6.

Table 8.5 – Scenarios used in vector-borne disease assessment

	Assuming current knowledge of vector & parasite prevalence in Portugal	Assuming the introduction of a small population of parasite infected vectors into Portugal
$1xCO_2$ (current) climatic conditions	Scenario 1	Scenario 2
$2xCO_2$ (future) climatic conditions	Scenario 3	Scenario 4

Table 8.6 – Potential vector-borne diseases risk level criteria

Parasite ⇒ / Vector ⇓	None Present	Imported human cases only	Low prevalence in vectors/hosts	High prevalence in vectors/hosts
None Present	No Risk	No Risk	No Risk	No Risk
Focal Distribution	No Risk	Very low Risk	Low Risk	Low Risk
Regional distribution	No Risk	Very low Risk	Low Risk	Medium Risk
Widespread distribution	No Risk	Very low Risk	Medium Risk	High Risk

8.2.1.3.6 Rodent-borne diseases

Available literature was reviewed and key national experts consulted (Filipe 2000; Collares-Pereira 2001) in order to identify which rodent-borne diseases might cause public health concerns under climate change. National official records and other relevant scientific material were assessed to determine rodent and parasite prevalence and disease incidences.

The relationships between climatic factors and disease transmission dynamics were determined from the literature. These relationships were used to determine the changes in the potential risk of contracting rodent-borne diseases under HadRM2 climate change scenarios.

8.2.1.3.7 Uncertainties

Uncertainties most likely to affect the conclusion of each health impact studied are listed in table 8.7. Uncertainty level associated with each was ranked based on the current state of knowledge into four classes namely (Moss & Schneider 2000);

- *Well-established:* when models incorporate known processes; observations largely consistent with models for important variables; or multiple lines of evidence support the finding.

Table 8.7 – Uncertainties incorporated in the assessment process

Uncertainty source	Evidence available to support finding
Common to all health outcomes assessed	
Observed climatic records for Portugal	Discussed in chapter 2
Model-generated climatic results for Portugal	Discussed in chapter 2
Use of current socio-economic conditions in future assessment scenarios	Speculative
Identification of climate change health outcomes of concern for Portugal	Established but incomplete
Heat-related deaths assessment	
Observed mortality data records for Portugal	Well-established
Establishment of heatwave definition for Lisbon	Competing explanations
Applicability of current heatwave definition to future populations in Lisbon	Competing explanations
Air pollution-related health outcomes	
Observed records of air pollution levels in Lisbon	Well-established
Establishment of climate-ozone relationship	Established but incomplete
Establishment of climate-pollen relationship	Established but incomplete
Health effects associated with air pollutants	Established but incomplete
Future pollution emission trends in Portugal	Speculative
Applicability of current climate-air pollutant relationship in future scenarios	Established but incomplete
Health effects associated with floods and drought	
Identification of health outcomes of concern	Speculative
Water and Food-borne disease assessment	
Identification of diseases of concern	Well-established
Observed disease incidence data for Portugal	Established but incomplete
Establishment of climate-disease transmission potential relationship	Well-established
Applicability of current climate-disease transmission relationship in future climate scenarios	Established but incomplete
Vector-borne disease assessment	
Identification of diseases of concern	Well-established
Observed disease incidence data for Portugal	Established but incomplete
Characterisation of disease transmission competent vector populations and pathogens in Portugal	Established but incomplete
Establishment of temperature-vector survival relationships	Well-established
Establishment of pathogen-vector survival relationships	Well-established
Applicability of favourable temperature ranges for vector and pathogen survival to assess period of days suitable of survival under different climate scenarios	Established but incomplete
Use of temperature as the only environmental factor of concern in disease transmission	Competing explanations
Assumption that vector survival can be an indicator of vector abundance and distribution	Speculative
Assumption that pathogen survival can be an indicator of pathogen prevalence in hosts and vectors	Speculative
Establishment of qualitative risk levels to assess potential disease transmission in Portugal	Speculative
Rodent-borne disease assessment	
Identification of diseases of concern	Well-established
Observed disease incidence data for Portugal	Established but incomplete
Determination of pathogen strain and infection status of hosts involved in disease transmission in Portugal	Established but incomplete
Establishment of climate-disease transmission relationship	Speculative
Applicability of above relationship to assess potential disease transmission under different climate scenarios	Speculative

- *Established but incomplete:* if models incorporate most known processes, although some parameterizations may not be well tested; observations are somewhat consistent with theoretical or model results but incomplete; current empirical estimates are well founded, but the possibility of changes in governing processes over time is considerable; or only one or a few lines of evidence support the finding.

- *Competing explanations:* if different model representations account for different aspects of observations or evidence, or incorporate different aspects of key processes, leading to competing explanations.

- *Speculative:* conceptually plausible ideas that have not received much attention in the literature or that are laced with difficult to reduce uncertainties or have few available observational tests.

8.2.2 DESCRIPTION OF DATA USED

Data used throughout the assessment process was obtained from official sources in order to minimise data errors and biases.

8.2.2.1 Climatic Data

8.2.2.1.1 Observed data

The Portuguese Institute of Meteorology supplied all the observed climate data used in all health impact assessments. Observed climatic variables used for each health impact assessment are listed in table 8.8.

8.2.2.1.2 Climate-model generated data

Climate change scenarios for Portugal used in health impacts assessed in this chapter were constructed based on results from the regional climate models (RCMs) PROMES and HadRM2. Climate variables used for each assessment are briefly described in table 8.8. Some health impacts made use of local (focal) model-climate data represented by a single model grid point. Others required regional climate variables that were composed by several model grid points. The latter was calculated as the mean of climate data from five regions in Portugal.

For the heat-related mortality study, future daily weather series were produced from the RCMs output.

Table 8.8 – Climate data used in assessment process

Health outcome	Observed climate variables	Climate-model generated variables
Heat-related deaths	Daily maximum temperatures for Lisbon (1950-1999)	Daily maximum temperatures from PROMES grid point 1618 and HadRM2 grid point 68
Air pollution-related health effects	Daily maximum temperatures for Lisbon (1998-1999)	Daily maximum and minimum temperatures, and windspeeds from PROMES grid point 1618 and HadRM2 grid point 68
Health effects related to extreme weather events	None used	Flood and drought potential results from chapters 2 & 5
Water and food-borne diseases	None used	Mean monthly temperature results from chapter 2 Precipitation, flood and drought potential results from chapters 2 & 5
Vector-borne diseases	None used	Daily mean temperatures for five regions in Portugal from PROMES and HadRM2 models. Precipitation, flood and drought potential results from chapters 2 & 5
Rodent-borne diseases	None used	Mean monthly temperature results from chapter 2 Precipitation, flood and drought potential results from chapters 2 & 5

We added the baseline climate (1969-98) daily temperatures with the RCMs mean monthly temperature anomaly, which was linearly interpolated between months. After calculating the average monthly temperature anomalies for both models, these values were linearly disaggregated into days to construct a 365-day period of temperature anomalies in order to avoid step changes between months (Figure 8.3).

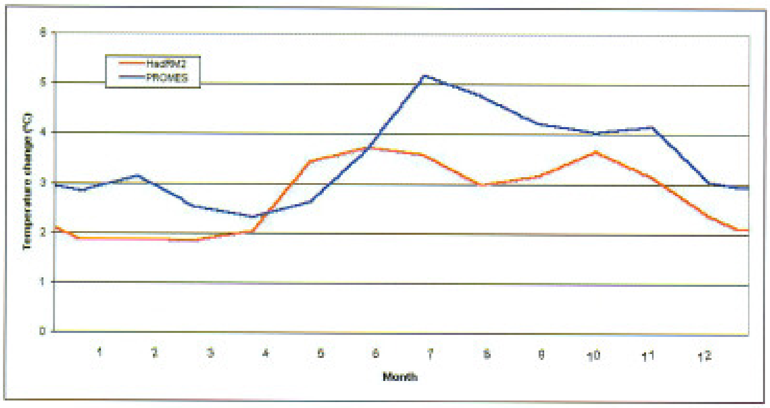

Figure 8.3 – Linear interpolation between mean monthly temperature change in HadRM2 and PROMES regional climate models for the 2040s.

A consistent increase in the number of days above the critical temperature in both RCMs was observed (Table 8.9). For the period 1980-98 these days constituted 52% of summer days, but in the future they increased dramatically. Acclimatization reduce days above the critical temperature in both RCMs and in HadRM2 the 2050s even have less days than the 2020s with no acclimatization. Substantial unobserved temperatures (above 0.5 days per year) are only reached by the 2080s. The RCMs are consistent in showing that unobserved temperatures only occur in summer before the 2050s, whereas in the 2080s some already occur outside summer.

8.2.2.2 Socio-economic Data

Portugal's administrative system comprises of 18 districts and 2 autonomous regions (the islands of Açores and Madeira). Health and socio-economic data collected from these districts are normally grouped and presented for seven regions; Northern region, Central region, Lisbon and Tagus Valley (LVT), Alentejo, Algarve, Madeira, and the Azores. The first mentioned five regions are for continental Portugal and the remaining two for each autonomous (non-continental) region. In the present study, the health and socio-economic data used were grouped into these five continental regions.

8.2.2.2.1 Observed data

Observed demographic, population mortality data, and information on accessibility to basic public health

Table 8.9 – Days above critical temperature per year compared to baseline climate (1968-98) for year-round and summer months assuming no and full acclimatization. Critical temperature is 29°C under no acclimatization, and an extra 1°C is added for each time slice with full acclimatization. In brackets is the number of days of unobserved temperatures per year. The shaded blocks are periods with more than 0.5 days of unobserved temperatures per year, which were not used in the study.

		Year-round			Summer (JJA)		
		2020s	*2050s*	*2080s*	*2020s*	*2050s*	*2080s*
No acclimatization	*HadRM2*	19.5 (0.07)	45.9 (0.17)	106.6 (2.13)	12.6 (0.07)	28.1 (0.17)	58.0 (1.73)
	PROMES	26.3 (0.07)	61.0 (0.40)	117.5 (8.8)	17.6 (0.07)	39.9 (0.4)	60.4 (7.97)
Full acclimatization	*HadRM2*	7.1 (0.03)	15.2 (0.03)	51.4 (0.20)	4.6 (0.03)	9.6 (0.03)	31.5 (0.20)
	PROMES	13.5 (0.07)	29.5 (0.10)	76.9 (2.03)	9.7 (0.07)	21.0 (0.10)	49.3 (1.83)

Table 8.10 – Observed health and socio-economic data used in assessment process

Data description	Data source
Identification of vulnerable populations	
Population demographics	INE 1998c
Poverty trends	Chapter 3
Foreigners residing in Portugal	INE 1998c
Living conditions of immigrants in Portugal	Baganha et al. 2000
Asthma and rhinitis prevalence in children in Lisbon	Allergone 2000
Heat-related deaths	
Daily mortality data for Lisbon (1980-1999)	INE 2000
Building characteristics in Portugal	INE 1998e
Urbanisation trends in Lisbon	Lucas 1991
Old inner city buildings in Lisbon, quality & inhabitants	Ribeiro 1991
Air pollution-related health effects	
Asthma hospital admission peak periods	Bastos et al. 1993
Allergic rhinitis seasonality in Lisbon	Lopes da Mata 2001
Water and food-borne diseases	
Foodborne outbreaks in Portugal (1987-1998)	WHO 1999c
Monthly incidences of notifiable diseases in Portugal (1994-1998)	DGS 1999
Seafood biotoxin contamination in Portugal	Sampayo et al. 1997 Vale & Sampayo 1999; 2001a & b
Public accessibility to tap-water and sanitation facilities	INE 1998e
Vector-borne diseases	
Disease incidences of malaria, Mediterranean spotted fever & Leishmaniasis in Portugal (1994-1998)	DGS 1999
Hospital admissions for dengue, yellow fever, West Nile fever, Lyme disease, TBE & Schistosomiasis in Portugal (1992-1998)	IGIF 2000
Rodent-borne diseases	
Disease incidence of leptospirosis in Portugal (1994-1998)	DGS 1999

infrastructures were obtained from the Portuguese National Institute of Statistics. Additional observed health and socio-economic data used in each health impact assessment is summarised in table 8.10.

8.2.2.2.2 Socio-economic scenario generated data

Most of the potential health outcomes investigated in this study could only be assessed qualitatively. Therefore, socio-economic scenarios were rarely used. An exception was the heat-related mortality assessment. Future demographic changes were calculated in consistency with the IPCC Special Report on Emission Scenarios (SRES; Nakićenović et al. 2000). OECD population growth rates from each SRES scenario was applied to the 1990 Lisbon population to produce 10-year spaced population figures until 2100.

In terms of population, Lisbon was shown to grow in all scenarios, reaching a maximum of 3.6 million (in SRES A2 scenario) and a minimum of 2.2 (in SRES B2) by 2100. The middle range scenarios all converged around 2.6 million. This median value was used in this modelling exercise.

8.3 IMPACTS OF CLIMATE CHANGE UPON HUMAN HEALTH

8.3.1 INTRODUCTION

8.3.1.1 Overview

Climate change is anticipated to affect human health through a variety of pathways (figure 8.4). Some are direct pathways such as extreme thermal exposure or floods. Others involve intermediate and multiple pathways such

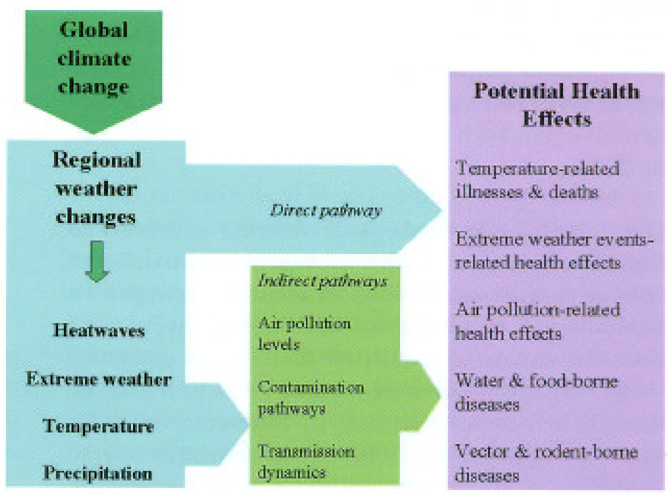

Figure 8.4 – Potential health effects of climate change.

as those affecting the transmission dynamics of vector-borne diseases.

8.3.1.1.1 Direct effects of climate change

Increased occurrences of extreme weather events and thermal extremes have direct impacts on human health. Exposure to thermal extremes may result in altered rates of heat and cold related illnesses and deaths (Kalkstein 1993).

Alterations in the frequencies and/or intensity of extreme weather events such as storms and floods may result in rapid increases in deaths, physical injuries, malnutrition, and psychological disorders. Additional health impacts can also result if these weather events damage public health infrastructures. An extreme weather event like drought may result in increased malnutrition, poverty and violence (McMichael & Haines 1997).

8.3.1.1.2 Indirect climate change effects

Health impacts due to indirect climate change effects such as those resulting from increased ambient air pollution levels and ecological disturbances are also possible.

Weather has a major influence on the dispersal and ambient concentrations of air pollutants. Increased ambient air levels of pollutants such as ozone, particulates, and aeroallergens will have a negative impact on respiratory and cardiovascular health outcomes. Higher air temperatures and altered precipitation patterns have the potential to increase the ambient concentration of tropospheric ozone and aeroallergens such as pollen (Wark et al. 1998; Patz et al. 2000).

Disturbances in ecological systems can lead to significant changes in the transmission dynamics of infectious diseases and regional changes in agricultural productivity. Infectious diseases of concern can be transmitted to humans either by vector organisms such as insects, ticks, and rats, or directly by human exposure to contaminated water and food (Epstein 2000). As a consequence to ecological disturbances, public health can also be affected by human population movements and by regional conflicts over shortages in food and water supplies (McMichael 1996).

Projections of the extent and direction of potential climate change health impacts are difficult as such assessments incorporate many confounding and poorly understood factors associated with potential health outcomes, population vulnerability and adaptation. Given the uncertainty regarding the potential climate change effects on human health, focusing on describing and reducing population vulnerability is essential. This section focuses on identifying and describing current national public health concerns that may intensify under climate change scenarios. Adaptation measures that may help reduce or eliminate these health impacts are discussed in section 8.4.

8.3.1.2 Detailed List of Impacts

8.3.1.2.1 Identified

Currently, there are very few published studies showing changes in the Portuguese population health status in response to the observed climatic changes. Identification of potential future health impacts of climate change in Portugal is thus difficult. Nevertheless, if potential global climate change health impacts (McMichael 1996) are considered in the context of climate change scenarios for Portugal, then the following potential health impacts are possible:

- Increased heat-related illnesses and deaths due to more frequent and more intense heatwaves,
- Decreased cold-related deaths due to milder winters,
- Increased prevalence of asthma and allergic disorders, as well as other respiratory disorders and deaths associated with poor air quality,
- Increased deaths, injuries, infectious disease risks, and mental disorders associated with floods and storms,
- Increased risks of infectious diseases and mental disorders associated with drought,
- Increased deaths, injuries, and cardiovascular and respiratory symptoms associated with forest and vegetation fires,

- Increased incidence of diarrhoea and other infectious water and food-borne diseases,
- Increased incidence of death-by-drowning and other water-related injuries as water recreational activities may become more frequent,
- Changed geographical ranges and incidence of vector-borne diseases,
- Increased risks of infectious diseases and mental disorders associated with population displacement and infrastructure damage due to sea-level rise, and
- Increased poverty, mental disorders and possibly malnutrition due to reduced agriculture yields and fishing.

Since current knowledge of future environmental and societal conditions is not complete, it is reasonable to conclude that additional, currently not identifiable, public health outcomes are possible due to future climatic and socio-economic changes in Portugal.

8.3.1.2.2 Studied

Several of the adverse potential health impacts identified above were assessed further in an attempt to avoid/reduce population vulnerability to climatic changes. Impacts, which, based upon available data, currently pose a public health threat in Portugal, were further assessed. These impacts were:

- Heat-related deaths,
- Air pollution-related health effects,
- Health effects associated with floods and drought,
- Water and food-borne diseases,
- Vector-borne diseases, and
- Rodent-borne diseases.

Potential health impacts due to heat-related illnesses, sea-level rise, and changed food yields were not further assessed due to insufficient available data and resources. Cold-related deaths were not studied further as the aim of the current investigation was to identify adverse impacts and recommend adaptation measures to reduce population vulnerability.

8.3.2 Heat-related deaths

Increased heat-related deaths are a typical direct health impact of climate change. Prolonged human exposure to elevated ambient temperatures can result in heat cramps, heat exhaustion, and heat stroke. The latter being the most common cause of death directly attributable to elevated temperatures. Elderly persons, individuals undergoing intense physical stress, and those with cardiovascular disease are most at risk (Lipscomb, 1992). Other causes of death observed following heat waves include ischemic heart disease, diabetes, and respiratory diseases (Ellis, 1972, Garcia et al., 1999).

Studies have shown that populations in urban areas are the most vulnerable to the adverse heat-related health effects largely due to the "urban heat island effect" (McGeehin & Mirabelli 2001). Heat-related deaths in Lisbon were assessed in the present study, since it is the urban region with the most population living in apartments, and hence more susceptible to the "urban heat island effect" (see table 8.1).

Future heat-related mortality in Lisbon was calculated based on its past relationship with temperature in conjunction with future socio-economic and climate change scenarios. Our analysis showed a consistent increase in death rates (Table 8.11). If we consider the possibility of heat-related deaths occurring year-round, considered a high estimate, a six-fold increase (compared to the present) in death rates is expected by the 2050s using PROMES and assuming no acclimatization. This is our most extreme scenario, which contrasts with only a 7% increase of heat-related mortality rates by the 2020s, under the HadRM2 assuming full acclimatization and only summer heat-related mortality; our most conservative approach.

From our analysis, it is clear that climate change will increase heat-related mortality in Lisbon. The magnitude of this increase depends on the assumptions made about acclimatization, excess death calculation method (summer months mean or 30-day running mean), seasonality (year-round or only summer heat waves). A preliminary uncertainty analysis (Dessai 2001) indicated that the greatest uncertainty arises in order of magnitude: from the RCMs, acclimatization/adaptation, seasonality, and lastly, excess deaths estimation method.

Table 8.11 – Modelled mortality rates (per 100,000 population) for the different model variants (summer months and 30-day running means), climate scenarios (HadRM2, PROMES), and set of assumptions about seasonality (year-round and summer) and acclimatization.

			Year-round		*Summer (JJA)*	
			2020s	*2050s*	*2020s*	*2050s*
Summer months mean	*No acclimatization*	HadRM2	11.6	21.5	9.1	16.6
		PROMES	15.1	35.6	12.1	28.8
	Full acclimatization	HadRM2	9.9	12.9	7.7	10.0
		PROMES	12.8	21.4	10.3	17.3
30-day running mean	*No acclimatization*	HadRM2	10.7	20.7	8.5	16.2
		PROMES	14.2	35.9	11.5	29.5
	Full acclimatization	HadRM2	7.3	9.5	5.8	7.3
		PROMES	9.6	16.5	7.8	13.4

8.3.3 AIR POLLUTION-RELATED HEALTH EFFECTS

Pollutants in the air are transported through the airspace by wind. Their distribution and concentration in the air is therefore dependent on the prevailing weather conditions. This section investigates the potential human health effects caused by anticipated changes of air pollution exposures associated with climate change scenarios.

Recent studies indicate that the most convincing evidence of global climate change on air pollution-related health effects are likely to be those associated from tropospheric ozone and aeroallergens exposures (Patz et al. 2000; Kovats et al. 2000b). These air pollutants were thus identified as the pollutants of potential concern in this study. As nitrogen dioxide and volatile organic compounds are important precursors of tropospheric ozone, they are also discussed here.

8.3.3.1 Air Pollutant Sources and Health Effects

Detailed reviews of the adverse health effects associated with air pollutants of potential concern are widely available (WHO 1999d; CalEPA 2000a & b; Burge & Rogers 2000). In the present study only the most essential points of tropospheric ozone and aeroallogens are presented. Population exposure to these pollutants in Lisbon, the largest urban centre in Portugal, is also discussed.

8.3.3.1.1 Tropospheric ozone

Ozone is a secondary pollutant formed during photochemical reactions involving nitrogen oxides (NOx), volatile organic compounds (VOCs) and sunlight. During 1990–1998 NOx and VOC emissions for Portugal increased by 16% and 27% respectively. The transport sector contributed the most to these emission increases (UNECE/CLRTAP 2000), although natural vegetation and wild fires also contributed significantly to the observed increase in VOC emissions (DGA 2000b). Recent studies indicate large increases in air and road traffic fuel consumption in Portugal until 2010, potential increases in NOx and VOC emissions are thus anticipated in the near future from the transport sector (DCEA 2000).

Health effects associated with ground-level ozone (O_3) exposures arise primarily due to the fact that it is a powerful oxidant capable of damaging tissues of the respiratory tract and lungs. Ozone is also known to induce damage to vegetation and ecosystems.

Short-term health effects of O_3 exposures include;

- induced changes in lung function and airway inflammation,
- increased airway responsiveness to bronchoconstrictors,
- increased numbers of hospital admissions from respiratory diseases,

- aggravation of asthma and other chronic lung diseases.

Review studies also suggest small, but consistent decrements in lung function due to long-term O_3 exposures (WHO 1999d; CalEPA 2000b).

Population groups most vulnerable to O_3 exposures are, children, adults that are active outdoors, and people with respiratory diseases, such as asthma, emphysema and bronchitis (CalEPA 2000b). Quantification of the health impacts of O_3 exposures can be achieved using coefficients of +3% and +3.5% for a 50 mm/g^3 8-hour mean O_3 increment for deaths and respiratory hospital admissions respectively (Touloumi et al. 1997; Spix et al. 1998).

Air quality monitoring stations situated in high traffic urban areas in the two largest cities in Portugal, Lisbon and Porto, indicate higher NO_2 levels in Lisbon. WHO guidelines are often exceeded in both cities (DGA 2000). At these high NO_2 concentrations, the risk of exaggerated responses to the cold and aeroallergens increases significantly in asthmatic individuals. Quantification of these health effects was not possible, as reliable exposure-response coefficients are currently not available.

Insufficient data and annual fluctuations in O_3 concentrations in Portugal prevent clear conclusions on time trends. Nevertheless, O_3 concentrations in Portugal seem to be lower than those reported in most Southern European countries (EEA 2000). Air quality data for Lisbon indicate highest O_3 levels at the Beato monitoring station. This station is within a residential zone in Lisbon. While data for 1999 show no exceedances above the EU 1-hour threshold, 8-hour exceedances of the WHO guideline and EU thresholds were recorded (DGA 2000a). Preliminary analysis indicate that these O_3 exposures may have contributed up to 1.6% of all deaths (± 350 cases) and 1.9% of respiratory hospital admissions in Lisbon during 1999 (Casimiro & Calheiros 2001).

8.3.3.1.2 Aeroallergens

Primary sources for outdoor allergens include vascular plants (pollen, fern spores, soy dust), and fungi (spores, hyphae). Floristic patterns thus have a fundamental role in the distribution of aeroallergens. Once airborne, aeroallergens follow the physical laws that apply to all airborne particles. Pollen and fungal spores are the main aeroallergens present in the ambient air.

Although pollen is known to play a significant role in allergic rhinitis, it is considered too large to penetrate the lower airways consequently, the mechanism whereby pollen exposure causes asthma remains speculative. Nevertheless, exposures to pollen, fungal spores and other airborne allergens such as soya have been reported to exacerbate asthma (Delfino et al. 1997; GINA 1996).

Short-term peaks of allergen exposure are sufficient to exacerbate allergic diseases such as hayfever and asthma. These result in increased use of medication, more medical treatment and more visits to hospital emergency rooms. In severe cases, an asthma attack can be fatal (GINA 1996).

The potency of aeroallergens is however simply not a matter of abundance, for example pollen from specific plant species such as; alder, birch, hazel, mugwort, ragweed, several grasses, and wall pellitory, are known to produce allergic symptoms more readily than pollen from other plants (EPI 2001). Furthermore, potency differences amongst the same species are not uncommon (reviewed in Burge & Rogers 2000).

Results from pollen monitoring studies in Lisbon indicate that the levels of pollen grains most likely to cause adverse health effects are highest in spring (Queiróz et al. 1998). Observational studies indicate peak hospital emergency admissions for asthma and consultations for allergic rhinitis in Lisbon both coincide with the onset and duration of the peak pollen season (Bastos et al. 1993; Lopes da Mata 2001).

A recent investigation on the concentration of airborne pollen from *Cupressaceae* species in Lisbon concluded that peak airborne pollen levels occur in February. This study also showed peak *Cupressaceae* pollen levels in Lisbon start and end sooner than in other Mediterranean cities (Ramos et al. 2000). Preliminary results indicate that 7% of the allergic population in Lisbon is sensitive to *Cupressaceae* pollen (Lopes da Mata 2001).

Table 8.12 – Typical pollen distribution levels in Portugal (source EPI 2001)

Blocks in white represent months with low pollen counts, those in green (G) months with moderate pollen counts, those in yellow (Y) months with high pollen counts, and those in red (R) months with very high pollen counts. Most allergic individuals will start to experience symptoms when count reaches the moderate category.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alder	Y	G										G
Cypress family	G	Y	Y	G								
Nettle/Pellitory	G	G	Y	Y	Y	G	G					
Birch			G	Y	G							
Olive tree			G	G	Y	Y	G					
Grasses			G	G	Y	R	Y	G				
Platain tree			G	G								

Typical pollen distribution levels in Portugal are summarised in table 8.12 (EPI 2001). This table suggests that grasses are probably the most important cause of pollinosis in Portugal.

8.3.3.2 The Role of Climate on Air Pollution Levels

Local concentrations of air pollutants depend upon the strength of their sources and the efficiency of their dispersion. Daily variations in ambient concentrations of air pollutants are however more affected by meteorological conditions than by changes in source strengths. Climate may affect air pollution levels by (Bernard et al. 2001);

- affecting local and regional weather and thereby air pollution concentrations,
- affecting the distribution and types of aeroallergens in the air, and
- affecting natural and anthropogenic sources of air pollution emissions.

In this section, the effects of climate on the levels of pollutants of concern were examined based on past ambient air pollution levels and climate variables in order to establish a relationship between the two.

Analysis on NO_2 levels in Lisbon show a trend of higher NO_2 levels in the winter months as well as peak traffic hour periods. Previous studies on air quality in Lisbon revealed that days with highest nitrogen dioxide pollution levels were those with windspeeds below 2m/s and lower temperatures (Andrade 1996).

As the name implies, VOCs are volatile substances. Increased temperatures are therefore most likely to result in evaporation increases of these compounds from their solid and liquid states. Moreover, VOCs vegetation emissions are known to be greater at higher temperatures.

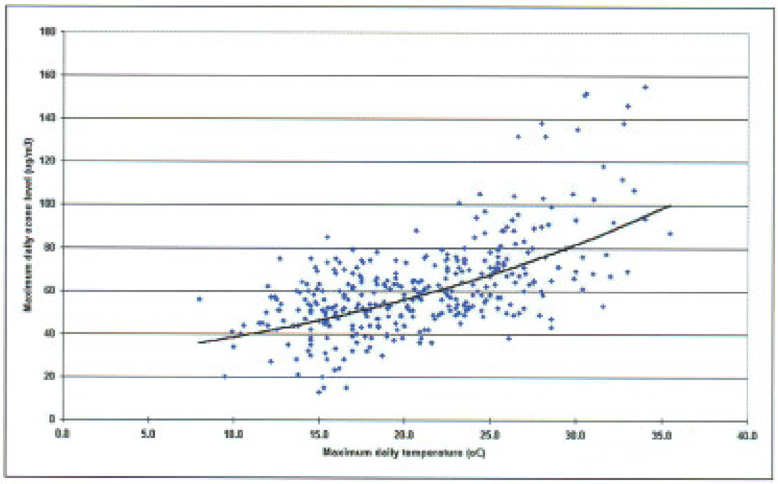

Figure 8.5 – Relationship between ozone and temperature in Lisbon in 1999
(data from DGA 2000a & IM 2000)

Ambient ozone levels in Lisbon are higher in the summer months. A direct correlation between temperature and ozone levels in Lisbon is observed in figure 8.5. Other studies have indicated that the simultaneous occurrence of daily maximum temperature above 25°C and low windspeeds favour the occurrence of summertime high ozone episodes (Anderson et al. 2001).

Aeroallergen particles are released from sources into the air by wind, rain, mechanical disturbance, or active discharge mechanisms. Information obtained from a study looking at daily levels of airborne pollen in Lisbon suggests that its concentration in the air increased with (Queiróz et al. 1998);

- increases in daily maximum temperatures during the flowering period,
- increases in cumulative rain-free days, and
- increases in windspeeds.

Results from studies conducted elsewhere have also indicated that grass pollen released during thunderstorms influence asthma epidemics significantly (Bellomo et al. 1992).

8.3.3.3 Climate Change Effect on Air Pollution-related Health Effects

Health effects associated with climate change impacts on air pollution will depend on future air pollution levels. However, determination of the direction of change at a particular location and the magnitude of the change in air quality that may be attributable to climate change cannot be determined with certainty. Potential health effects associated with climate change impacts on nitrogen dioxide, ozone and airborne pollen in Lisbon are thus *qualitatively* assessed relative to health effects associated with current air pollution levels.

PROMES and HadRM2 model results (table 8.13) both point to higher windspeeds during the cooler months in the future. Better dispersion of NO_2 during these months is thus anticipated. Consequently, if current air pollution emission levels are maintained, NO_2 levels in winter are likely to decrease. Reductions in health effects associated with acute ambient NO_2 exposures are thus likely to result.

Climate change is anticipated to increase the risk of forest and wild fires (see chapter 10) and consequently increase ambient air levels of VOCs and dust. Health effects associated with haze episodes such as respiratory illnesses and eye irritations are thus likely to increase.

Climate change scenarios also indicate (table 8.14) that meteorological conditions of low windspeeds and daily maximum temperatures above 25°C will occur more frequently. These conditions will thus be more conducive to higher ozone pollution episodes. Furthermore, global photochemical models also indicate increased ozone levels for Portugal (Anderson et al. 2001).

Human exposure levels are not only dependent on the pollutant concentration in the environment, but also the "contact time" in that environment. Days in which ozone levels are anticipated to be high will also have higher than normal ambient temperatures. Warmer days encourage people to spend more time out-of-doors and so increase exposure (contact time). It is therefore very likely that climate change will aggravate current ozone related health effects.

Table 8.13 – Meteorological conditions conducive to high nitrogen dioxide levels in Lisbon

Meteorological Condition	Baseline climate scenario (% days per year)		Climate change scenario (% days per year)		% Change relative to baseline scenario	
	PROMES	HadRM2	PROMES	HadRM2	PROMES	HadRM2
Days with windspeeds at or below 2 m/s	7	2.5	6	1.5	-1	-1
Days with windspeeds at or below 2.5 m/s	14	5	13	4.5	-1	-0.5
Days with windspeeds at or below 3 m/s	25	10.5	20	11	-5	-0.5
Days with windspeeds at or below 2m/s and temperature minima at or below 0°C	0.4	1	0.1	0.5	-0.3	-0.5
Days with windspeeds at or below 2m/s and temperature minima at or below 5°C	2	2	0.5	1	-1.5	-1
Days with windspeeds at or below 2m/s and temperature minima at or below 10°C	3.5	0.1	1	0	-2.5	-0.1

Table 8.14 – Meteorological conditions conducive to high ozone levels in Lisbon

Meteorological Condition	Baseline climate scenario (% days per year)		Climate change scenario (% days per year)		% Change relative to baseline scenario	
	PROMES	HadRM2	PROMES	HadRM2	PROMES	HadRM2
Days with windspeeds at or below 2 m/s	7	2.5	6	1.5	-1	-1
Days with maximum temperatures at or above 25°C	27	30	53	42	26	12
Days with maximum temperatures at or above 25°C and windspeeds at or below 2m/s	1	0.1	1.5	0.2	0.5	0.1
Days with maximum temperatures at or above 25°C and windspeeds at or below 2.5m/s	2	1	4	2	2	1
Days with maximum temperatures at or above 25°C and windspeeds at or below 3m/s	5	3	9	5	4	2

If current land-use patterns are assumed, as well as climate change scenarios that are warmer and drier, then it seems reasonable to anticipate that relative to current weather;

- the amount of pollen produced may increase, subsequent to temperature changes and increased atmospheric CO_2 concentrations (reviewed in Burge & Rogers 2000),
- airborne pollen levels may be higher due to higher pollen production as well as less rainy days,
- alterations in areas of favourable growth for allergen-producing plants may result in geographical shifts in species, and
- peak airborne pollen levels will most likely occur earlier in the year.

However, it is not clear whether this will result in pollen seasons with longer duration.

Higher pollen levels will inevitably lead to increases and possibly more severe incidences of allergic conditions and asthma. Land-use changes will however have the most significant impact in future aeroallergen levels.

8.3.4 HEALTH EFFECTS ASSOCIATED WITH FLOODS AND DROUGHT

Floods have the potential of affecting human health directly and indirectly. Direct effects are those caused by the floodwaters such as physical injuries and drowning, while indirect effects are those caused by other systems damaged by floods. The latter include mental disturbances, water-related diseases, and vector and rodent-borne diseases. Indirect health effects generally affect more individuals (Kovats et al. 2000a; International Federation of Red Cross and Red Crescent Societies 2001).

Drought conditions have been associated with widespread crop failure leading to famine in developing countries. This scale of malnutrition and starvation are not public health concerns in developed nations. However, drought associated crop failure, desertification, and wildfires have been observed in Portugal during the last few decades (see chapters 2, 5, 7, and 10). Such drought-related effects have obvious economic losses that may affect human health adversely. Potential health outcomes include mental disorders, fire-related illnesses and deaths, water-related diseases, and vector and rodent-borne diseases.

Potential climate change impacts on flood and drought associated waterborne diseases and appropriate vector and rodent-borne diseases in Portugal are assessed in sections 8.3.5–8.3.7.

8.3.5 WATER AND FOOD-BORNE DISEASES

Water and food-borne diseases are transmitted to humans when they come into contact with biotoxin and pathogen-contaminated water or foods. These infectious diseases are a serious public health problem in developing countries and to a lesser degree in developed nations. However, in recent years, concern about water and food-borne disease transmission has increased in developed countries (Rose et al. 2001; Stanwell-Smith 2001; Bentham 2001; Henrickson et al., 2001). Emergence of new, antibiotic-resistant strains, chlorine-resistant pathogens, and an ever-increasing susceptible population is likely to aggravate the situation in the near future.

Although gastro-enteritis is the most common health effect, other health outcomes such as respiratory, renal and hepatic disorders and even some cancer types may result due to pathogens transmitted by water and foods (table 8.15). Selected water and food-borne pathogens of concern are also listed.

Human exposure to water and food-borne pathogens can occur via many pathways, including:

- Drinking contaminated water,
- Eating foods prepared in/with contaminated water,
- Eating foods that were irrigated with or grown in contaminated water,
- Eating foods that were in contact with contaminated individuals,
- Breathing in water aerosols/mist that contain pathogens,
- Dermal contact with contaminated water.

Determination of the route of exposure of many water and food-borne diseases is however difficult as the pathogen is often found in both water and foods (table 8.15). This is complicated further by the fact that some diseases may be transmitted from person-to-person. Disease incidence rates for notified water and food-borne diseases of concern appear in table 8.16.

Water and food-borne disease transmission is influenced by climate directly and indirectly. In this section, potential climate change health impacts from

Table 8.15 – Health outcomes associated with selected water and food-borne diseases
(adapted from Rose et al 2001)

Health outcome	Pathogen	Found in sewage sewage	Waterborne transmission	Food-borne transmission
Cancer, peptic ulcer	*Helicobacter pylori*	Possibly	Possibly in groundwater	Yes
Cholera	*Vibrio Cholerae*	Yes	Yes	Yes
Dermatitis/diarrhoea related to blue green algae	Toxins of *Cyanobacteria spp.*	No	Yes	Yes
Diarrhoea and gastro-enteritis	*Giardia, Cryptosporidium, Salmonella, Shigella, Campylobacter, Staphylococcus aureus, Escherichia coli,* & enteric viruses	Yes	Yes, most	Yes
Fascioliasis	*Fasciola hepatica*	Yes	Yes	Yes
Hepatitis	*Hepatitis A virus* *Hepatitis E virus*	Yes No	Yes Yes	Yes Potentially
Kidney failure	*Escherichia coli (0157), Microsporidia, Cyclospora, Vibrio vulnificus, Cyanobacteria*	Yes, most	Yes, most	Yes
Liver failure	*Hepatitis A virus* *Hepatitis E virus* *Cyanobacteria*	Yes No No	Yes Yes Yes	Yes Potentially Yes
Legionnaire's Disease	*Legionella*	No	Yes	No
Typhoid fever	*Salmonella typhi & paratyphi*	Yes	Yes	Yes

Table 8.16 – Incidence rates of selected water and food-borne diseases in Portugal for 1998 (source DGS 1999)

Disease	Incidence rate (/100 000)
Typhoid fever	3.0
Nontyphoidal Salmonellosis	3.4
Shigellosis	0.1
Hepatitis A	2.7
Cholera	0

two overlapping environmental health-related areas will be addresses. The areas studied include:

- Waterborne diseases associated with drinking water, recreational freshwater and coastal water.
- Food-borne diseases linked to fresh and seawater contamination.

8.3.5.1 Waterborne Diseases

Quantification of the present threat of waterborne diseases in Portugal is difficult due to lack of appropriate data and the fact that many waterborne diseases, notably gastrointestinal illness, are underreported. Recent studies linking waterborne pathogens and disease outbreaks in Portugal are few, while studies linking water quality or waterborne diseases to climate could not be found.

Results from an epidemiological investigation on water quality and acute diarrhoea showed a statistically significant association between acute diarrhoea and households using drinking water with high levels of microbiological indicators (Falcão et al. 1997). Other studies have reported clear seasonal occurrences in the incidence of acute gastroenteritis, with most cases being reported during the warmer months (Paulo et al. 1989; Lima et al. 1998).

Results from the 1998 water for human consuption national monitoring programme indicate that at least 1.5 million (about 15% of the total population) individuals are exposed to tap water with microbiological contamination above drinking water quality limits. The Northern and Central interior are the regions where less water disinfecting occurs and consequently, where microbiological contamination is the greatest (DGA 1999). Potential exposure to waterborne pathogens is thus greater in these regions.

Freshwater quality is influenced by changes in precipitation, temperatures, and wind. Several studies have shown that freshwater quality is negatively affected by drought, and by storm water drainage and raw-sewage run-off following precipitation events (Atherholt et al. 1998; Rose et al 2000; Rose et al. 2001), while other studies have indicted that pathogenic growth is favoured by warmer temperatures (table 8.17). Higher evaporation rates may also concentrate pathogen and chemical pollutants in freshwater bodies.

Water quality depends not only on weather events but also to a large extent on how water resources are managed and protected. Poor management and disposal of sewage and other wastes into fresh and seawater bodies has a negative impact on water quality. Extreme precipitation and increased urbanisation have the potential to exacerbate this further. Current monitoring results on surface freshwater indicate that less than 20% of monitored water is within national recommended recreational water quality limits (INAG 2000).

Climate change scenarios (see chapters 2 & 5) indicate warmer ambient temperatures and more

Table 8.17 – Effect of temperature on pathogen survival

Pathogen	Temperature effect	Reference
Salmonella	Grow above 7°C, Optimal growth at 37°C	Baird-Parker, 1994
Cryptosporidium	Survive –20°C to 60°C	Fayer & Nerad, 1996 Fayer, 1994
Campylobacter	Growth only above 30°C	Lacey, 1993
Cynobacteria (in general)	Photosynthetic capacity, specific respiration rate and growth rate optimised at 25°C	Robarts & Zohary, 1987
Cynobacteria – Microcystis	Sensitive below 15°C	Robarts & Zohary, 1987
Cynobacteria – Oscillatoria	Optimal toxin production at 25°C.	Sivonen, 1990

frequent extreme precipitation events. Warmer ambient temperatures will most likely lead to warmer surface water temperatures. These climatic changes have the potential to exacerbate the already poor surface water quality. Thus, if current water management practises are maintained, climate change scenarios indicate that freshwater quality and consequently drinking water quality is likely to deteriorate even more. Deterioration of surface and drinking water quality is likely to increase the risk of waterborne disease transmission.

8.3.5.1.1 Cyanobacteria issues

The presence of blue-green algal (cyanobacteria) blooms in surface waters used for drinking water sources and recreation is common throughout Portugal. Approximately 60 % of these blooms produce toxins harmful to humans. During the last decade blooms have become more frequent. This has been attributed to high nutrient levels in the water, warmer climate and more droughts (Vasconcelos & Araújo 1997).

Blue-green algal blooms can have dramatic effects on the aquatic ecosystem and for public health. Human health outcomes associated with cyanobacteria biotoxins that have been detected in freshwaters in Portugal include; hepatic disorders, which could lead to death and cancer, neurological effects including paralysis of vital muscles (skeletal & respiratory) that may result in death, skin and eye irritations, allergies and hayfever, and gastrointestinal symptoms (INAG 1996; Ressom et al 1994). Moreover, deterioration in drinking water quality is also possible since water treatment is made difficult when freshwater is contaminated with algal blooms.

Cyanobacteria blooms appear in surface waters in Portugal from May to October, being more intense during the summer months (Vasconcelos & Araújo 1997). Environmental conditions known to favour blooms include (Ressom et al 1994):

- Increased temperatures (see table 8.17),
- Changes in nutrient levels,
- Increased stability of water bodies,
- Changes in light intensity,
- Air movement changes, and
- Increased UV irradiation.

As described in chapters 2 and 5, climate change scenarios point to warmer temperatures and more frequent extreme weather events. Since, these weather conditions favour bloom formation, which may have negative health impacts, climate change may increase the incidence of health problems related with cyanobacteria presence in freshwater bodies.

8.3.5.1.2 Coastal issues

Coastal-related activities are an important aspect of the Portuguese culture. Population exposure to seawater and other coastal related issues (beach sand, seashells etc.) is thus significant. Pathogen and chemical contamination of seawater may result in public health impacts of concern in exposed individuals.

Health outcomes associated with coastal water and other coastal related exposures include:

- Drownings and physical injuries,
- Skin & eye irritations and allergic reactions to seawater contaminants,
- Psychological and socio-economic effects of beach closures, and
- Microbiological infections due to pathogen ingestion or dermal contact with seawater.

Microbiological contamination of seawater occur mainly due to (WHO 1999b):

- Sewage and other waste discharges into sea, and
- Microbiological agents present in freshwaters that flow into the sea.

Results from the 1999 coastal water quality programme indicate that 20 % of the 274 beaches analysed did not meet recommended national water quality limits. Quantification of the present public health threat of the poor coastal water quality was not possible due to lack of appropriate health data.

Changes in precipitation are known to influence coastal water quality. As explained earlier, extreme precipitation events may increase the pathogen contamination in freshwater. Higher pathogen levels in freshwater are carried to coastal waters, reducing coastal water quality. In addition, increased freshwater flow into the sea reduces seawater salinity, which favours pathogenic survival in coastal water (WHO 1999b).

Temperature changes also affect coastal water quality, with warmer temperatures favouring pathogen survival. In addition, warmer months are accompanied by increased human exposures to coastal waters due to increased recreational activities during summer vacations. Moreover, as the population in coastal towns increase, so does the sewage volume, and hence the risk of exposure to higher levels of pathogens in coastal waters.

Climate change scenarios indicate (chapters 2 and 5) more frequent extreme precipitation events as well as warmer ambient temperatures. Consequently, coastal water quality may deteriorate even more with climate change. Potential health risks associated with coastal water and other coastal related exposures might thus increase due to climate change.

8.3.5.2 Food-borne Diseases

Food-borne diseases are mostly caused by ingestion of foods that were contaminated with pathogens during their preparation (via contaminated water/person/animal) as well as foods that were irrigated or grown in water that was contaminated with pathogens or biotoxins. Official records of food-borne disease outbreaks indicate a rise in the number of disease outbreaks as well as cases (WHO 1999c). Similar findings have been reported in other developed nations (Kaferstein & Abdussalam 1999; Rose et al. 2001; Bentham 2001). Several factors are believed to have contributed to this increase, including:

- Better disease diagnosis and reporting,
- A growing susceptible population (elderly and immunocompromised),
- Increased importation of food from global markets,
- Changing food-processing technology,
- Changing food consumption patterns.

In 1998, food-borne diseases in Portugal were linked to at least 1,411 cases of illness, with 602 hospitalisations (WHO 1999c). Since many cases are not notified this is very likely to be a large underestimate of the real level of incidence. Although in most cases the infectious agents cannot be positively identified, the two pathogens most often associated with food-borne illnesses were *Salmonella spp.* and *Staphylococcus aureus* (WHO 1999c). Other investigations have however indicated that infections due to *Campylobacter, Shigella, Brucella, Clostridium,* Hepatitis A virus, Hepatitis E virus, *Helicobacter pylori, E.coli, Cryptosporidium, Giardia, Fasciola hepatica,* and *Yersinia* also occur (WHO 1990; Melo Cristino et al. 1988; DGS 1999; Novais 1990). Most infectious food-borne outbreaks have been attributed to poor hygiene practices during food preparation in public eating places such as canteens and restaurants. Foods of animal origin were the primary source of many food-borne cases (WHO, 1999c). Seafood poisonings due to various shellfish-associated toxins have also been reported (Silva 1980; Vale & Sampayo 1999).

Figure 8.6 shows that food-borne diseases such as Typhoid fever and Salmonellosis have higher incidence rates during the warmer months (DGS 1999). Laboratory results conclude that higher temperatures (see table 8.17) favour multiplication of many pathogens found in foods.

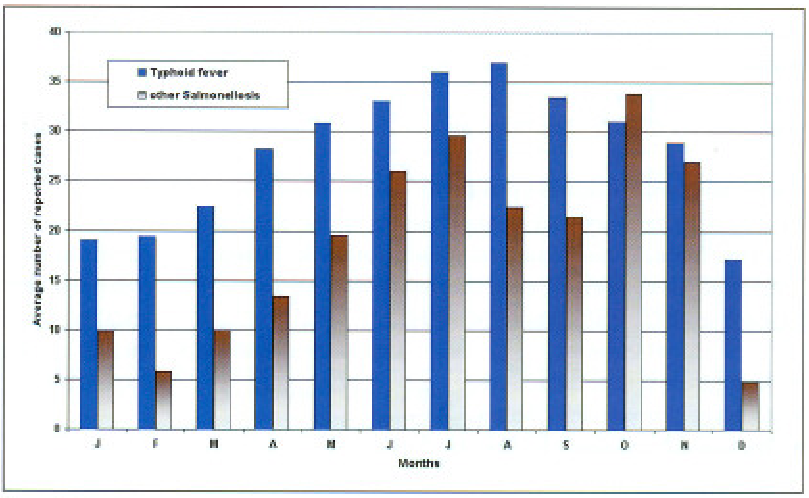

Figure 8.6 – Average monthly distribution of Salmonellosis incidence in Portugal from 1994-98
(data from DGS 1999)

Data presented in figure 8.6 also indicates that food poisoning cases where humans are the only reservoir and host such as Typhoid fever (caused by *Salmonella typhi*) peak in months with higher temperatures than those cases caused by *Salmonella* species that have animal reservoirs. The latter observation has also been reported by other researchers and has been attributed to food contamination during early stages of the food production process such as animal husbandry and slaughtering (Bentham & Langford 1999).

Since food-borne diseases are directly associated with warm weather, increases in temperatures have the potential to increase disease transmission risk. In conclusion higher future temperatures may exacerbate the food poisoning problem, which is already a significant threat to public health.

8.3.5.2.1 Seafood poisoning

Seafood poisoning is caused by a group of biotoxins produced by planktonic algae such as dinoflagellates and diatoms upon which zooplankton, shellfish and herbivorous fishes feed. These biotoxins accumulate in fishes and shellfish such as clams, oysters, and mussels; often reaching levels that may cause adverse health effects if ingested by humans. Potential health outcomes associated with consumption of seafood contaminated with algal biotoxins include acute gastrointestinal symptons within 30mins to 3hours after ingestion, followed by acute neurological effects in some cases. Fatalitiy rates can be as high as 15%. New evidence indicates that some biotoxins are also tumour promoters, cyctotoxic, and clastogenic and therefore potential carcinogens (Maynes et al. 2001; Traore et al. 2001).

These biotoxins are temperature stable, so cooking does not ameliorate toxicity in contaminated seafoods. Apart from the direct health effects of shellfish poisoning, marine algal blooms are responsible for extensive die-offs of fish and shellfish, which reduce quantities available for human consumption, which, in turn, may result in socio-economic, nutritional, and psychological impacts (HEED 1998; Van Dolah 2000).

The first records of seafood poisoning in Portugal occurred in the late 1950s. These were traced to biotoxin contaminated seafood consumed from a coastal lagoon in Óbidos (situated mid-way along the Portuguese Atlantic coastline) (Silva 1980). More recently, in 1998, another significant seafood poisoning outbreak occurred, in which 18 individuals reported intoxication symptoms (Vale & Sampayo, 1999).

Global increases in the distribution and occurrences of algal biotoxins of human health concern have been reported since the 1970s. These global changes have been attributed to changes in several environmental factors such as (Van Dolah 2000; HEED 1998):

- World-wide increases in maritime transportation,
- Significant loss of marine life,
- Increased coastal eutrophication due to higher nutrient levels in seawater, and
- Sea surface temperature anomalies.

Since 1986, the Instituto de Investigação das Pescas e do Mar (IPIMAR) has been monitoring fish, shellfish, and coastal waters for harmful marine algal biotoxins.Results from this monitoring programme confirm the presence of algal biotoxins along the Portuguese coastline responsible for;

- Paralytic Shellfish Poisoning (PSP),
- Diarrhetic Shellfish Poisoning (DSP), and
- Amnesic Shellfish Poisoning (ASP).

Clear seasonal patterns in seafood biotoxin contamination have not emerged. Nevertheless, while summer blooms are frequent, highest levels seem to occur in spring and autumn months (Sampayo et al. 1997; Vale & Sampayo 2001b).

Similar observations have been reported along the American Atlantic coast (HEED 1998). In this study, the rapid changes in sea surface temperatures and precipitation regimes (leading to increased nutrient levels in seawater) associated with spring and autumn months were suggested to be a significant cause for the increased harmful marine algal biotoxins. Moreover, the observation that the incidence of marine algal blooms increase significantly during El Niño events, when sea surface temperatures are higher than normal, has lead to the speculation that climate change may be an underlying cause to the increased occurrences of marine algal blooms (HEED 1998).

Climate change scenarios for Portugal indicate future increases in extreme precipitation events that may potentially increase nutrient levels in fresh and seawaters. In addition, these scenarios also indicate higher ambient temperatures, which may result in warmer sea surface temperatures. Changes in climate and the possible relationship between climate and bitoxin production described above may favour the production of harmful marine algal biotoxins along the Portuguese coast, worsening the current public health threat of seafood poisoning. However, as climate is only one of the many environmental factors that may impact marine algal biotoxin levels, additional research and appropriate time series data are required in order to draw any definite conclusions on this topic.

8.3.6 VECTOR-BORNE DISEASES

Vector borne diseases are infectious diseases transmitted to humans and other vertebrates by pathogen-infected invertebrates (vectors) such as mosquitoes, ticks, and snails. These diseases often exhibit distinct seasonal patterns that clearly suggest that they are weather sensitive.

Disease transmission is influenced by the co-presence of reservoir hosts (normally warm-blooded creature), competent vector population, and pathogen at adequate numbers to maintain transmission. Transmission to humans requires human contact (exposure) with the parasite-infected vector. This exposure is influenced by a variety of factors including, human behaviour, socio-economic conditions, environmental management practices, and primary health care practices. Disease transmission only occurs if all of the above factors are favourable for transmission. A suitable climate is hence necessary, but not a sufficient condition for vector-borne disease transmission to humans.

Countries with a temperate climate, such as Portugal, are at risk of future climate conditions that may be more favourable to vector-borne diseases due to global warming. Potential changes in vector-borne disease risks in Portugal are discussed in this section.

8.3.6.1 Mosquito-borne diseases

Diseases transmitted by mosquitoes such as malaria, dengue fever and yellow fever are of great public health concern.

Mosquitoes acquire the disease-causing parasite (pathogen) when they take a blood meal from an infected reservoir host (human or animal). Once inside the mosquito, the parasite reproduces several times so that when the mosquito takes its next blood meal it is capable of delivering disease-causing doses of the parasite to a previously disease-free person.

Mosquitoes are very sensitive to meteorological conditions. Cold weather kills many mosquito eggs, larvae and adults outright. On the other hand, excessive heat also kills mosquitoes (Epstein 2000). However, warmer temperatures affect disease transmission dynamics by (reviewed in Martens 1998a);

- increasing the mosquito biting rate,
- allowing mosquitoes to proliferate faster and
- increasing the parasite developmental rate inside the mosquito.

Mosquito survival is also dependent on other environmental factors, including suitable breeding sites, humidity, and mosquito predators. Floods and droughts can help trigger outbreaks by creating breeding grounds for insects whose desiccated eggs remain viable and hatch in still water. Moreover, extreme weather events such as drought may also reduce the number of natural mosquito predators such as frogs and ladybirds, resulting in elevated numbers of adult mosquitoes (Epstein 2000).

Portugal has a temperate climate favouring mosquito-borne disease transmission during several months. Field studies have indicated that there are about 40 mosquito species in Portugal, some of which are known to be capable vectors of agents that cause diseases in humans (Ribeiro et al., 1988). Over the past three decades, mosquito-borne disease epidemics have not been reported. This is largely due to the malaria eradication campaigns of the 1950's, and improved socio-economic conditions.

Recent studies have suggested that a global mean temperature increase of several degrees as indicated by the IPCC may result in a real risk of reintroduction of several mosquito-borne diseases into disease free areas such as Portugal (Epstein 2000; Martens et al. 1995). Potential risk of reintroduction of mosquito-borne diseases into Portugal was investigated further and the results are summarised below.

8.3.6.1.1 Malaria

On a global scale, malaria has been identified as the disease most likely to be affected by climate change (Kovats et al. 2000b). Malaria epidemics have reemerged in Eastern Europe posing a serious public health concern to neighbouring countries and most of southern Europe (WHO 1999e).

Prior to the malaria eradication campaigns of the 1950's and 1960's, malaria was a common summer disease throughout Portugal. Currently, there are no local malaria cases reported, however, an average of 80 imported malaria cases per year are reported (DGS 1999). These are attributable to the strong cultural and economic ties with malaria endemic countries such as Angola, Guinea-Bissau, and Mozambique.

The first clinical signs of the malaria infection appear 10-14 days after the bite of a female mosquito that has been infected with the *Plasmodium* parasite. The infected person may experience headaches, pains in the arms and legs, backache, insomnia, nausea and vomiting. Severe attacks follow as the infected person's blood cells are destroyed and the toxins appear in the bloodstream. Infections involving *Plasmodium falciparum* are often associated with fatal complications such as anaemia and cerebral malaria.

Studies show that during the past two decades imported malaria cases in Portugal have invloved *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale, and Plasmodium malariae* parasite strains. Most cases (93%) have been due to *P. falciparum* followed by *P. vivax*. The same studies also indicate that malaria is often quickly diagnosed by medical professionals, resulting in favourable recoveries in most cases (Proença et al. 1996). Most cases are reported from the larger cities, with majority of the cases being reported in the LVT region (DGS 1999).

Six malaria-competent mosquito species are known to be present in Portugal. Of these *Anopheles atroparvus* is the mosquito that offers the most public health concern. Firstly this species is nationaly distributed, secondly it is the most abundant mosquito, and lastly it is capable of transmitting both the temperate and tropical strains of *P. vivax*. Moreover this was the species responsible for most malaria transmission prior to the eradication of the disease in the 1960's (Ribeiro et al. 1988).

The relationship between climate and malaria transmission is well documented. The two most climate sensitive parameters in malaria transmission are the relationship between temperature and the adult mosquito survival probability, and the relationship between temperature and the developmental rate of the parasite inside the adult mosquito. The latter seems to be the more sensitive parameter. *P. vivax* will not develop at temperatures below 14.5°C and *P. falciparum* below 16°C, while the proportion of either parasite surviving decreases rapidly at temperatures above 35°C. For most anopheline species, adult mosquito survival below 10°C and above 40°C is very limited (reviewed in Martens 1998a). In view of the above, it seems reasonable to conclude that disease transmission of *P. vivax* malaria occurs mostly when temperatures are between 14.5°C and 35°C, whereas *P. falciparum* malaria occurs mostly when temperatures are between 16°C and 35°C. However, as other abiotic factors such as water-breeding sites, humidity, and low altitudes are also known to favour disease transmission, interpretations of the results presented below should be made with caution.

The current Portuguese climate is already conducive to *P. vivax* malaria transmission, having several days with mean daily temperatures between 14.5°C and 35°C (tables 8.18 and 8.19). The fact that no local malaria cases are reported is an indication that the local mosquito population is not infected with malaria parasites. Thus the current (scenario 1 from table 8.5) potential risk of contracting *P. vivax* malaria is very low. However, if a population of *P. vivax* infected mosquitoes were to be introduced into Portugal and current environmental conditions are assumed (scenario 2), the potential risk of contracting malaria would increase from very low to low levels. Higher risk levels are not anticipated to be reached, as infected humans (hosts) would be treated for the disease reducing the parasitic prevalence rates.

Table 8.18 – Mosquito-borne disease transmission favourable periods based on PROMES mean daily temperature results

Region in Portugal/ Climate Scenario*	Percent days per year within favourable temperature range for parasite survival			Percent days per year within favourable temperature range for mosquito survival	
	Plasmodium vivax (14.5-35°C)#	Plasmodium falciparum (16-35°C)#	Dengue virus (11.9-37°C)#	Aedes (6-40°C)#	Anopheles (10-40°C)#
Northern					
– $1xCO_2$	37	30	50	86	60
– $2xCO_2$	50	43	67	97	79
Central					
– $1xCO_2$	44	35	59	93	72
– $2xCO^2$	60	51	79	98	90
LVT					
– $1xCO_2$	54	43	74	99	89
– $2xCO_2$	75	62	94	99	99
Alentejo					
– $1xCO_2$	53	46	69	98	83
– $2xCO_2$	71	60	90	99	97
Algarve					
– $1xCO_2$	59	50	79	99	92
– $2xCO_2$	81	68	96	100	99

* $1xCO_2$ is representative of the current (baseline) climate scenario, where as $2xCO_2$ is representative of a future climate scenario.
# Temperature range used as favourable.

Table 8.19 – Mosquito-borne disease transmission favourable periods based on HadRM2 mean daily temperature results

Region in Portugal/ Climate Scenario*	Percent days per year within favourable temperature range for parasite survival			Percent days per year within favourable temperature range for mosquito survival	
	Plasmodium vivax (14.5-35°C)#	Plasmodium falciparum (16-35°C)#	Dengue virus (11.9-37°C)#	Aedes (6-40°C)#	Anopheles (10-40°C)#
Northern					
– $1xCO_2$	28	23	42	85	55
– $2xCO_2$	57	49	76	99	87
Central					
– $1xCO_2$	37	30	54	93	69
– $2xCO^2$	68	58	87	99	94
LVT					
– $1xCO_2$	50	40	74	98	87
– $2xCO_2$	86	75	97	99	99
Alentejo					
– $1xCO_2$	51	43	70	97	83
– $2xCO_2$	81	71	95	99	98
Algarve					
– $1xCO_2$	50	40	71	98	85
– $2xCO_2$	86	75	97	99	99

* $1xCO_2$ is representative of the current (baseline) climate scenario, where as $2xCO_2$ is representative of a future climate scenario.
# Temperature range used as favourable.

Climate change scenarios used in this study indicate that the number of days with mean temperatures between 14.5°C - 35°C will increase by more than 30% (tables 8.18 and 8.19), indicating a more favourable climate for *P. vivax* malaria transmission. However, if no infected vectors are present (scenario 3), the potential risk of contracting *P. vivax* malaria should remain very low, but increase to a medium risk level if a population of *P. vivax* infected mosquitoes were to be introduced (scenario 4) as oulined in table 8.20.

The potential risks of contracting *P. falciparum* malaria assuming the four scenarios appearing in table 8.5 are lower than those for *P. vivax* malaria (see table 8.20) due to two overriding reasons. Firstly the *An. atroparvus* population currently present in Portugal seems to be refractory to tropical African strains of *P. falciparum* (Ribeiro et al. 1989), and secondly because current and future climatic conditions for *P. falciparum* malaria transmission are less favourable (tables 8.18 and 8.19).

Table 8.20 – Potential risks of mosquito-borne diseases in Portugal

Disease	Scenario *	Suitable Vector	Parasite	Risk level #
Vivax malaria	1	Widespread distribution	Imported cases only	Very low
	2	Focal distribution (new vector)	Low → High prevalence	Low
	3	Widespread distribution	Imported cases only	Very low
	4	Focal → potentially regional distribution (new vector)	High focal prevalence → Low prevalence, regional distribution	Low-Medium
Falciparum malaria	1	None present	Imported cases only	None
	2	Focal distribution	Low → High prevalence	Low
	3	None present	Imported cases only	None
	4	Focal v potentially regional distribution	High focal prevalence → High prevalence, regional distribution	Low-medium
Dengue	1	None present	Imported cases only	None
	2	Focal distribution	Low → High prevalence	Low
	3	None present	Imported cases only	None
	4	Focal → potentially regional distribution	High focal prevalence → High prevalence, regional distribution	Low-medium
Yellow fever	1	Widespread distribution	Imported cases only (very few)	Very low – none
	2	Focal distribution (new vector)	Low → High prevalence, focally distributed	Low
	3	Widespread distribution	Imported cases only	Very low
	4	Focal → potentially regional	High focal prevalence →	
		distribution (new vector)	Low prevalence, widespread distribution	Low-medium
West Nile fever	1	Widespread distribution	Low prevalence, focally distributed	Low
	2	Focal distribution (new vector)	Low → High prevalence, focally distributed	Low
	3	Widespread distribution	Low → High prevalence, regional distributed	Low – medium
	4	Focal distribution (new vector)	Low → High prevalence, focally distributed	Low

** listed in table 8.5*

 # described in table 8.6

8.3.6.1.2 Dengue

Dengue is the most important viral vector-borne disease and an increasing global problem. During the past three decades, dengue outbreaks have occurred in the Americas, Africa, Southeast Asia, the Western Pacific region, and in several Eastern Mediterranean countries (WHO 1997c). Distinct seasonal patterns and disease outbreaks are evident in most dengue outbreaks (Hales et al. 1999).

The disease is currently not present in Portugal and has caused minimal public health concern in the past. During 1992-1999, official hospital admission records indicate a single imported case of the disease in continental Portugal (IGIF 2000). Dengue infections cause various clinical symptoms, ranging from no clinical observations to severe and fatal haemorrhagic disease. Disease transmission to humans is similar to that of malaria. The dengue parasite is a virus of the family Flaviviridae. There are four dengue serotypes: DEN-1, DEN-2, DEN-3, and DEN-4 (WHO 1997c).

Of the 40 mosquito species currently present in Portugal, none are known dengue vectors. Records do however indicate that prior to 1956 *Aedes aegypti*, the most problematic dengue vector, was in fact present in Portugal (Ribeiro et al. 1988). In recent years the appearance of another dengue vector, *Aedes albopictus*, in some regions in southern Europe has prompted environmental health concerns that this species may also infest Portugal (Filipe 1993; Schaffer & Karch 2000). Several investigations are currently being undertaken in Portugal to investigate the possibility of the latter occurrence. Preliminary results show no indication of the presence of either *Aedes aegypti* or *Aedes albopictus* in Portugal currently (Almeida 2000). However, the possibility that dengue infected *Aedes* mosquitoes could be introduced in the future cannot be completely ruled out.

Dengue viruses require a minimum temperature of 11.9°C to develop. Viral development decreases dramatically above 37°C. As *Aedes* mosquitoes often occupy human dwellings they are generally less responsive to ambient temperatures than *Anopheline* mosquitoes. However, survival of *Aedes* mosquitoes below 6°C and above 40°C declines rapidly (reviewed in Martens 1998a). A temperature range of 11.9°C to 37°C, thus favours dengue transmission dynamics.

The current climate is already conducive to dengue transmission (tables 8.18 and 8.19), however, as no suitable vector is known to be present, the potential risk of contracting dengue is non-existent (scenario 1 from table 8.5). If however, a dengue-infected vector population was to be focally introduced (scenario 2), the potential disease risk would become low.

Future climate change scenarios point to increased numbers of days with mean temperatures within the favourable disease transmission range (tables 8.18 and 8.19). However, if no competent vector is present (scenario 3), potential disease risk will remain non-existent. In the presence of a focal infected mosquito population (scenario 4), the disease risk may increase from low to medium, as the vector widens its geographical distribution as indictaed in table 8.20.

8.3.6.1.3 Yellow fever

Yellow fever is a hemorrhagic fever also caused by a virus of the Flaviviridae family. The disease is transmitted to humans and monkeys by the bite of several different species of mosquitoes of the genus Aedes and other genera.

The most significant European yellow fever outbreak occurred in Lisbon during the autumn of 1857. During this period, 6000 deaths by yellow fever were reported in Lisbon. The outbreak came to an end at the start of winter, when it is belived that the cold weather made survival of the *Aedes aegypti* mosquito population unfavourable (Filipe 1993). Official records indicate that locally contracted cases have not been reported for several decades. Nevertheless, a single imported yellow fever case was hospitalised in Portugal during 1992–1999. (IGIF 2000).

Presently, neither *Aedes aegypti* nor *Aedes albopictus* are present in Portugal. However, another potential vector, *Aedes vittatus* is present in Portugal (Ribeiro et al. 1988). As no local cases of yellow fever have been reported in Portugal for several decades, it seems reasonable to assume that this local *Aedes* species is not infected with the virus.

Studies have shown that the survival of *Aedes* mosquitoes below 6°C and above 40°C declines rapidly (reviewed in Martens 1998a). Temperature threshold survival values for the yellow fever virus development inside the mosquito could not be obtained in the available literature. The former temperature range was thus used as an indicator of favourable disease transmission periods in the present study. Future climate scenarios (table 8.18 & 8.19) indicate increases in the number of days per year with mean daily temperatures within this favourable range.

In the abscence of the parasite, the current potential risk of contracting yellow fever is thus very low to none (scenario 1). Potential changes in disease transmission for the remaining scenarios are summarised in table 8.20.

8.3.6.1.4 West Nile fever

Since its initial isolation in Uganda in 1937, West Nile fever soon became recognised as the most widespread of the flaviviruses, with a geographic distribution that includes Africa, Asia, Europe, and recently North America. Bird-feeding mosquito species seem to be the principle vectors of the virus. Migratory birds are therefore instrumental in the introduction of the virus worldwide. Although the incidence of West Nile fever in Europe is largely unknown, recent disease outbreaks in France (Valenciano 2000), Italy, Romania and Poland have prompted concerns that the disease may be re-emerging in Europe (Hubalek & Halouzka 1999).

Four human clinical cases of West Nile fever were hospitalised in Portugal during 1992-1999. Three in the summer of 1995 and the other in July 1997 (IGIF 2000). Between 1967 and 1970, the presence of West Nile virus infections was detected in humans, cattle, sheep, horses, and wild birds (Filipe et al. 1990). On a global scale, the virus has been isolated from 43 mosquito species, predominately of the genus Culex.

Competent mosquito vectors present in Portugal include *Anopheles atroparvus, Aedes caspius, Culex modestus, Culex molestus, Culex theileri,* and *Culex univittatus* (Ribeiro et al. 1988). In 1996, the West Nile virus was isolated from an *Anopheles atroparvus* population around the Tagus estuary (LVT region). Mosquitoes from other parts of Portugal were not infected (Fernandes et al. 1998). Two decades prior to the latter study, mosquitoes in Aljustrel (southern Portugal) were found to be positive for the virus (Filipe 1972). Studies are currently being conducted to determine if the virus is still present in the mosquito populations or in suitable animal hosts (Almeida 2000).

Studies have shown that *Aedes spp.* and *Anopheles spp.* mosquitoes require temperatures between 6°-40°C and 10°-40°C respectively for adult survival (reviewed in Martens 1998a). These vector survival temperature ranges were thus used as indicators of favourable disease transmission periods in the present study, as temperature threshold values for West Nile virus developmental survival inside the mosquito could not be obtained in the available literature.

Tables 8.18 and 8.19 show that the current temperatures in Portugal are conducive to *Aedes* and *Anopheles* survival. Although suitable *Aedes* species have not been reported to be present in the last few decades, several suitable *Anopheles* species, notably An. *atroparvus,* currently enjoy an abundant and widespread distribution (Ribeiro et al. 1988). Moreover, the virus has been known to be present in vectors, animals and humans at selected locations. In view of these findings it is reasonable to conclude that the current risk (scenario 1) of contracting West Nile fever in Portugal is low.

Mosquito survival periods are likely to increase under future climate scenarios (tables 8.18 and 8.19). Higher parasite prevalence rates are thus possible as infected hosts extend their distrubution range and increase in numbers. Hence, the potential risk of contracting West Nile fever assuming such climatic changes (scenario 3 of table 8.5) might increase from low to a medium level.

8.3.6.2 Tick-borne diseases

Ticks are vectors of more kinds of micro-organisms than any other single arthropod, including mosquitoes. As some of these micro-organisms can cause pathological conditions in humans, the ability of ticks to transmit pathogenic organisms to humans is thus of great public health concern.

The infectious agent is transmitted to humans when ticks infected with the pathogen acquire a blood meal. Ticks require blood meals once per life cycle stage, as a larva, a nymph and an adult, between which they spend long developmental and host-seeking periods on the ground. Although transmission can occur during any of these life stages, the nymphal stage is regarded as the most significant stage for disease transmission in humans. This is because infection prevalence in nymphs is usually higher than in larvae, and nymphs are more abundant and smaller (less noticeable) than adults.

Tick-borne disease transmission dynamics is complex and in some cases not well understood. Factors that are known to affect the transmission include biological risk parameters as well as human and host (birds and mammals) activities. Biological parameters such as tick distribution, abundance, pathogen presence, and the pattern of seasonal activity are fundamental in the transmission of tick-borne infections. Climatic conditions such as temperature and precipitation patterns, as well as environmental management practices pertaining to land-use and water management can have significant influences in these biological risk factors (Filipe 1969). Human activities, such as farming, hunting, and various outdoor leisure pursuits are additional risk factors in disease transmission.

The Iberian Peninsula has climatic, botanical and faunal conditions that are favourable for tick fauna. Studies have indicated that there are 36 tick species in the Iberian Peninsula, 24 of which are known to occur in Portugal (Caeiro 1999). Of the latter, 10 tick species are known to be capable vectors of agents that cause diseases in humans (Dias 1994). Lyme disease and Mediterranean spotted fever are currently the tick-borne infections that cause greatest public health concerns in Portugal (Filipe 2000).

8.3.6.2.1 Lyme disease

Lyme disease has emerged as the leading arthropod-borne disease in Europe. The disease is caused by a spirochete (bacterium) named initially *Borrelia burgdorferi*. In Europe, the European sheep tick (*Ixodes ricinus*) is the principle vector involved in Lyme disease transmission (EUCALB 2000).

In Portugal, the first clinical case of Lyme disease was reported in 1989 (de Morais et al. 1989), disease presence was however suspected years prior to this case (Filipe et al. 1990). Subsequent serological studies confirmed the prevalence of antibodies for *Borrelia burgdorferi* in the human population. In a study done in the Alentejo region, 9.7% of the population tested sero-positive for the antibodies against *Borrelia burgdorferi* (Núncio, et al. 1992). In the same region, 14 cases of Lyme disease were hospitalised during 1988-1991 (de Morais et al. 1992). Official records indicate that during 1994-1999 an average of 20 cases per year were hospitalised in continental Portugal (IGIF 2000). The disease was declared as compulsory notifiable in 1999.

The disease affects the skin, nervous and musculoskeletal systems and rarely the heart. It has a good recovery rate and low lethality. A few weeks following infection, a characteristic skin rash, erythema migrans, appears near the bite in most patients. Not all individuals exposed to the bacteria develop the disease (O'Connell 1995).

During the last decade several strains of *B. burgdorferi* have been isolated, not all of which are pathogenic to humans. Recent studies have identified *B. lusitaniae, B. garinii, B. valaisiana* and *B. afzelli* in ticks obtained from sylvatic habitats in Portugal (de Michelis et al. 2000; Baptista et al. 2000). However, the local human pathogenic strain has not been isolated as yet (Collares-Pereira & da Franca 2000).

I. ricinus ticks are present throughout continental Portugal (Caeiro 1999). In 1992 *Borrelia burgdorferi* was isolated from male *I. ricinus* collected in the Alentejo region (Núncio et al. 1993; de Michelis et al., 2000). *I. ricinus* have a wide host range, however, birds and small mammals seem to be commonly parasitised by larvae and nymphs whereas adult ticks tend to feed on larger animals such as sheep, and cattle (Caeiro 1999). Humans are incidental hosts for the tick at any life cycle stage (O'Connell 1995). People living or working in forest or rural areas are at higher risks of exposure to infected ticks (Núncio et al. 1992).

I. ricinus collected from sylvatic habitats were reported to have high (up to 75%) infection prevalence, but most infections are however of the non-pathogenic strain, B. *lusitaniae* (de Michelis et al. 2000, Baptista et al. 2000). To date, ticks infected with human pathogenic strains such as *B. garinii* and *B. afezlli* have only been observed in one of the natural parks. Overwintering birds from Northern Europe have been suggested as the reservoir hosts responsible for the focal introduction of the pathogenic strain in this natural park (Baptista et al. 2000). The present focal distribution of the pathogenic *Borrelia* strains leads one to conclude that current (scenario 1) potential risk of contracting Lyme disease in Portugal is low.

As mentioned, disease transmission to humans is dependent on tick distribution, tick abundance, and human exposure to the tick. Climate change can have a significant influence in some of these disease transmission factors. The most noticeable of which is probably the observation that disease transmission below 7°C is extremely rare (Sonenshine 1993) and that the tick requires temperatures of 15-30°C in order to advance into the next life-cycle stage (Caeiro 1992). A temperature range of 7-30°C thus favours disease transmission. As tick distribution is more influenced by suitable host availability, land-use and agricultural practices than by climatic conditions alone (Filipe 1969 and Mawby & Lovett 1998), it is not possible to determine if the present tick distribution will change using only climate change scenarios. On the other hand, the well-documented seasonal changes in tick activity patterns are an excellent example of how tick abundance is influenced by climatic conditions (Caeiro 1992).

I. ricinus ticks are found throughout Portugal, but with less abundance in the drier and warmer southern regions of Portugal. In contrast to Northern Europe, the tick is found throughout the year in the Iberian Peninsula, being more abundant during the cooler months (Caeiro 1999). This is to be expected, as this tick is sensitive to prolonged heat and low soil moisture. Climate change scenario data appearing in tables 8.21 and 8.22 indicate that climatic conditions will become less favourable for disease transmission in Southern Portugal, but more favourable in the Central and Northern regions. Keeping in mind that the human population in the southern regions is much smaller than that of the rest of the country, and that no pathogenic strains have been isolated in ticks in Southern Portugal, it is reasonable to conclude that the national prevalence rate of Lyme disease is not likely to decrease given future climatic conditions (scenario 3). In fact, it is anticipated that disease risk may potentially change to a medium level as focally

Table 8.21 – Vector-borne disease (except mosquito-borne disease) transmission favourable periods based on PROMES mean daily temperature results

Region in Portugal/Climate Scenario*	Percent days per year within favourable temperature range for parasite survival	Percent days per year within favourable temperature range for vector survival		Percent days per year within favourable temperature range for vector activity	
	Schistosoma (15-39°C)#	*Phlebotomus papatasi* (10-40°C)#	*Phlebotomus ariasi* (5-30°C)#	*Phlebotomus perniciosus* (15-28°C)#	*Ixodes ricinus* (7-30°C)#
Northern					
– 1xCO_2	34	60	91	34	81
– 2xCO_2	48	79	96	41	92
Central					
– 1xCO_2	41	71	95	39	89
– 2xCO^2	58	90	94	47	92
LVT					
– 1xCO_2	51	89	99	47	97
– 2xCO_2	71	99	92	58	92
Alentejo					
– 1xCO_2	51	84	98	47	95
– 2xCO_2	68	97	90	52	90
Algarve					
– 1xCO_2	56	92	98	51	97
– 2xCO_2	77	99	89	60	89

* 1xCO_2 is representative of the current (baseline) climate scenario, where as 2xCO_2 is representative of a future climate scenario.
# Temperature range used as favourable.

Table 8.22 – Vector-borne disease (except mosquito-borne disease) transmission favourable periods based on HadRM2 mean daily temperature results

Region in Portugal/Climate Scenario*	Percent days per year within favourable temperature range for parasite survival	Percent days per year within favourable temperature range for vector survival		Percent days per year within favourable temperature range for vector activity	
	Schistosoma (15-39°C)#	*Phlebotomus papatasi* (10-40°C)#	*Phlebotomus ariasi* (5-30°C)#	*Phlebotomus perniciosus* (15-28°C)#	*Ixodes ricinus* (7-30°C)#
Northern					
– $1xCO_2$	26	55	90	26	79
– $2xCO_2$	55	87	92	43	90
Central					
– $1xCO_2$	35	69	95	34	89
– $2xCO^2$	66	94	89	50	88
LVT					
– $1xCO_2$	46	87	99	45	97
– $2xCO_2$	84	99	91	69	91
Alentejo					
– $1xCO_2$	48	83	98	45	94
– $2xCO_2$	82	98	82	57	81
Algarve					
– $1xCO_2$	46	85	99	45	97
– $2xCO_2$	83	99	89	65	89

* $1xCO_2$ is representative of the current (baseline) climate scenario, where as $2xCO_2$ is representative of a future climate scenario.
\# Temperature range used as favourable.

infected ticks and hosts widen their geographical distribution. Table 8.23 suggests that focal introduction of additional human pathogenic infected ticks are not likely to change the potential disease risk levels for current (scenario 2) and future climate conditions (scenario 4).

8.3.6.2.2 Mediterranean spotted fever

Mediterranean spotted fever (MSF), commonly referred to as "tick bite fever" or "Boutenneuse fever", is probably the most important human tick-borne disease in Portugal. Clinical signs of the infection appear 5-7 days following the tick bite. These include chills, fever, lymphadenitis, and persistent headaches. A distinctive small ulcer with a dark brown, centre, the primary eschar (*tache noire*) frequently appears, near the tick bite. Untreated cases usually recover (Sonenshine, 1993). Individuals that are most vulnerable to the disease include the immuno compromised, the aged, and sufferers of diabetes mellitus, cardiac diseases, chronic alcoholism, and glucose-6 phosphate dehydrogenase deficiency (Walker & Fishbein 1991).

Disease is transmitted to humans by the bite of the brown dog tick (*Rhipicephalus sanguineus*) infected with a rickettsia (pathogen) called *R. conorii*. This tick is by far the most abundant tick species in Portugal, found countrywide in both rural and urban settings. In rural settings the tick is associated with farm and wild animals, whereas in urban settings it is associated with domestic dogs. In contrast with other tick-borne diseases, human exposure to ticks infected with *R. conorii* is not limited to outdoor activities. *R. sanguineus* has a remarkable capacity to adjust to most environmental conditions, completing 2-3 life cycles per year. Studies in Portugal and Spain have show that *R. sanguineus* is not the only tick capable of carrying rickettsiae (Bacellar 1999 & Oteo et al. 1996). Future investigation is however needed to ascertain the public health relevance of these findings.

Portugal has a high prevalence rate of MSF, with official health statistics indicating 800 –1,000 cases per

Table 8.23 – Potential risks of vector-borne diseases in Portugal (excluding mosquito-borne diseases)

Disease	Scenario *	Suitable Vector	Parasite	Risk level #
Lyme Disease	1	Widespread distribution	Low prevalence, focally distributed	Low
	2	Focal distribution (new vector)	Low → high prevalence, focally distributed	Low
	3	Widespread distribution	Low prevalence, focal distribution → High prevalence, regional distribution.	Medium
	4	Focal → potentially regional distribution (new vector)	High prevalence, focal distribution → High prevalence, regional distribution.	Medium
TBE	1	Widespread distribution	None present	None
	2	Widespread distribution	Low prevalence, focally distributed	Low
	3	Widespread distribution	None present	None
	4	Widespread distribution	Low prevalence, focally distributed	Low
Mediterranean spotted fever	1	Widespread distribution	High prevalence, Widespread distribution	High
	2	Widespread distribution	High prevalence, Widespread distribution	High
	3	Widespread distribution	High prevalence, Widespread distribution	High
	4	Widespread distribution	High prevalence, Widespread distribution	High
Leishmaniasis	1	Widespread distribution	High prevalence, regional distribution → Low prevalence, widespread distribution.	Medium
	2	Widespread distribution	High prevalence, regional distribution → Low prevalence, widespread distribution.	Medium
	3	Widespread distribution	High prevalence, Widespread distribution	High
	4	Widespread distribution	High prevalence, Widespread distribution	High
Schistosomiasis	1 2	Widespread distribution Focal distribution (new vector)	Imported cases only Low → high prevalence, focally distributed	Very low Low
	3	Widespread distribution	Imported cases only	Very low
	4	Focal → potentially regional distribution (new vector)	High prevalence, focal distribution → High prevalence, regional distribution.	Medium

** listed in table 8.5*
 # described in table 8.6

annum. The incidence rate for 1998 was 7.21 per 10,000 individuals. The actual disease prevalence is, however, anticipated to be much higher due to under reporting, self-treatment, and undiagnosed cases. Official health statistics reveal that the Alentejo region is the area with the highest incidence rates, followed by the Central region, the Algarve, the Northern region and lastly the LVT region. The young (1-14 years) and the aged (+65 years) are the population groups reporting most disease cases. Cases are reported throughout the year, but maximum amount of cases are reported during July, August, and September (DGS 1999). Serological studies have indicated that in Southern Portugal 7.6% of the human population tested positive to antibodies of *R. conorii* (Bacellar et al. 1991). In a separate study in the same region, 85.5% of stray dogs were serological positive (Bacellar et al. 1995).

Summer is the period of maximum activity of *R. sanguineus* (Caeiro 1992). Disease transmission is thus favoured during the warmer months. Predicting changes in disease transmission is very difficult as there is no simple statistical correlation between temperature and incidence of disease. An assessment of the factors known to affect tick-borne disease transmission, such as tick distribution and abundance provides useful insight to this end. As *R. sanguineus* has a remarkable ability to adapt to its environment, its distribution is not likely to change solely due to climatic changes. *R. conorii* infected *R. sanguineus* already have an abundant and widespread distribution consequently, current (scenario 1) potential risk of contracting MSF in Portugal is high. The potential risk level is not expected to decrease for the remaining three scenarios investigated in the study (table 8.23).

8.3.6.2.3 Tick-borne encephalitis

Tick-borne Encephalitis (TBE) is a viral infection of the central nervous system, which often results in fatalities. *Ixodes persuleatus* and *Ixodes ricinus* are the ticks involved in Tick-borne Encephalitis (TBE) in Europe. The latter tick is present throughout Portugal, but are not known to be infected with the TBE virus at present, consequently, there are no reported cases of locally transmitted TBE in Portugal (Filipe 2000). During 1992-1999 no TBE cases (imported or local) were hospitalised (IGIF 2000). The potential risk of contracting TBE in Portugal is thus non-existing at present (scenario 1).

TBE viral survival seems to be influenced not only by the tick's geographical range but also by climatic conditions, preferring continental climatic conditions to oceanic or tropical climatic conditions (Randolph et al. 2000). This is probably why TBE is not currently endemic in Portugal. Predictive statistical modelling study results do not indicate that Portugal will be threatened by the TBE virus under future climate change scenarios (Randolph & Rogers 2000).

8.3.6.2.4 Other tick-borne diseases

During the last decade, serological surveys have revealed at least three individuals in Portugal that had antibodies for the Crimean-Congo hemorrhagic fever (CGHF) virus. The CGHF virus is transmitted by the bite of the tick *Hyalomma marginatum* (Filipe 1993). This tick is present throughout Portugal, being most active during the warmer months of the year (Caeiro 1999).

In the winter of 1991, the first and only case of local human ehrlichiosis was reported in the Alentejo region of Portugal. Serological examination confirmed that the individual was serum-positive for *Ehrlichia chaffeensis*. The fact that this case was reported in the middle of winter is interesting. Attempts to determine which tick was the possible vector were inconclusive (de Morais et al. 1992).

8.3.6.3 Leishmaniasis

Leishmaniasis is a disease caused by protozoa of the genus *Leishmania*. The disease occurs mostly in two clinical forms, cutaneous and visceral leishmaniasis. It is prevalent in tropical, sub-tropical and Mediterranean regions, affecting some 12 million people world-wide. The parasites are transmitted from animal reservoirs to humans by the bite of female sandflies.

Visceral leishmaniasis (VL), also known as Kala-azar, is currently endemic in Portugal.

Clinical symptoms vary between individuals and geographic region. In countries bordering the Mediterranean basin, the most common symptoms include high fever, chills, fatigue, abdominal pain and diarrhoea. Anaemia and enlargement of spleen and liver are typical clinical manifestations. If untreated VL has high fatality rates. The disease is often complicated by serious secondary bacterial infections such as pneumonia and pulmonary tuberculosis. Clinical manifestations of the disease vary from a few weeks to several years after a person becomes infected. Children and the immuno-compromised are most vulnerable to VL. The number of VL cases among patients with human immuno-deficiency virus (HIV) infection has increased rapidly in recent years. *Leishmania*/HIV co-infection is currently considered to be a real "emerging disease" in southern Europe, with intravenous drug users being the population group most at risk (WHO 1999f).

There are three well-known VL foci: the Alto Douro zone in the Northern region, the Algarve region, and the Lisbon Metropolitan area in the LVT (Pires 2000). It has been a notifiable disease for several decades. This database indicates a steady decline in reported cases, from an average of 53 cases per year in the 1970's to 16 cases per year during the last five years. However, the actual disease incidence rate is believed to be much higher due to underreporting (Vicente 1990). The majority of notified cases are of children, although there has been a steady increase in cases from the 25-35 years group during the last decade (DGS 1992; DGS 1999). The latter is anticipated to be due to the increasing number of cases of *Leishmania*/HIV co-infections (Romão et al. 1995).

Domestic dogs are the principal reservoir hosts of *Leishmania infantum,* the protozoa involved in VL transmission. Studies conducted in Portugal revealed that the *L. infantum* infection prevalence in domestic dogs to vary from 11.4% to 7% (Campino et al. 1995; Sampaio-Silva et al. 1993; Abranches et al. 1987) whereas the infection prevalence in sandflies is below 3% (Pires 2000).

Sandflies of the genus *Phlebotomus* are involved in leishmaniasis transmission in Europe. These are flies having 2-3 mm body lengths, are known to breed in warm, humid micro-climates and are typically found in rodent burrows, forest areas, and rotting organic matter. The female sandflies require blood for egg production (Killick-Kendrick 1999). Typically, they have blood meals every 6-8 days during their adult life. The adult female becomes infected with the parasite during blood meals from infected reservoir hosts. Eggs from infected females are not infected. The entire life cycle is typically about two months.

In Portugal, there are four *Phlebotomus* species that are competent *Leishmania* vectors. The most widespread and abundant is *Phlebotomus perniciosus.* This sandfly is a known vector for *L. infantum,* and parasite-infected sandflies have been reported throughout Portugal. It is without doubt the most important vector in the transmission of VL in Portugal. *Phlebotomus ariasi,* another competent vector for *L. infantum,* is the second most abundant *Phlebotomus* in Portugal. Although this species also enjoys a widespread distribution, it is more abundant in the cooler and more humid regions in Northern Portugal. The third most abundant sandfly is *Phlebotomus sergenti,* a vector of *L. tropica* and thus important in the transmission of human cutaneous leishmaniasis. In Portugal, *Ph. sergenti* is currently known to be present in the Alentejo and Algarve regions. By far the least abundant *Phlebotomus* found in Portugal is *Phlebotomus papatasi,* this species has only been found in the Algarve. *Leishmania* infected *Ph. sergenti* and *Ph. papatasi* have not been captured in Portugal (Pires 2000).

Field studies in Portugal indicate that adult sandflies are found from May to November. These studies also show that the maximum activity periods of the flies to be at night when humidity is greatest (Pires 2000).

Distribution of *Phlebotomus* species is known to be highly dependent on environmental conditions. Laboratory studies show that adult sandflies are sensitive to high temperatures and low humidity. These studies indicate that *Ph. ariasi* are most sensitive to high temperatures while *Ph. papatasi* the most tolerant of high temperatures. Assuming humidity levels are not too low, survival of the former is best between 5-30°C (Rioux et al. 1985), while temperatures between 10-40°C ensure *Ph. papatasi* survival (Theodor 1936). It is thus no surprise that *Ph. ariasi* are found predominantly in the cooler and more humid northern regions of Portugal and *Ph. papatasi* in the warmer southern most regions. Laboratory studies have also shown that *Ph. perniciosus* develop relatively fast at 28°C and that development is stopped at 15°C (Tesh 1992). The maximum temperature tolerable for *Ph. perniciosus* survival is unclear.

Laboratory studies show that *L. infantum* development in the vector was achieved at all ambient temperatures suitable for vector survival, however, an optimum temperature for development was observed at 25°C (Rioux et al. 1985). These findings suggest that vector survival is more sensitive than parasite development to climate change. The former was thus used as an indicator for leishmaniasis transmission in the present study.

Unlike mosquitoes, sandflies do not need water pools for breeding, precipitation is thus not as important in the sandflies's life cycle as ambient temperature and humidity. Sandfiles adjust their behaviour to reduce their exposure to low humidity environments. For example, they are known to breed and inhabit microclimates (rodent burrows, wall cracks etc.) that are relatively high in humidity and adult flies are active at night when humidity is higher. These behaviours thus protect the flies from unfavourable ambient air humidity levels. Nevertheless, they remain very sensitive to ambient temperatures.

Current ambient temperature is conducive to *Phlebotomus* survival for several months. Field studies also show that parasitic prevalence is relatively high in reservoir hosts (dogs) in several regions in Portugal, resulting in a current (scenario 1 as per table 8.5) medium disease potential risk. Focal introductions of additional infected vectors (scenario 2) are not likely to change the disease potential risk level.

Tables 8.21 and 8.22 indicate that the number of days suitable for *Ph. ariasi* survival are likely to decrease in the future throughout Portugal except in the Northern region. Since this sandfly species is currently predominate in the Northern region, potential disease risk levels are not anticipated due to *Ph. ariasi* transmission dynamic changes. Data listed in these tables also indicate significant increases in days with favourable temperatures for *Ph. pernicious* activity for the whole of Portugal. If the latter is assumed as well as the fact that parasitic prevalence in Portugal remains high in both humans and reservoir hosts, it seems reasonable to conclude that the potential risk of contracting Leishmaniasis in Portugal may become high (scenario 3). Introduction of additional infected sandflies (scenario 4) is not anticipated to change the latter risk level.

8.3.6.4 Schistosomiasis

Schistosomiasis, also known as bilharziasis, is a disease caused by parasitic worms of the genus *Schistosoma.* Disease prevalence has increased worldwide owing to the expansion of irrigation systems in hot climates, enabling snail populations to survive and the parasite to find human carriers. The disease currently affects more than 200 million people and contributes to a million premature deaths each year (WHO 1998). Humans become infected with the parasite by dermal contact to free-swimming parasitic larvae (cercaria) in fresh water. Freshwater snails are the intermediate hosts in the schistosome life cycle.

Disease clinical manifestations are dependent on the schistosome species a person is infected with. Individuals infected with *S. haematobium* suffer from urinary and bladder signs and symptoms, of which haematuria (blood in urine) is the most frequent. *S. intercalatum, S. mansoni* and *S. japonicum* infections have two clinical distinct stages, initial clinical symptoms appear weeks after infection and typically include fever, nausea, headache, cough and diarrhoea. The chronic form of the disease manifests several years after infection, the most noticeable symptoms are the granulomatous reactions and fibrosis in the intestines, spleen and liver.

In Portugal, endemic *S. haematobium* infections were known to occur in the Algarve region until half a century ago (Grácio 1981). Currently, local disease transmission has not been documented, however, during 1999-2000, a total of 58 imported Schistomiasis cases were diagnosed from a single laboratory (Grácio 2001). During 1992-1999 an average of 35 imported schistosomiasis cases per year were hospitalised in Portugal (IGIF 2000). The majority of these infections were by *S. haematobium* and *S. intercalatum* and acquired while individuals were in African countries (Correia 2000; Grácio 2001).

Each schistosome species is dependent on specific intermediate snail host species. Generally, *S. mansoni* uses snails of the *Biomphalaria* genus as intermediate hosts, *S. japonicum* those of the genus Oncomelania where as *S. haematobium* and *S. intercalatum* those of the *Bulinus* genus (WHO 1998, Grácio 1998). It is interesting to note that field studies conducted in Portugal showed that the freshwater snail *Planorbarius metidjensis* and not *Bulinus* water snails were responsible for the disease transmission in the past (Azevedo et al. 1948). Although *Bulinus* snails are frequently found throughout Portugal, schistosome infected ones were never captured. More recent field studies indicated that while *P. metidjensis* and various *Bulinus* species are indeed widespread in Portugal, neither snail species was infected with Schistosoma species (Grácio 1981).

Laboratory investigations revealed that *P. metidjensis* captured in the Algarve could become infected with *S. haematobium* from Guinea-Bissau. Attempts to infect the same snail species with other schistosome species failed (Azevedo et al. 1954). Additional laboratory studies conducted on *Bulinus contortus* captured in Algarve and Coimbra (Central region) showed that this snail could also become infected with *S. haematobium* from Guinea-Bissau, Angola, and

Mozambique (Xavier et al. 1972). Infections with *S. haematobium* from Guinea-Bissau were also successful in *Bulinus truncatus* snails captured in Coimbra (Azevedo & Xavier 1965). All four Schistosoma species have similar life cycles.

Schistosomiasis transmission to humans is a complex system influenced by the co-presence of the appropriate snail and schistosome species as well as humans in the same aquatic environment. In addition, transmission is also influenced by environmental factors that influence snail and schistosome survival rates and activity. Water availability and temperature being the most important. Without water, snail and parasite death is certain, and thus disease transmission ends. Studies on the relationship between disease transmission and water temperature indicate that below 15°C, parasite development inside the snail is inhibited, while above 39°C snail and parasite death occur. As snails and schistosoma larvae are mobile, they are able to react to extreme temperatures by moving to less hostile conditions within their aquatic medium. Nevertheless, water temperatures between 15-39°C are thus required for schistosomiasis transmission (reviewed in Martens 1998a).

Assuming ambient air temperatures as approximations of shallow water temperatures, it is clear from tables 8.21 and 8.22 that current ambient temperature in Portugal is conducive to schistosomiasis transmission. The same tables also indicate that future temperatures will become more favourable for transmission. However, as competent vectors in Portugal have not been reported to be infected during the past decade (Correia 2000; Grácio 2001), current (scenario 1) and future (scenario 3) potential risks of contracting schistosomiasis are very low.

Worldwide, human activities have been known to introduce fresh water snails to water bodies that do not form part of the same drainage basin (Brown et al. 1998). Focal introduction of snails infected with Schistosoma species in Portugal is thus a possibility. Moreover, focal introduction of the parasite from infected imported human cases to the currently non-infected snail population is also a potential risk. If a focal parasite infected snail population was to occur, and current climatic conditions are assumed (scenario 2), the potential risk of schistosomiasis would be low due to focal infected snail distribution. However, if a warmer climate scenario is assumed (scenario 4), the infected vector population is anticipated to widen its geographic distribution and thus increase the potential disease risk to a medium level. In addition, regions such as the Alentejo and Algarve where water shortages may be aggravated by warmer climates, authorities may opt to change irrigation systems (i.e the Alqueva dam Project), and in doing so potentially increase the host snail population distribution and survival rates in these regions (Grácio et al. 1994).

8.3.7 RODENT-BORNE DISEASES

Rodent-borne diseases are zoonoses that are transmitted directly to humans by contact with rodent biofluids and faeces. These diseases do not always involve an arthropod (cold-blooded) host and are therefore less directly affected by temperature. Transmission of these diseases to humans is influenced by human and rodent activities. Local rodent population density and behaviour heavily influences human exposure to infected rodents. Local food availability as well as environmental conditions such as unusually high rainfall and drought events affects rodent survival, and hence rodent population density.

Although, regional climatic changes could affect the rodent population dynamics significantly, determination of the potential effects of climate change on infectious agents transmitted by rodents to humans are more uncertain and have received less attention than have vector-borne diseases (Gubler et al. 2001).

Rodent-borne diseases known to be currently prevalent in Portugal include leptospirosis and hemorrhagic fever with renal syndrome. Potential changes in disease transmission of the former disease due to climate change in Portugal is assessed below.

8.3.7.1 Leptospirosis

Leptospirosis is a zoonotic disease with world-wide prevalence caused by the bacteria of the genus *Leptospira.* It has a wide clinical spectrum, ranging from mild influenza-like symptoms to severe renal and respiratory malfunctions that may lead to death in some cases. On the other hand, some infected individuals have no symptoms at all (CDC 1999).

The disease is transmitted to humans by oral or dermal contact with water, dust (soil), and foods contaminated with urine and other biofluids from infected animal hosts. Rodents, dogs, pigs, and cattle are the animal hosts often infected with the bacteria. It is a rural, occupational, and recreational hazard world-wide (CDC 1999). Disease outbreaks often occur after heavy rainfall episodes as surface and drinking water become contaminated with animal urine and waste (Ko et al. 1999; Gubler et al. 2001).

Official records indicate that during the period of 1994-1998, 273 cases of leptospirosis were reported in Portugal. Although the disease has been an obligatory notifiable disease in Portugal since 1986, the true prevalence rate is believed to be underdiagnosed (Collares-Pereira et al. 1989; Falcão et al. 1999). Statistical records indicate a significant increase in the number of reported cases and deaths since 1997 (DGS 1999).

Disease prevalence is highest in rural populations (Collares-Pereira et al. 1989). Field studies have indicated rats and to a lesser extent cattle to be the animal hosts responsible for most infection transmissions to humans (Collares-Pereira et al. 1996; Vieira et al. 1999). Over 20% of rodents captured in rural and urban settings in continental Portugal were reported to be seropositive for Leptospira interrogans senso lato (Collares-Pereira et al. 1996; Collares-Pereira et al. 2000).

Climate change model results forecast increased flood risks for Portugal, especially in the central and northern regions (see chapter 5) where leptospirosis is currently a problem. Consequently, climate change may increase the potential risk of leptospirosis transmission in Portugal.

8.4 ADAPTATION MEASURES

Adaptation measures are society's responses to diminish anticipated climate change adverse impacts. Thus, within the context of the health sector, the primary objective of the adaptations interventions discussed here is to reduce population vulnerability to certain health outcomes.

Interventions can be either autonomous or planned. Autonomous (spontaneous) adaptation refers to the changes that human systems undergo in response to changing surroundings, irrespective of any policy, plan or decisions (Kovats et al. 2000b). These include biological (passive) and behavioural adaptation measures that take place at the individual level. Examples of biological adaptation include the manner by which individuals may become physiologically adapted to change in ambient temperature or when immunity levels rise in response to increased exposure to an infectious agent. Behavioural adaptation measures include actions individuals take to reduce their risk of exposure to a health hazard such as avoidance of excessive heat (McMichael & Kovats 2000b).

Planned adaptation is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to or maintain a desired state (Kovats et al. 2000b). Autonomous adaptations are in response to a changed state whereas planned adaptations are generally prospective anticipatory in nature. The latter is evidently preferable.

8.4.1 Approach Used to Develop Adaptation Measures

Adaptation measures to reduce human health impacts of climate change can be thought of in terms of the classical categorisation of preventive measures in public health (McMichael & Kovats 2000b):

- Primary prevention measures which are actions taken to prevent/reduce human exposure to hazards. Examples include improved housing and availability of potable water and sanitation drainage;

- Secondary prevention measures are actions taken to detect early evidences of changes in health risk or health status, and then taking specific targeted action. An example of such an adaptive measure would be the introduction of environmental controls in response to observed (monitored) increase in specific vector-borne disease incidence rate or vector abundance; and

- Tertiary prevention measures that are health-care actions taken to lessen the morbidity or mortality caused by newly encountered diseases (e.g. improved disaster response capacity, improved diagnosis and treatment of cases of heatstroke, malaria, etc.).

Secondary and tertiary prevention measures are both, in general, less effective than primary prevention measures. Furthermore, in the long term they are both usually more expensive than primary prevention measures (Kovats et al. 2000b).

Primary and secondary preventative adaptation measures for potential climate change health impacts are discussed below. Success of these measures will depend on factors such as:

- Political will
- Financial resources
- Public acceptance
- Technical knowledge
- Capacity of the health care system and public health infrastructures
- Intersectoral and cross-sectoral collaboration.

In this study, a conscious effort was made to focus on "no-regrets" adaptation measures. These are measures that will be beneficial to society even if anticipated climate change health impacts prove inaccurate.

During the course of this study insufficient monitoring and surveillance data was a constant problem. As unforeseen climate change impacts on health are possible, improvements to surveillance and monitoring systems will be highly valuable. Table 8.24 summarises suggested improvements for selected monitoring and surveillance programmes that may reduce this problem in the future. Improvements to monitoring and surveillance systems are essential climate change adaptation measures (Haines & McMichael, 1997).

8.4.2 ADAPTATION MEASURES FOR HEAT-RELATED DEATHS

Observed data indicate that excess deaths occur following days with high ambient temperature. Since the frequency and intensity of heatwaves are

Table 8.24 – Suggested monitoring and surveillance improvements

Health impact requiring data	Suggested improvements to monitoring/surveillance
Heat-related deaths	•Improve accessibility to daily mortality data and improve monitoring of relevant morbidity data •Improve monitoring of urban violence reporting •Improve accessibility to monitored daily climate variables
Air pollution-related health outcomes	•Establish national database with daily asthma and allergic rhinitis hospital admissions and emergency room visits. This database should be easily accessibly to researchers (not just medical doctors) •Improve accessibility to monitored daily mortality data •Extend current air pollution monitoring programme to be more nationally representative. This is essential for long-range pollutants such as ozone.
Flood and drought-related health outcomes	•Improve accessibility of daily mortality data and improve monitoring of relevant morbidity data •Improve accessibility to flood and drought-relief financial aid data •Improve agriculture yields, pest, and disease surveillance
Water and food-borne diseases	•Improve drinking water monitoring and treatment systems for key pathogens •Improve wastewater management to facilitate monitoring •Improve food-borne disease monitoring to facilitate pathogen identification and original contamination source •Improve accessibility to monitored data •Improve disease surveillance to reduce the number of undetected and/or unreported cases
Vector and rodent-borne diseases	•Establish an integrated national surveillance programme for estimation of vector, rodent, and intermediate host populations •Determination of pathogen prevalence in these population is essential •Improve disease surveillance to reduce the number of undetected and/or unreported cases

anticipated to increase significantly during the next decades, adaptation measures that may reduce the number of individuals vulnerable to heat-related deaths as well as heat-related illnesses are presented here.

Autonomous (physiological acclimatisation) adaptation is anticipated to reduce some of the impacts of future increases in the frequency or intensity of heatwaves. Acclimatisation to hotter environments may be in two forms; "instant" acclimatisation that may occur following a few days of higher temperatures, while "complete" acclimatisation to higher temperatures that will require several years to occur. Examples of both acclimatisation forms are evident at the population level. Studies have demonstrated that the impact of the first heatwave on mortality is often greater than the impact of subsequent heatwaves within a single season. Populations from areas with tropical weather are less sensitive to higher temperatures than populations from colder climates (McMichael & Kovats 2000b). However, as all individuals in the community will not achieve autonomous adaptation, planned adaptations are required.

Planned adaptation measures are crucial for vulnerable population groups such as the aged, individuals with pre-existing cardiovascular conditions, and inner city inhabitants. Several adaptation measures to reduce heat-related illnesses and deaths have been proposed (McMichael & Kovats 2000b). Adaptation measures that may prove beneficial include:

- Public education programmes to avoid heat and replace fluid loss during heatwaves;
- Establishment of nation-wide weather watch and warning systems to alert the public of anticipated dangerous hot days. For maximum efficacy, such systems should work in conjunction with public education programmes so that the general public will know what preventative measures to take during these weather conditions;
- Sensitise health personnel to detect and treat heat stress, specially personnel from urban and peri-urban health units;
- Appropriate urban planning to diminish the "heat island" effect in cities. The following includes:
    - Include design features that reduce heat load, and
    - Planting trees in urban zones.
- Sensitise architects and civil engineers so that future projects will have design features that reduce heat load and have improved ventilation features; and
- Usage of air-cooling devices such as fans and air conditioners in buildings that are already built and are susceptible to high indoor air temperatures. Implementation of this adaptation measure must be carefully considered, as this is likely to be an energy demanding practice that may increase greenhouse gas emissions. In addition, it has the potential to increase risks of adverse health outcomes, such as Legionnaires' disease.

8.4.3 ADAPTATION MEASURES FOR AIR POLLUTION-RELATED HEALTH IMPACTS

Data from current air quality monitoring programmes frequently report air pollution levels that may be hazardous to public health. If the climate becomes warmer and more variable, air quality is likely to be affected. Pollutant levels that may increase due to climatic changes include tropospheric ozone and aeroallergens such as pollen. Higher ambient air levels of these pollutants may exacerbate asthma and other respiratory diseases, which currently cause significant public health concerns.

Adaptation measures that may reduce population vulnerability to potential air pollution-related health outcomes include:

- Establishment of *nation-wide air* quality monitoring and warning systems to alert the public of high pollutant levels;
- Development of programmes to provide people with information on local air pollution levels, their potential health effects, and suggested means to reduce exposure;
- Reduction of local air pollution emissions;
- Establishment of a national electronic asthma and allergic rhinitis database at hospital emergency rooms;

- Reinforcing weed-control initiatives in order to minimise exposure to grass pollen;

- Educating town planners, landscapers, and the general public as to which plants produce pollen that may result in adverse health effects in sensitive populations, so as to reduce the number of such plants in landscaped environments; and

- Encouraging community programmes aimed at reducing the risks of forest and vegetation fires.

8.4.4 ADAPTATION MEASURES FOR FLOOD AND DROUGHT-RELATED HEALTH IMPACTS

Flood and drought are reoccurring events, resulting in significant economic and health outcomes. Climate change scenarios point to an increase in the frequency and intensity of both events. Adaptation measures that have proved useful around the world at reducing population vulnerability to these events include (Kovats et al. 2000b):

- Ensure that disaster preparedness and mitigation initiatives are in place and are updated regularly. The following measures are relavant:
  - Establish early warning systems;
  - Ensure that drainage systems and solid waste management practices are adequate and properly maintained to allow for rapid floodwater drainage;
  - Adopt and enforce land-use planning and construction design approaches to minimise erosion, flash-flooding, and restoration of wetlands;
  - Prohibit construction of houses and buildings on flood risk zones; and
  - Regulatory measures to ensure irrigation efficiency;

- Ensure that efficient disaster response and recovery programmes are in place;

- Traditional methods used for coping with floods and drought should be carefully evaluated to ensure that mistakes are not repeated;

- Critical assessment of agricultural practices to ensure that vulnerability to flood and drought risks are minimised and that they are environmentally sustainable practices;

- Encourage community programmes aimed at reducing the risks of forest and vegetation fires; and

- Improve infectious disease monitoring and surveillance systems.

8.4.5 ADAPTATION MEASURES FOR WATER AND FOOD-BORNE DISEASES

Current water quality and food-borne disease outbreaks pose significant public health concerns. Anticipated climatic changes have the potential to increase these concerns. Implementation of adaptation measures listed below may reduce current as well as potential climate change water and food-borne disease risks.

- Improvements in the efficacy of basic public infrastructures (nation-wide) such as:
  - Water treatment facilities;
  - Sewage and sanitation systems; and
  - Waste removal and treatment systems.

- Integrated policies to protect all water resources;

- Improvements in monitoring and surveillance programmes for key water and food-borne diseases. Rapid identification of pathogen type and original contamination source should be encouraged. Results from these programmes may be used as early warning systems;

- Establishment of alternative safe potable water distribution to the public when treated water does not meet drinking water requirements;

- Enforcement of pollution reduction and pollution control policies;

- Inform the general public of local water quality and food-borne outbreaks at regular intervals;

- Public education on safe food preparation and storage practices as well as on health hazards associated with consumption of biotoxins in seafoods;
- Introduction of extra label and handling guides for selected foods such as seafood, pre-baked foods, and fresh produce such as watercress and berries; and
- Increase enforcement efforts to ensure compliance with food safety regulations during all food production and preparation processes.

8.4.6 ADAPTATION MEASURES FOR VECTOR AND RODENT-BORNE DISEASES

Diseases transmitted by rodents and vectors such as mosquitoes, ticks, sandflies, and water snails are frequently reported. Projected climatic changes indicate that conditions for rodent, vector, and parasite survival may become more favourable. Potential increases in disease transmission risks are thus possible.

Primary and secondary adaptation measures effective at reducing population vulnerability have been documented (Kovats et al. 2000b). Planned adaptation measures that may be relevant for Portugal include:

- Ensuring that public health infrastructures do not deteriorate;
- Improvements to current vector and disease surveillance and monitoring system including:
  - The establishment of a national surveillance programme for vector populations or other intermediate hosts; and
  - The creation of an online database to which medical doctors can report any vector or rodent associated condition. The primary objective of this database should be to monitor changing risks as they are happening so that preventative and control measures can be promptly applied.
- Public education incentives to encourage elimination of artificial breeding sites and other vector and rodent control measures;
- Sensitise health care givers in geographically vulnerable regions;
- Improve rodent, vector and reservoir host population control measures, in an attempt to eliminate those that are infected with parasites harmful to humans;
- Anticipate effects of irrigation projects and other land-use and agricultural changes on vector breeding sites and rodent population size; and
- Promote the use of window screens, insect repellents and protective clothing in disease endemic locations.

8.5. RESEARCH GAPS

The lack of research on many questions related to human health and climate (and other environmental hazards) was a major setback during the current assessment. It is evident that future research is thus required in order to reduce uncertainties associated with potential climate change health impacts in Portugal. Research areas requiring urgent attention include:

- Assessment of climate change potential health impacts associated with international travel and trade,
- Assessment of potential health impacts due to sea level rise,
- Assessment of health impacts associated with food shortages due to climate variablity,
- Assessment of health impacts due to stratospheric ozone depletion,
- Assessment of potential health impacts associated with climate change adaptation meaures suggested by other SIAM groups,
- Assessment of direct health effects of extreme weather events,
- Assessment of underlying factors that contribute to cold-related morbidity and mortality,
- Distinguish more clearly between the effects on health of climate and of air pollution,

- Assessment of the role of climate on infection disease transmission. There is a need for basic laboratory and field investigations of vector (and rodent) ecology and pathogen infectivity under different climatic conditions and regions,
- Assessment of long-term human and marine animal health effects of marine algal biotoxin bioaccumulation in seafoods, and
- Assessment of remote sensed satellite data as to its efficacy to determine infectious disease risks in Portugal.

8.6 CONCLUSIONS

In this chapter, potential adverse health impacts of projected climatic changes in Portugal were assessed and adaptation measures to avoid/reduce these impacts were suggested. This study also offers a review of the literature on; health issues influenced by global climate change, recent global initiatives on climate change and human health assessment, and methods that are currently available to study climate change impacts on human health.

During the past three decades socio-economic improvements have resulted in significant improvements in the overall health and life expectancy years of the Portuguese. In 1998, Portugal had a population of about 9.5 million, of which 15.2% were 65 years or older and 16.8% younger than 15 years. Since life expectancy is expected to increase during the next decades, significant increases in the proportion of individuals above 65 years are expected. Legally residing immigrants make up about 2% of the total population in Portugal.

Currently, chronic diseases are the major causes of death. Infectious diseases account for only 2% of deaths. Leading causes of deaths include cancer and disorders related to the circulatory and respiratory systems. Childhood public health concerns include accidents, asthma and acute gastrointestinal and respiratory infections.

Despite significant improvements in recent years, progress towards identifying and reducing environmental health hazards has been slow in Portugal. Universal accessibility to basic public health infrastructures such as water, sanitation, and electricity has not been achieved. Moreover, poor water and air quality pose significant environmental health risks in Portugal. Portuguese population sub-groups that are currently most vulnerable to environmental health risks include the poor, the elderly, the very young, the immunocompromised, immigrant populations, and rural communities who lack basic infrastructures.

Currently, there are few published studies showing changes in the Portuguese population health status in response to the observed climatic changes. This makes identification of potential future health impacts of climate change difficult. Nevertheless, several health impacts were identified that may be adversely affected due to climate change. The present study focused on the following health categories:

- Heat-related mortality
- Air-pollution-related health effects
- Health effects associated with floods and drought
- Water and food-borne diseases
- Vector and rodent-borne diseases.

Health impacts due to stratospheric ozone depletion, sea levels rise, food shortages, and international travel were not assessed in the present study.

Key findings of each health category are summarised in table 8.25. Insufficient health and environmental data in Portugal and the significant number of knowledge gaps on the relationship between health and climate has resulted in many uncertainties being incorporated in the assessment. Consequently, no definite conclusions could be reached on the magnitude of change on potential climate change health impacts in Portugal.

Table 8.25 – Summary of key assessment findings

Potential health impact	Population most vulnerable	Weather factor of interest	Direction of possible change	Example of adaptation measure suggested
Heat-related mortality	- The elderly - People with cardiovascular conditions - The poor - Urban residents	- Extreme heat periods	↑	- Early warning system - Urban planning - Air conditioning
Air pollution-related health effects	- The young - The elderly - People with respiratory conditions	- Temperature - Windspeed	↑	- Pollution control - Warning system
Health effects associated with floods & drought	- Individuals in low-lying and erosion–prone regions - The young - The elderly - The poor - Immunocompromised individuals	- Precipitation variability - Temperature	↑	- Early warming system - Improved zoning and building codes - Engineering
Water & food-borne diseases	- Immunocompromised individuals - The young - The elderly - The poor - Rural communities	- Ambient temperature - Water temperature - Precipitation	↑	- Improved water systems engineering - Improved sanitation systems - Surveillance
Vector & rodent-borne diseases	- Immunocompromised individuals - The young - The elderly - Rural residents	- Temperature - Precipitation variability - Relative humidity	↑ or ↓ (disease & region dependent)	- Surveillance - Improve vector and rodent control programmes - Improved sanitation systems - Improved clinical diagnosis, treatment and public health measures

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