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Workshop Report

Climate Variability and Change and their Health Effects in Pacific Island Countries

Apia, Samoa
25-28 July 2000

Protection of the Human Environment

Geneva

Healthy Settings and Environment

Manila

December 2000

This workshop was organized by the World Health Organization under the auspices of the Interagency Network on Climate and Human Health which includes WHO, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). For this regional workshop, collaboration also came from US National Oceanic and Atmospheric Administration, Office of Global Programs, and the US Environmental Protection Agency, Global Change Research Program.

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I. WORKSHOP SUMMARY

A. Workshop objectives

The Workshop on Climate Variability and Change and their Health Effects in Pacific Island Countries was conducted in Apia, Samoa, from 25 to 28 July 2000.

The objectives of the workshop were:

1. to review and share the experiences of the impacts of climate variability (e.g. El Niño Southern Oscillation – ENSO), and long-term climate change in the Pacific island region;

2. to learn about available tools on the Internet for ENSO and other climate predictions useful for early warning, and for ongoing research on early warning for protection of human health;

3. to acquire basic understanding the linkages between climate change and health; the tools available for predicting the nature and extent of climate change and the associated adverse impacts on health; and the measures that can mitigate these adverse impacts;

4. to develop plans for sustainable future activities; and

5. to prepare recommendations to be reported at a policy-makers' forum.

The workshop was attended by 13 participants from Cook Islands, Fiji, Kiribati, Federated States of Micronesia, Niue, Palau, Papua New Guinea, Samoa, Tonga, Tuvalu and Vanuatu. There were eight representatives from international partner agencies, including the Australian Agency for International Development (AusAid), South Pacific Applied Geoscience Commission (SOPAC), South Pacific Regional Environment Programme (SPREP), United Nations Environment Programme (UNEP), and World Meteorological Organization (WMO). Also present were five observers from the Department of Health, Samoa. WHO provided a consultant, three temporary advisers and two WHO staff members, serving as the secretariat. There were also ten resource persons funded by themselves or organizations (e.g. USEPA and NOAA).

The workshop presentations included: a keynote address on climate change and health for small island states; presentation of working papers on regional health/climate initiatives, climate change and forecasting, health implications, impacts on water supply, and national and regional assessment; plenary discussions and group exercise on application of meteorological data to assess major health problems in the region, dengue simulation modelling and regional and international institutional resources and data, and a round table discussion to develop recommended future activities in the region.

B. Conclusions

The workshop participants concluded the following:

(1) Climate variability and change are important determinants of heath in the region. Although diseases and other impacts vary by country, the participants identified as high priority in the Pacific region, malaria, dengue, diarrhoeal disease/typhoid; skin diseases; acute respiratory infections; food security and malnutrition; water quality and quantity.

(2) Participants noted that social aspects such as culture and traditions are important in reducing impacts of climate change and variability on health.

(3) There is increasing evidence of linkage between climate variability/change and health conditions in the region.

- Better understanding of these linkages through research will provide a basis for improving response/prevention strategies.
- Evaluation of links across disease categories is important because response strategies may not be health outcome-specific. This evaluation will allow a shifting of priorities and emphasis for public health planning, and resource management.
- Climate/health linkages are complex and must be viewed in the context of other environmental stressors and human activities.

(4) Climate forecasting is one of several tools for responding to hazardous conditions relevant to health.

- National and regional forecasting capacity will be needed for success.
- Temperature, rainfall, tropical cyclones and sea level variability are important factors to include in the current forecasts available to the island nations and the region as a whole.
- Communication should be facilitated between the medical/public health community and national meteorological and hydrological services, as well as other relevant agencies or organizations.
- Consolidated forecasts, e.g. "indices", are needed for improved application. Cross sector coordination (e.g., with water and agricultural sectors) is a high priority.

(5) Capacity building at all levels is important to reduce vulnerability to climate variability and change.

(6) It is essential to capitalize on already existing regional efforts that address the impacts of climate variability and change.

C. Needs and recommendations

(1) Policy needs:

- National policy should address direct and indirect climate change impacts on public health. Integrating the recommendations of this workshop with other national and regional efforts in the areas of climate variability/climate change ranks as high priority.

- A regional mechanism to coordinate climate variability/change and human health should be encouraged. This mechanism would facilitate the exchange of information and services between National Ministries of Health, other relevant agencies, and end-users.

- Existing policies, including current initiatives at the international (e.g. UNFCCC) and regional (e.g. PICCAP) levels should be reviewed and implemented. In particular, the results of this workshop should be incorporated into the draft Pacific Islands Framework for Action on Climate Variability and Change.

- Intersectoral and interagency collaboration should be encouraged to maximize effective resource use.

(2) Research needs:

- Basic entomological research, including the distribution of vector species, their responses to climate variability, habitats and biting habits and the effectiveness of control measures.

- Social, cultural, and economic aspects of linkage between climate and health, including important modifiable factors contributing to vulnerability and adaptation should be explored.

- Development of an index of health risk that incorporates both linkages to environmental indicators, such as the Environmental Vulnerability Index and social and human dimensions of climate variability and change (SOPAC, for example) could be a resource for integrated assessments.

- Evaluation of the effectiveness of response strategies and policies related to climate/health.

- Consolidation of and improved access (via the Internet) to regionally relevant information, including water quality, air quality, climate data, GIS and remote sensing data, health outcome data, and applied research and response strategies.

- Initiation of new studies on specific climate-sensitive diseases, such as skin, respiratory, and waterborne diseases.

(3) Training and technical assistance:

General training and technical assistance falls under three general categories:

- Health information systems should be improved at all levels.
- Services should include education, training, technical assistance, and public health infrastructure (for example, water resources and sanitation).
- Community attributes should include social cohesiveness, networking for wider support systems and community response and participation.

Further recommendations for expanding information systems:

- Establishing integrated health surveillance and environmental monitoring, and include laboratory testing and clinical diagnosis methods.
- Enhancing communication skills, including coordination between clinical, laboratory and public health staff.

Further recommendations for expanding services:

- Training of health professionals in environmental monitoring methods, such as vector monitoring and water quality tests and strengthen environmental monitoring. In addition, intersectoral training, bringing together experts from multiple disciplines, is a priority.
- Improving understanding of and expertise in the use of tools, such as software tools, available to assess vulnerability of and adaptation of climate variability and change.
- Providing user-friendly climate forecasts and applications information at the national and regional levels. Accurate and simple information, translated into simple language, should include information about floods and droughts, tropical cyclones, temperature and sea level variability.
- Providing seasonal temperature and rainfall forecasts and historical graphs and trends for each island/locality.

II WORKSHOP BACKGROUND PAPER

Climate and Health in Small Island States

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Description of the problem

Climate variability and long-term climate change present special concerns to small island states, which have been identified by the United Nations Intergovernmental Panel on Climate Change (IPCC) as likely the countries most vulnerable to climate change. Small island states are relatively isolated and are already susceptible to natural weather disasters. Additionally, they are constrained in their ability to adapt to climate change by limited physical size and natural resources.

A rise in sea level could result in saline contamination of estuaries and aquifers, direct inundation of low-lying areas, shore erosion, destruction of coral reefs and fisheries, and exacerbation of coastal flooding and storm damage (1). IPCC projections for climate change from 1990 to 2100 are an increase in temperature ranging from 1.6 to 6°C and a rise in sea level ranging from 14 to 80 cm. (2). The projected rise in sea level is primarily due to thermal expansion as the ocean waters warm, but also due to increased melting of glaciers.

For small islands, short-term climate changes, such as those that occurred with El Niño Southern Oscillation (ENSO) may be even more significant and can give clues to the environmental and health impacts that may be expected with long-term climate changes. For the small island states of the Pacific, the key concern will be weather extremes such as floods and/or droughts as well as more severe cyclones. The ENSO event of 1997/98 brought Supertyphoon Paka, which caused serious damage to Guam, the Commonwealth of Northern Mariana Islands, and the Marshall Islands in December 1997. Following this supertyphoon, the first half of 1998 brought severe droughts to the Marshall Islands, Federated States of Micronesia, Guam, Samoa, and others.

The Pacific ENSO Applications Center (PEAC) was able to predict the drought and alert the islands allowing them to formulate and implement emergency plans and mitigate the impacts of the disaster. Wildfires caused by the drought destroyed many acres and resulted in serious air quality problems which led to increased cases of respiratory illness (3). The advance warning provided by PEAC permitted these small island states to launch extensive public education and awareness campaigns aimed at reducing the risk of waterborne diarrheal diseases and vector-borne diseases such as dengue. Still, these nations sustained substantial losses in the form of damaged lands and ecosystems, damaged crops, and increased financial costs of importing water and food (3). This scenario could become much more common.

Studies of short-term climate changes such as ENSO have helped with projections of long-term climate change, but uncertainties of future variability still exist. Global warming has not been uniform. Climate change models predict greater warming in the tropical Pacific associated with a greater increase in sea surface temperatures in the eastern Pacific than in the western Pacific (4). This could result in long-term changes in precipitation patterns causing drought conditions over Australasia in the future (4).

Health Effects of Climate Change

Weather Extremes:

The most direct effect of global warming on human health is that of heat stress which impacts the very young, the very old, and people of all ages who are engaged in hard physical labor, such as farming or fishing. Individuals with chronic illnesses such as heart disease are also at increased risk of dying from heat exhaustion or heat stroke (5). Air pollution, especially urban ozone, is also affected by high temperatures and can potentially change under future climate (5a).

Possibly of most concern for small island populations would be changes in severe weather systems. Natural disasters can arise from a variety of geophysical and weather-related events such as typhoons, floods, or droughts, which may become more frequent and more severe with future climate change. The most vulnerable populations to deaths from disasters are people who live along coasts, in substandard housing, with already limited food and water sources. To illustrate the increased vulnerability of small island states, the risk of dying in a tropical cyclone in Fiji is 1 in 100,000 per year. The risk of drowning from a dike failure in the Netherlands is 1 in 10,000,000 per year (6).

Although there is controversy about whether the evidence supports an expected change in the frequency of tropical cyclones (typhoons) with global warming over the long term, there is more agreement that warmer ocean temperatures may increase the intensity of storms (7,8). During an El Niño year, however, storm tracks are shifted to the West in the Pacific and typhoons are 2.6 times more likely to occur near the Marshall Islands, for example, than during a regular year (8). Similarly, the number of tropical cyclones observed in the north Australian cyclone season is related to El Niño Southern Oscillation (ENSO) and can be forecasted by monitoring an ENSO index (Darwin Pressure) in the months preceding the cyclone season (9). In addition to typhoons, precipitation patterns change with ENSO. Western Pacific islands may be drier during an ENSO event, while Eastern Pacific islands can expect more rain than usual (10).

Fires caused by El Niño-driven droughts raged across many parts of the world in 1997 and 1998. Massive forest fires besieged the Indonesian island of Sumatra during the summer of 1997. Air quality was affected over regions much greater than the immediate burn areas. People in Yap and Palau thought their air quality was being affected by the Indonesian fires as well as wildfires burning more locally. There were more cases of respiratory illnesses and allergy symptoms reported (3). The ability to predict severe weather events such as these coupled with the ability to disseminate the information via the Internet and other methods will enable early warning systems to mitigate the human and environmental cost of disasters (see Early Warning section below).

Vectorborne and Waterborne Diseases:

Many vector-borne diseases are weather sensitive and even small changes in the weather can dramatically affect disease transmission. Dengue fever, for example, is carried by the domesticated mosquito *Aedes aegypti.* This mosquito thrives in urban environments and breeds in artificial containers that hold water, perhaps explaining some of the indirect effects climate change can have on disease as disruption of regular supplies of water lead to changes in water storage practices (11). The incidence of dengue is seasonal; increases are associated with warmer, more humid weather (12). Hales et al. (1999) investigated the relationship between incidence of dengue fever and ENSO in 14 island nations in the South Pacific. Their research showed that the larger islands with larger populations, where the disease is endemic, demonstrated an increased incidence of dengue with ENSO. In addition, there was also an increase in dengue transmission from larger islands to their smaller island neighbors (13).

Cholera is not endemic in the South Pacific, but there is some evidence that rising sea surface temperatures may increase the risk of cholera spreading far beyond endemic regions (14). Indonesia, Malaysia, and the Philippines experienced significant outbreaks of cholera during the 1997/98 ENSO (15). Water-borne diseases such as typhoid, shigella, and hepatitis A and E can become more of a problem with flooding and contamination of surface water with sewage (14). Drought conditions can lead to increased concentrations of pathogens in surface water and increased morbidity and mortality from a combination of diarrhea and dehydration (14).

Algal blooms occur more frequently with unusually warmer or cooler water temperatures (16). Some of these algal blooms cause diseases in humans, but the most frequent cause of human illness caused by a marine toxin is Ciguatera. The toxin is eaten by herbivorous fish, and then becomes more concentrated as it passes up the food chain. When humans eat predatory reef fish, the amount of toxin consumed can be enough to cause illness. In Tuvalu, Cook Islands, Kiribati, and Samoa, where El Niño caused higher sea surface temperatures, the risk of fish poisoning increased according to one study, suggesting increases in ciguatera fish poisoning could increase with global warming (17).

Since most of the populations of island nations live along the coastlines, sea-level rise and more severe storms could combine to displace many people, both in the short and the long term. These “environmental refugees” could overtax an island’s ability to provide healthcare, sanitation, food, and shelter (18).

Indirect Impacts on Health: Cross-sector Linkages

Many small island states rely on a single source for their water supply such as groundwater, rainwater, surface reservoirs, or shallow wells that draw from freshwater lenses just beneath the surface (19). These sources are climate sensitive and changes in precipitation or rising sea levels will present special challenges. Rising sea levels can result in salinity intrusion into the freshwater lens (20). Global climate change is expected to cause some areas of the tropical Pacific to get increased precipitation causing floods, impeded drainage, or elevated water tables, while other areas experience droughts (20). Completely protecting water sources from adverse effects of climate change may not be possible, but the management of water resources can be improved. During the severe drought following the 1997/98 ENSO, early warning from PEAC allowed islands to repair leaky water distribution systems and water catchment systems, install new household catchment tanks in some areas, develop and educate the public about water conservation plans, and procure reverse osmosis units for other areas (3).

Agriculture of subsistence food crops and crops for export in the tropical Pacific may be adversely affected by changes in precipitation; rising temperatures causing heat stress; salinization resulting from sea level rise; and extreme events such as cyclones, floods, or droughts. Again, the climate variability of ENSO can offer clues to what might happen with long-term climate change. El Niño changes in 1991 and 1994 caused widespread rice crop failures in Indonesia (21). Approximately 50% of the rice and corn crop losses in the Philippines were due to climate variability, primarily cyclones and floods, but also droughts (21). Almost all of the islands in the Pacific sustained crop damage and loss of both food and cash crops during the drought following the 1997/98 ENSO (3). For example, on Pohnpei over half the banana trees had died or were seriously stressed and on Yap taro losses were estimated at 50-65 percent. The Marshall Islands required supplies of relief food to begin in January of 1998, after being hit by Typhoon Paka, while many other islands didn't require relief food until May, during the drought (3). Adaptations to mitigate crop failures and resulting food shortages in the medium- to long- term include crop breeding to select for species better equipped to handle the lower-water, higher-temperature conditions, growing different crops or species with better survivability for adverse conditions, and better soil-building techniques (22).

Coral reefs are likely to experience adverse effects from a range of climate change related events such as increases in sea-water temperature, sea-level rise, changes in storm patterns and coastal currents, changes in rainfall patterns, and additional pressures from nearby cities and settlements (22). Although coral reefs can recover from brief episodes of warmer water, prolonged periods (greater than 6 months) of increases in seawater temperature result in irreversible bleaching (23). Coral reefs are an integral part of the island ecosystem. For example, during the 1982/83 El Niño event, sea surface temperatures in the Caribbean exceeded 29°C, which led to extensive coral bleaching throughout the Caribbean. The coral reef surrounding the island of Jamaica experienced several stresses that eventually resulted in the total collapse of the coral reef. These stresses included previous overharvesting of the reef fish (which clean the reef of unwanted algae and detritus), widespread coral bleaching, the proliferation of algal populations associated with waste runoff from the island, and the simultaneous disease and die-off of the sea urchins that normally clean the bottom of the reef and remove macroalgae (24). The entire island ecosystem was affected and the reefs and fish populations still haven't recovered, resulting in extended losses in food, tourism and the economy (16).

Early Warning Systems and Disaster Planning

A variety of mathematical models may aid in predicting the impact of climate change on transmission of vector-borne diseases such as dengue, malaria, and schistosomiasis (25). Models combining variables determining vectorial capacity have found increases in potential transmission of dengue and malaria due to climate change (26). Also, models based on soil moisture, for example, have been used in Kenya to better predict malaria. Geographic Information Systems (GIS) consider such variables as weather, soils, slope, land use, and land cover to predict risk for a particular disease. Satellite remote sensing uses vegetation to determine vector populations and has been used to predict transmission of malaria and other vector-borne diseases (27).

El Niño has provided an opportunity to study diseases under conditions of extreme climate variability. The "ENSO Experiment" was created in 1997 to "examine the relationship between climate variability and human health, and to explore the potential for using climate-forecast information to provide early warning of conditions posing a public health threat" (28). The ENSO Experiment coordinated approximately 25 separate research activities around the globe spanning a range of topics related to health and climate variability. This research has provided valuable information about what to expect with short- and long-term climate change.

There is now a full array of Tropical Atmosphere-Ocean buoys recently established in the Pacific Ocean. The 1997/98 El Niño was the first event to be observed using this equipment and thus provided much new data and an opportunity to test and refine scientific understanding and evaluate forecasting techniques (14). Recently accurate forecasts have been derived using coupled ocean-atmosphere general circulation models (29,30). There are many sources of seasonal forecasts available on the Internet (14).

Experience with ENSO has shown the value of seasonal forecasting to mitigate disaster, assist with medium-term planning and use resources more wisely. There are several famine and drought early warning systems already in use including the Global Information and Early Warning System (GIEWS) of the Food and Agriculture Organization of the United Nations (FAO) that uses satellite data to continuously monitor crop and food supplies worldwide. This information is used to assist governments in averting famine disasters. The Famine Early Warning System (FEWS) was set up by USAID for countries in Africa and uses seasonal forecasting to help governments plan which crops to plant at what times. A similar early warning system could conceivably be used in the Pacific islands. Experience with these systems has demonstrated that effective early warning depends not only on the monitoring system but also upon multisectoral and interdisciplinary collaboration among all concerned parties (14).

Additional disaster planning also would include extensive analysis of vulnerabilities and resources, formation of a detailed disaster plan, and a mechanism for evaluation of the disaster response after a disaster has occurred (31). The occurrence of geophysical disasters may not be preventable, but thoughtful planning and prevention measures can mitigate the effects of the disasters (31).

Adaptation to Climate Change

Adaptation strategies for reducing immediate health threats related to climate change include effective health education programs, improvement of health care infrastructure, disaster preparedness plans, vector monitoring and control, and appropriate sewage and solid-waste management practices. Use of early warning systems as discussed above can help guide prevention plans and concentrate resources where most needed (32). Adaptations for the longer term include decreasing human population growth and slowing emissions of greenhouse gases.

In general, there are substantial uncertainties in climate change projections. These uncertainties lend themselves to two disparate theories about how to plan for adaptation strategies: low cost, "no-regrets" responses or high cost, reactive measures. A "do nothing" policy would necessitate high cost reactive measures in the future (33). A well-planned response, on the other hand, that anticipates a range of possible physical and health impacts of climate change, sea level rise, and extreme weather events will provide a wider range of options for future generations at lower costs (22). "No regrets" measures make sense on their own merit regardless of climate change (34).

Climate change will interact with and exacerbate many other factors that will contribute to the vulnerability of a particular region. Over-exploitation of resources, decreasing fresh-water supplies, urbanization, pollution, rapid population growth, changes in social structure, and effects of economic globalization all contribute to the decreased resiliency and adaptability of populations to the added stresses of climate change, thereby increasing vulnerability of small island states (35). In addition, as pointed out by Woodward et al. (1998), dependency leads to a sense of fatalism and enhanced vulnerability (36). For example, many small island states must rely on larger foreign nations to provide and interpret weather data. Therefore, one step in reducing vulnerability to climate change and extreme weather events would be for small island states to acquire the skills and technology needed to effectively use and share data which is collected in and pertinent to their region (36).

Tools to assess vulnerability can be used to make planning and design of adaptation strategies more efficient. A variety of these tools have been developed such as the Environmental Vulnerability Index which accounts for climate and non-climate stresses on the environment (37). VANDACLIM is another regional model that considers three key components: 1) projections of temperature and sea level rise, 2) regional climate change scenario, and 3) sectoral impact models for agriculture, coastal zone, human health and water resources (38).

Aerial videotape-assisted vulnerability analysis (AVVA) is an assessment technique that uses videotaping of the coastline from a small airplane flown at low elevation to predict local impacts of sea level rise. This relatively low technology approach may be quite useful for small island states to get an accurate, contemporary view of the topography and development of their respective coastlines (1).

Habitat loss and overexploitation have already stressed fisheries in many locations. In addition, breeding grounds for many fish and shellfish are located in shallow waters near coasts where mangrove, coral reefs, seagrass beds, and salt ponds are likely to be affected by climate change (22). Management strategies include restoration and enhancement of vital habitats, and establishment of marine reserves and protected areas for critical species (22). Several Pacific islands have successfully established protected areas using community-based decision making techniques and allowing for multiple uses (39). Close monitoring and reporting of diseases of fish, shellfish, and other invertebrates would enable the development of an early warning system that could be used to stem the spread of disease before it becomes devastating (16).

Strategies for adaptation to sea level rise fall into three main categories: retreat, accommodate, and protect. Retreat indicates the planned abandonment of land to reduce risk and minimize loss of associated infrastructure (33). In the Pacific Islands, this could mean abandoning some low-level islands or abandoning low-level areas and moving to higher ground, if available on the same island. Accommodation suggests changing land use as water levels rise such as raising buildings or changing to more salt-tolerant crops. Protection often uses constructed barriers to keep the sea away from coastlines (33).

"Hard" structures such as seawalls and breakwaters have traditionally been used for protection (40). These "hard" structures, however, can cause additional erosion to adjacent unprotected coastal areas (1). Other approaches, which may be more practical and efficient for small island states, include "softer" options such as the use of vegetation to stabilize beaches (22). Adding sand and stone to existing beaches, termed "nourishment", or raising the height of some coastal villages may be useful in some places (40). Precautionary approaches such as the enforcement of enlarged building setbacks, land-use regulations, and building codes are gaining popularity (22).

Integrated Coastal Management (ICM) incorporates a variety of management systems such as traditional land tenure systems, community-based management systems, and Western continental style management systems. Both medium- and long-term climate change challenges can be addressed using ICM as both an anticipatory and predictive tool (41).

Areas of further needed research

Additional information and research will be needed to fine-tune the prediction models and develop appropriate strategies for coping with the identified challenges. Better assessment techniques are required straight away for meaningful planning to occur. Climate models that can provide more specific information focusing on the unique needs of the small island states are essential. Better understanding of the impacts of climate change at the local and regional levels is necessary as is development of early warning systems that are specifically useful to small island states (22).

Direct effects of climate change to human health will benefit from further studies into heat stress morbidity and mortality as well as disaster mitigation. Multidisciplinary research is needed to untangle the complexities of vector-borne, water-borne, and other infectious or toxic diseases and their relationships to climate variability and change (18).

Surveys of the fresh water lenses on atolls to assess the emergency water supply resources would help quantify the vulnerability of atoll populations (20). Additional exploration is needed into better methodologies for water conservation as well as protection of future freshwater sources in the face of climate change. Studies of long-term climate change effects on rice and corn as well as on other important crops such as cassava, soybean, and sugarcane will need to be undertaken (21). Agricultural adaptations for salt- and heat-tolerant crops to avoid widespread malnutrition are urgently required.

With respect to sea level rise, further work is needed on the direct impacts such as saltwater intrusion into freshwater supplies, the interaction of sea level rise with other expressions of climate change such as increasing storm intensity, and the analysis of optimal timing and economic impact of different strategies to respond to sea level rise (1). Studies of economically feasible, socially acceptable methods for protection of coral reefs and other critical habitats are imperative if island ecosystems are to survive the challenges of climate change. Better monitoring is needed of how ecosystems respond to climate change and sea-level rise over the long term, with particular attention to the complex interactions occurring within and between human and natural systems in small island states.

Adaptation measures will vary in effectiveness and cost, and will have both co-benefits and potential negative side-effects (42). Among important adaptations for the Western Pacific Region will be continued education and cooperation among and between the inhabitants of small island states. It is hoped that this workshop, along with more to follow, will help facilitate this goal.

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III WORKSHOP REPORT

1. Introduction

1.1 Background information

Climate variability and long-term climate change present special concerns to small island states, which have been identified by the UN Intergovernmental Panel on Climate Change (IPCC) as likely to be the most vulnerable countries to climate change. Temperature increases and sea level rise are occurring in the Pacific islands at a rate faster than the global average.

The most immediate threats to small islands include extreme climate variability due to El Niño, affecting rainfall patterns and moisture and storm events. The strong El Niño of 1997/98, for example, led to droughts in Micronesia, Fiji, Papua New Guinea, Kiribati, and the Marshall Islands. Such events have both direct and indirect implications for human health and well-being. The El Niño adversely affected taro crops and fisheries. Also, sea level rise may directly threaten coastal infrastructures, as well as water resources and agriculture due to salination of freshwater aquifers. Long-term trends in coral reef bleaching due to higher water temperatures or sea level rise can further compromise population nutrition by affecting fisheries.

Many diseases are linked to climate variability in the region. For example, vector-borne diseases such as malaria, dengue fever and lymphatic filariasis occur in the region, and some have been linked to El Niño-driven climate fluctuation. In combination with rapid urbanization, dengue has spread throughout the region and currently presents a major health risk. Water-borne diseases, such as typhoid, remain problematic in Papua New Guinea and Tonga, and intestinal worms are still common in the region. Though cholera has not been epidemic, rising sea temperatures may potentially increase the occurrence of the disease. Toxic algae and ciguatera have also been linked to periodic ocean warming events.

In recognizing the importance of disaster preparedness and management in the Region, WHO has recently organized two regional meetings to address issues of emergency preparedness (i.e. the workshop on strengthening emergency preparedness in November 1998, and the training course on health emergency management in October 1999). These meetings concluded, among other things, that many countries had basic information on the occurrence of disasters, but more accurate data to evaluate health impacts need to be collected, and access to information through the use of different media, including Internet, should be improved. These meetings dealt with the disaster-preparedness and management issues common in both large countries as well as small island states. This workshop was designed to address the health impacts of climate variability and change in Pacific island countries.

The workshop will help inform the stakeholders in the region about the potential health vulnerabilities as well as control and management measures that can be adopted to reduce the risks from present climate variability (e.g. El Niño) and long-term sea-level rise and climate change. Partial funding for the workshop came from a donation to WHO from Dr Tapa, the former Minister of Health, Tonga.

1.2 Objectives

At the end of the workshop, the participants will have:

(1) reviewed and shared the experiences of the impacts of climate variability (e.g. El Niño Southern Oscillation – ENSO), and long-term climate change in the Pacific island region;

(2) learned about available tools on the Internet for ENSO and other climate predictions useful for early warning, and for ongoing research on early warning for protection of human health;

(3) acquired basic understanding of the linkages between climate change and health; the tools available for predicting the nature and extent of climate change and the associated adverse impacts on health; and the measures that can mitigate these adverse impacts;

(4) developed plans for sustainable future activities; and

(5) prepared recommendations to be reported at a policy-makers' forum.

1.3 Participants

The workshop was attended by 13 participants who were technical government officials involved in or concerned with the health aspects related to climate change or disaster management. The participants were from Cook Islands, Fiji, Kiribati, Federated States of Micronesia, Niue, Palau, Papua New Guinea, Samoa, Tonga, Tuvalu and Vanuatu. There were eight representatives from international partner agencies, including the Australian Agency for International Development (AusAid,) South Pacific Applied Geoscience Commission (SOPAC), South Pacific Regional Environment Programme (SPREP), United Nations Environment Programme (UNEP), and World Meteorological Organization (WMO). Also present were five observers from the Department of Health, Samoa. WHO provided a consultant, three temporary advisers and two WHO staff members, serving as the secretariat for the workshop. There were also ten resource persons funded by themselves or organizations (e.g. USEPA and NOAA). A list of participants, temporary advisers, consultants, resource persons, observers, representatives and secretariat members is given in Annex 1.

1.4 Organization

The workshop programme is in Annex 2. A list of documents distributed during the workshop is given in Annex 3. The documents include papers presented on the various aspects of climate variability and change and associated health implications. Copies of these papers can be obtained upon request from the WHO Regional Office for the Western Pacific. Summaries of presentations are given in Annex 4. The opening speech is given in Annex 5.

The officers of the workshop were selected as follows:

Chairperson	-	Dr Caleb Otto, Republic of Palau
Vice-Chairperson	-	Ms Ketiligi Hetutu, Niue
Rapporteur	-	Mr William Muru, Papua New Guinea

The technical sessions of the workshop started with a keynote address on climate change and health for small island states by the WHO consultant. The keynote address provided an overview of the issues. A series of papers were presented by temporary advisers and resource persons. The topics included regional health/climate initiatives, climate change and forecasting, health implications, water supplies, and national and regional assessments. The paper presentations and discussions that followed addressed the first objective of the workshop.

The second and third objectives were dealt with by plenary discussions and group exercises. In the first exercise, major health problems in the region were identified and their relationships with the meteorological data studied. The future health problems were predicted, using climate forecast data. Another training exercise was provided on the use of dengue simulation modelling. A plenary discussion was held to inform the participants of regional and international institutional resources and data available to assess and manage potential health impacts resulting from climate change and variability.

A round table discussion was held to develop recommended future activities in the region to improve the assessment and management of health risks of climate change and variability (i.e. the fourth and fifth objectives). Results of the discussion were summarised as the workshop conclusions which were presented and endorsed by the participants at the closing session.

1.5 Opening remarks

1.5.1 WHO Headquarters

Dr Carlos Corvalán, from the Department of Protection of the Human Environment, World Health Organization in Geneva welcomed participants to the workshop and emphasized how this activity was made possible through the generous personal donation from Dr Tapa, former Minister of Health, Kingdom of Tonga.

Dr Corvalán elaborated that the workshop was planned jointly with the United Nations Environment Programme and the World Meteorological Organization and was to have been held in Fiji. However, it was necessary to move the workshop to a new venue at very short notice, and he expressed his gratitude to the Government of Samoa for making it possible to hold the workshop in Apia, given such a short notice.

He continued by elaborating that a number of organizations carrying out significant climate related activities jointly developed the Inter-Agency Committee on the Climate Agenda, of which WHO is a member. Dr Corvalán said that WHO contributed towards the health aspects of the Climate Agenda within the general field of climate impact assessment and response strategies to reduce vulnerability.

Reverend Falefatu Enari was invited to bless the workshop prior to the official opening.

1.5.2 Alliance of Small Island States (AOSIS)

His Excellency Tuiloma Neromi Slade, Ambassador and Permanent Representative of Samoa to the United Nations and Chairman of the Alliance of Small Island States (AOSIS) addressed the workshop participants. Ambassador Slade described the activities of AOSIS and the ongoing international negotiations in relation to climate change and variability (e.g. ENSO) and their impacts on small island countries. He concluded his remarks by highlighting the importance of United Nations agencies and other international and regional organizations in coordinating their efforts in supporting capacity development of small island states.

1.5.3 World Meteorological Organization (WMO)

Mr Henry Taiki spoke on behalf of the World Meteorological Organization (WMO). He described the important role WMO played in various international fora on climate change. One such example was the UNEP/WHO/WMO Inter-Agency Network on Climate and Health to enhance the implementation of services related to climate and health. He stated that climate and health was a priority area of the WMO Commission for Climatology, and the Thirteenth WMO Congress held in May 1999 had urged that increased attention be given to human health and urban issues for Small Island Developing States. The WMO Climate Information and Prediction Services (CLIPS) Project would be incorporating climate and health applications in a series of seminars, and support the Climate Outlook Forum and provide capacity building to national Meteorological and Hydrological Services (MMHSs).

1.5.4 United Nations Environment Programme (UNEP)

Dr H.N.B. Gopalan, Issue Team Leader (Environment and Health) welcomed the participants on behalf of Dr Klaus Teopfer, Executive Director, United Nations Environment Programme. Dr Gopalan stressed the importance of the impacts of climate change and climate variability on the people living in the small island countries of the South Pacific. He referred to the importance UNEP attaches to the health and welfare of small island countries, as evidenced by the recent visit to Samoa of UNEP's Executive Director. Dr Gopalan referred to some of his ongoing activities at UNEP on the health impacts of climate change and climate variability, particularly the Inter-Agency Network on Climate Change, jointly with WHO and WMO, and the heat/health watch/warning systems being developed jointly with the University of Delaware, US-EPA, WMO and WHO.

Dr Gopalan thanked the Government of Samoa for hosting the workshop at short notice and wished the participants well in their deliberations.

1.5.5 WHO Regional Office for the Western Pacific

Ms Pamela Messervy, Acting WHO Representative in Samoa, delivered a speech on behalf of Dr Shigeru Omi, WHO Regional Director for the Western Pacific (Annex 5). She highlighted diseases or health problems experienced in the Pacific region, which were considered to be associated with the 1997-98 El Niño. Vector-borne diseases, such as malaria, dengue fever and lymphatic filariasis, water-borne diseases such as typhoid, were among those influenced by climate variability. She reviewed recent WHO meetings on emergency preparedness, stating that many countries had basic information on the occurrence of disasters, but more accurate data to evaluate health impacts were needed. She then outlined the objectives and programme of the workshop, and wished the participants a fruitful week of discussions. Before closing her remarks, she thanked the Government of Samoa for hosting the workshop and Dr Tapa, the former Health Minister of the Kingdome of Tonga, for his donation to the workshop.

1.5.6 The Government of Samoa

The Honourable Misa Telefoni, Minister of Health, Samoa, addressed the opening by introducing the workshop to local participants in the Samoan language. Later, in English, noting the increased availability in recent years of scientific information on climate change and variability and health impacts, he emphasized that there was a growing need to make clear information or message on health impacts of climate change accessible to the general public and decision makers. He welcomed the participants to Samoa, and expressed his sympathy to participants from Fiji about their political problem that had forced the workshop to move to his country. He also praised Dr Tapa's personal contribution to the workshop, and then declared the workshop open.

2. Proceedings

2.1 Summary of presentations

2.1.1 Keynote Address on Climate Change and Health for Small Island States: Need for Integrated Approach

Dr Jonathan Patz opened the technical session of the workshop outlining the general framework and goals of the workshop. The goals were to: review and share results from ongoing studies in the region that address climate variability and change; learn tools available for predicting regional climate variability and apply these tools to local health impacts; assess the potential for preventive measures, as would be demonstrated for dengue fever, later in the workshop; and develop plans and recommendations for sustainable future activities in the region. He further set forth key workshop themes that: El Niño climate variability may provide a window into future climate change, and that short-term variability may be superimposed on top of long-term climate trends; cross-sector impacts are to be expected requiring integrated assessments across multiple sectors; and predictive capability will augment disease prevention strategies.

The health effects most anticipated from climate change are those stemming from heat waves, extreme storms, exacerbated urban air pollution, water- and vector-borne infectious diseases, illness from consumption of toxic marine organisms, and malnutrition from threatened fisheries and land crop failure. Climate variability and long-term climate change present special concerns to small island states, which are relatively isolated and are already susceptible to natural weather disasters. Also a rise in sea level could result in saline contamination of estuatries and aquifers, direct inundation of low-lying areas, shore erosion, destruction of coral reefs and fisheries, and exacerbation of coastal flooding and storm damage. However, for the small island states of the Pacific, of equal or even greater concern will be weather extremes such as floods and/or droughts as well as more sever cyclones. (Extended summary in Annex 4).

2.1.2 South Pacific Regional Environment Programme (SPREP)

Mr Gerald Miles gave a brief history of the formation of SPREP and a brief summary of the science of climate change as it relates to small island countries in the Pacific. Some observed changes consistent with global climate change in the region are increased coastal erosion, more saline soils, shifting fishing grounds, more droughts and water shortages, and increased reports of malaria and dengue. Ongoing research in this area includes sea level monitoring, greenhouse gas inventories, vulnerability and adaptation assessments, development and use of computer models such as PACCLIM (assess climate change vulnerability in the Pacific), atmospheric radiation measurement, and strengthening meteorological services and climate monitoring.

SPREP is spearheading key regional initiatives to address the health impacts of climate change in the Pacific by supporting international negotiations, adaptation in the Pacific, strengthened participation in global observation networks, and the formation of a regional climate centre. Other regional initiatives include the Pacific Islands Climate Change Assistance Programme (PICCAP). SPREP has identified the following gaps in knowledge and topics for further research: lack of up-to-date information on the patterns of disease in relation to climate change; understanding links between climate and other sectors such as agriculture and water supply; understanding the ENSO and monitoring its effects and their implications for long-term climate change; integrated pest management; climatic requirements of organisms; understanding groundwater resources; and detailed studies on the impacts of climate change and variability on human health.

SPREP is working on building capacity in the region by providing regular access to workshops, conferences, meetings and Internet services, providing training and equipment/technology, encouraging education and awareness-raising skills and campaigns, improving management of water catchments in rural and urban areas, encouraging legislation for adoption of economic and development policies which promote an improved environmental quality, standard of living and public health. If the health impacts of climate change are ignored, the costs of inaction are significant, but difficult to quantify. SPREP estimates the costs of inaction for Fiji alone would be US$5 to 19 million by the year 2050 in terms of loss of public safety, increased vector- and water-borne diseases, increased malnutrition from food shortages during extreme events, but not including direct damage from cyclones.

2.1.3 The Climate System

Dr Nick Graham provided an overview of the basic workings of the climate system. Radiation from the sun is greatest at the equator, which creates an imbalance between heat in the tropical regions and the extra-tropical regions. The heat is transferred from one region to the other via the trade winds and circulations. There is very intense high-pressure zone in the South Pacific that stretches out to form the South Pacific Convergence zone. During El Niño Southern Oscillation (ENSO), various convergence zones shift causing changes in rainfall in different localities. Droughts occur in some areas, while heavy rainfall and floods occur in others. Greater temperature variability also occurs with ENSO events as do changes in sea level. Higher sea levels occur in the eastern Pacific while lower sea levels occur in the western Pacific during an ENSO event.

ENSO can give clues to what to expect with global warming and climate change. Evaporation transfers heat back to the atmosphere and the evaporation/precipitation cycle runs faster with global warming, but CO_2 makes the atmosphere more resistant to letting out heat, so the planet has to warm up more to shed the same amount of heat. Models can be used to predict temperature trends and changes. When the results of the models are compared with actual observed temperatures, there is good correlation.

2.1.4 Climate Forecasting

As part of the Pacific ENSO Applications Center (PEAC), Mr Chip Guard provided a brief history of El Niño research and how past patterns of rainfall during El Niño events can be used to predict future rainfall patterns once an event has begun. He used his experiences during the ENSO event of 1997-98 to relate the importance of direct contact between the forecaster and the customer receiving the forecast as to how the forecast is perceived by the customer and whether the forecast will elicit the desired response in terms of preventive measures taken. For example, during the 1997-98 ENSO event, Mr Guard personally visited small island countries expected to suffer sever consequences of the predicted drought and informed these countries of the severity of the expected drought. The countries responded by creating drought response teams and initiating measures which prevented much suffering and loss of life when the drought hit. Mr Guard emphasized the importance of the forecaster in personally interpreting the forecast and providing the information in a form the customer can understand and use.

2.1.5 Regional Vulnerability to Climate Change

Dr Alistair Woodward established a framework for assessing vulnerability to climate variability and change. Vulnerability is the increased probability of adverse outcomes for a given exposure. This term can apply to an individual, a group, a region, or a country. Adaptation is responding to change in a positive manner. Destructive growth, poverty, political rigidity, dependency and isolation add to vulnerability in the Pacific region, thus vulnerability can improve or worsen as a region's situation changes. When deaths due to storms, floods, and droughts are examined in the Asia-Pacific region, Japan and the Republic of Korea have had far fewer deaths in recent years. This decline was not due to a change in climate, but to changes in infrastructure that reduced vulnerability. India and the Philippines, however, have had an increase in deaths from disasters over the same period.

In general, there are five strategies to reducing vulnerability: anticipate disaster; install surveillance and early warning systems; respond rapidly to an event; spread risks (for example, do not allow society to become dependent on only one crop), and develop social cohesiveness and trust. Traditional Pacific agriculture provides some resistance to vulnerability, or resilience, by using crop diversity, drought-resistant staples, reliable food preservation methods, and building social networks including inter-island trade networks.

Vulnerability can be assessed and measured, using models and assessment tools such as the Environmental Vulnerability Index or PACCLIM, to determine best adaptation strategies. Priorities for reducing vulnerability in the Pacific region are developing appropriate information systems, building community support, and creating service infrastructure. All three are needed in combination for effective adaptability.

2.1.6 ENSO and Infectious Diseases in the Region

Through retrospective research, Dr Lewis explored the relationship between the reported incidence of three water-related diseases (dengue, diarrhoeal disease, and fish poisoning) and climate data (rainfall, temperature, southern oscillation index SOI, sea surface temperature SST, and SOI/SST) for 21 Pacific nations and territories between 1973 and 1994. The data on dengue, which proved most amenable to analysis, showed outbreaks began at the end of the dry season and peaked in the summer season with heavy rainfall, high temperature and high humidity. This pattern was not found in Tuvalu and Samoa, however, when dengue outbreaks occurred in the dry season. The data also showed that there were more dengue outbreaks during normal years and during cold events than in El Niño years. Although climate does seem to impact diseases, the actual occurrence of a disease is affected by a multitude of factors. Therefore, rather than attempting to use forecast data to predict if a particular disease will occur, it is more useful to predict that the climate forecasted may increase the risk of a particular disease.

The most important conclusions drawn from this work are the importance of scale and local level variation in understanding the dynamics of ENSO and disease in the Pacific. ENSO events do not affect the Pacific islands uniformly and the impact varies from event to event. This has important practical and policy implications for the application of forecast information in this insular region.

2.1.7 Case Studies in Regional Climate/Vector- and Food-borne Diseases

Dr Simon Hales investigated the relationship between three vector- and food-borne diseases (fish poisoning, dengue fever, and diarrhoeal disease) and regional climate. Higher rates of fish poisoning were found on islands that experienced higher sea surface temperatures such as those associated with ENSO. Increases in dengue fever were found on islands that experience higher rainfall and warmer temperatures with La Niña, except Fiji. However, further dengue study shows differences on a national scale.

With a variety of factors, in addition to climate, contributing to development of disease outbreaks and epidemics, prediction of an increased risk of a dengue outbreak with particular climate forecasts becomes more practical than the prediction of an actual outbreak. Diarrhoeal illness was found to be more common during droughts and floods. Thus, accurate climate forecasting can provide valuable information to public health officials about how, when, and where to concentrate resources to avert epidemics. (Extended summary in Annex 4).

2.1.8 Leptospirosis, Climate and Agriculture

Mr Navi Litidamu presented the results of a study conducted by the Fiji School of Medicine on the incidence of leptospirosis over the years 1991 to 1997 by age, gender, ethnicity, and geographic location. They found an increase in males, ethnic Fijians, and those living in rural agricultural areas. Some researchers believe that attempting to change the cultural and behavioural patters of people that place them at increased risk for leptospirosis is futile; therefore, further studies are being conducted to determine the feasibility of ecological control measures.

2.1.9 Climate and Water Supplies

Mr Rishi Raj presented impacts of climate change and variability on water resources in the Pacific. Small island countries of the Pacific vary in their water resources. Larger volcanic islands often have abundant surface water, while smaller islands must rely on rainwater collection and limited groundwater sources. The freshwater supplies of almost all Pacific islands are threatened during times of drought. Flooding, too, can threaten freshwater supplies by contaminating surface water with sewage runoff. Global climate change may cause more frequent and more severe floods and droughts and associated sea level rise may result in more saline intrusion of freshwater sources.

ENSO events cause predictable patterns of rainfall, often beginning with severe tropical cyclones and flooding, then progressing to markedly decreased rainfall and drought. Accurate and well-communicated forecasts are invaluable in planning for these extreme events and averting at least some of their disastrous results. (Extended summary in Annex 4).

2.1.10 US National Assessment on Climate Variability and Change

Dr Joel Scheraga introduced his experiences in conducting the national assessment on climate variability and change in the United States of America. Climate variability and change pose significant risks to human health both directly (such as heat stress and injuries due to extreme weather events) and indirectly (such as endangering water resources and increasing the spread of climate-sensitive diseases like dengue. The United States recently completed its first National Assessment of "The Potential Consequences of Climate Variability and Change on the US." Some of the insights gained from the US National Assessment about risks and adaptations may be applicable to the small island countries of the Pacific.

This study found that there is a regional texture to the effects of climate change; therefore, adaptive responses must be region-specific. Some regions are more vulnerable than others and a national assessment can help identify the most vulnerable regions and allow these areas to be targeted for adaptive measures. Adaptation strategies must be carefully designed to ensure that they are affordable and effective, and do not advertently lead to negative side effects that may be more severe than the problems they are attempting to address. (Extended summary in Annex 4).

2.1.11 National Oceanic and Atmospheric Administration

Ms Juli Trtanj gave a review of the history of the National Oceanic and Atmospheric Administration (NOAA) studying ENSO and the ENSO Experiment research activities, which provided such a wealth of information about ENSO events. One of the more important lessons learned from the ENSO Experiment was the tremendous need for greater and sustained interaction between the climate community and international, national, and regional organizations. The Pacific ENSO Applications Center (PEAC) was formed as an attempt to meet this need. Ms Trtanj ended her presentation by challenging the participants to think about barriers they have encountered in obtaining and interpreting climate forecasts and any climate-related needs they may have that continue to be unmet.

2.1.12 Disaster Planning

Mr Atu Kalowmaira briefed on the vulnerability of Pacific island countries to disasters caused by climate variability such as tropical cyclones, storm surges, flooding, and drought for a variety of reasons. During disaster events, island economy can be disrupted by as much as 40% of GDP. In response to the UN International Decade for Natural Disaster Reduction, Pacific leaders have institutionalised disaster management and programming activities in their countries shifting the focus from response and relief to pre-event measures. South Pacific Applied Geoscience Commission (SOPAC) has the regional mandate for improving disaster management capacity in Pacific island countries. National Disaster Management Offices have been created to establish linkages between stakeholders and now offer a nationally integrated management approach to mitigating hazards including climate change and variability.

Disaster managers want to have quantifiable impacts to use as the basis for planning responses and preparedness measures, but El Niño impact study in Fiji exposed many information gaps. Some of these gaps included different perceptions of drought by different sectors, difficulty in clearly assessing medium to long-term impacts due to drought, and little understanding of El Niño effects by planners. The absence of research on impacts over the years following an event, as well as a lack of studies on impacts of small El Niño events constrain proper cost-benefit analysis, particularly for long term measures. Work continue in developing production-based drought intensity indices to assist impact assessment.

The current work of SOPAC on creating an environmental vulnerability index will help identify potential health impacts. It was observed that incidences of contagious diseases and nutrition problems had short-term impacts, most probably due to the effectiveness of intervening measures. Further research is needed on economic and social impacts of climate variability and change to allow better-informed policy decisions. (Extended summary in Annex 4).

2.1.13 Determining Country-Specific Key Climate-Health Issues, Drawing Upon Data Brought to Workshop

Dr Mike Hamnett discussed the Pacific ENSO Application Center (PEAC) project. The PEAC project, funded by grants from US Office of Global Programs (NOAA), was established as a pilot project to provide ENSO (El Niño Southern Oscillation) forecasts and information products to the US affiliated Pacific islands. The University of Guam, the University of Hawaii, the Pacific Regional Office of the US National Weather Service, the US Office of Global Programs (NOAA), and the Pacific Basin Development Council developed PEAC as a joint venture to serve American Samoa, the Commonwealth of Northern Mariana Islands, the Federated States of Micronesia, Guam, Hawaii, the Republic of the Marshall Islands, and the Republic of Palau.

The project began by asking leaders of the US affiliated Pacific islands: what can be forecast, and what climate forecast information do you need? In 1997, when models showed an ENSO event forming, and historical data suggested it would be a strong event, PEAC notified island governments to expect very dry conditions. The governments said they needed more specific information. They wanted to know what percent of normal rainfall they would get, so PEAC looked at the data and provided a forecast of how much normal rainfall could be expected. The forecast were fairly accurate and PEAC was able to effectively communicate the forecast information to the island governments allowing them to implement plans for severe drought and avert much suffering and loss of life.

The measures taken in response to the forecasts were "no regrets" or "good housekeeping" measures such as repairing the water system in Palau and repairing the well pumps on Majuro. These were measures that should have been taken anyway, but the threat of severe drought provided additional motivation to spend limited resources and take prompt action.

2.2 Summary of discussions and exercises

2.2.1 Group exercise on climate variability and health effects

The participants were asked to provide a list of all health problems or conditions that might be impacted by climate. The group then reviewed the list and each condition was labelled as whether it was thought to be seasonal, nonseasonal, or possibly related to events such as droughts or floods. Participants were then divided up into three groups based on climate similarities of the islands they represented and assigned a facilitator. Each group was asked to determine the 4 or 5 most important health problems for their area, look at the data about incidence rates they brought with them for these health problems and determine if there were seasonal wet/dry variability, ENSO related incidence, or cyclone effects. Each group was then given a climate forecast for a representative island in their region and asked to complete two worksheets as a group exercise.

After interpreting the climate forecast for their region, the first worksheet asked the group to answer the following four questions:

(1) What mitigation measures should be taken?

(2) What would be the timeline for mitigation activities?

(3) What resources are required to accomplish the mitigation activities?

(4) Who is responsible for carrying out the mitigation activities?

The second worksheet asked each group to list, for each of the identified health problems, unmet needs with respect to research, forecast, technical assistance, training and policy.

The results of the group exercise were reported back at a plenary session. In summary, there were striking commonalities between the different groups. The most important health problems identified were dengue, respiratory illnesses, malnutrition, diarrhoeal diseases, skin diseases, and malaria. All groups focused on public awareness campaigns during the first 3 to 6 months following the receipt of a worrisome forecast of an event like to occur approximately one year away. The groups learned that as the event gets closer, the accuracy of the forecast improves dramatically; therefore, it is reasonable to start with low-cost, common sense measures and progress gradually to measures that require greater investments as the forecast becomes more accurate.

The groups also discovered that they had an opportunity to address several health problems with common risk factors at the same time. Fore example, health problems thought to be associated with dry season are malnutrition or diarrhoeal diseases; if the forecast says it is going to get drier, the risk for all the diseases associated with dry season increases.

2.2.2 Introduction to Dengue Simulation Modelling and Risk Reduction

Dr Dana Focks introduced a dengue simulation modelling and discussed ways to reduce dengue fever cases. Aedes aegypti is the mosquito that carries dengue fever. These mosquitoes feed mostly on humans, but also on animals. A. aegypti is wonderfully adapted to living in urban areas, preferring to lay eggs just above the water line in artificial containers such as tires or buckets. The eggs are resistant to drying out, so even if the water is poured out, if it reaccumulates, the eggs can still hatch. Depending on the food supply, there is a high mortality rate for larvae. If food supply is limited, 1000 larvae might yield only 3 pupae that will become adult mosquitoes.

Temperature affects the rate at which virus develops inside the mosquito. Therefore, during an ENSO event, when temperatures increase an average of 2.5 degrees C, the virus will replicate much faster in the mosquito, the mosquitoes become infectious more quickly and bite more frequently increasing transmission rates, and dengue can spread and become epidemic much more rapidly.

If enough A. aegypti mosquitoes effectively spread the virus, and enough people who have not had that type of dengue virus before and are therefore not immune, a dengue epidemic occurs. These factors are all used to determine a "threshold" number (pupae/person/area). Below the threshold , the risk of dengue epidemic is low; above the threshold number, the risk increases. The threshold number decreases as temperature increases, so a climate forecast can be very helpful to alert public health officials to an increased risk of a dengue epidemic when increased temperatures are expected.

The threshold is expressed in numbers of pupae per person in a given area. Dr Focks reviewed the specifics of how to conduct a household survey to determine the number of pupae/person/area that actually exist in an area of interest. The participants were given a demonstration of how to sample containers and identify pupae, and the participants practised these skills.

Following the field demonstration, the participants reassembled and were given a demonstration of how to use a computer model produced by Dr Focks to determine what the threshold would be in a given situation. The model allows actual data from the household survey of number of pupae/person, current or anticipated temperature, and seroprevalence rate (used as a measure of herd immunity to determine how many people are still susceptible to a particular type of dengue) to compute the threshold number. The information from the household survey is used to target specific types of containers to empty or scrub so that the number of pupae/person can be reduced below the threshold number and avert an epidemic. By targeting specific containers, resources can be used most appropriately to reduce the risk of an epidemic. Participants were all given a floppy disc by Dr Focks containing the complete model that can be used when they return to their respective islands. (Extended summary in Annex 4).

2.2.3 Integrated National-Scale Models for Climate Impact Assessment

Drs Richard Warrick and John Hay provided a demonstration of how computer models they developed can be used to assess vulnerability in a particular area. The usefulness of the computer model, however, depends on the accuracy and completeness of the specific regional information used to create the model. Climate data such as rainfall variability, temperature variability, extreme events such as ENSO, are entered into the model to produce a picture of current climatology. Then information regarding global greenhouse gas emission scenarios is entered to produce a picture of future climatology. Once information such as region-specific land use is entered, the impacts of future climatology on specific sectors can be predicted, aiding assessment of present and future vulnerabilities.

2.2.4 Round table discussion

A small group consisting of the workshop officers and the WHO consultant and temporary advisers prepared draft workshop conclusions and recommendations based on specific responses to the worksheets and conclusions drawn from the group exercise. These conclusions and recommendations were discussed at a round table session and comments were made by the participants. After the comments were incorporated and further discussion was made, the draft conclusions and recommendations were endorsed by the participants at the closing session.

3. Conclusions and recommendations

3.1 Conclusions

(1) Climate variability and change are important determinants of heath in the region. Although diseases and other impacts vary by country, the participants identified as high priority in the Pacific region, malaria, dengue, diarrhoeal disease/typhoid; skin diseases; acute respiratory infections; food security and malnutrition; water quality and quantity.

(2) Participants noted that social aspects such as culture and traditions are important in reducing impacts of climate change and variability on health.

(3) There is increasing evidence of linkage between climate variability/change and health conditions in the region.

- Better understanding of these linkages through research will provide a basis for improving response/prevention strategies.

- Evaluation of links across disease categories is important because response strategies may not be health outcome-specific. This evaluation will allow a shifting of priorities and emphasis for public health planning, and resource management.

- Climate/health linkages are complex and must be viewed in the context of other environmental stressors and human activities.

(4) Climate forecasting is one of several tools for responding to hazardous conditions relevant to health.

- National and regional forecasting capacity will be needed for success.

- Temperature, rainfall, tropical cyclones and sea level variability are important factors to include in the current forecasts available to the island nations and the region as a whole.

- Communication should be facilitated between the medical/public health community and national meteorological and hydrological services, as well as other relevant agencies or organizations.

- Consolidated forecasts, e.g. "indices", are needed for improved application. Cross sector coordination (e.g., with water and agricultural sectors) is a high priority.

(5) Capacity building at all levels is important to reduce vulnerability to climate variability and change.

(6) It is essential to capitalize on already existing regional efforts that address the impacts of climate variability and change.

3.2 Needs and recommendations

(1) Policy needs:

- National policy should address direct and indirect climate change impacts on public health. Integrating the recommendations of this workshop with other national and regional efforts in the areas of climate variability/climate change ranks as high priority.

- A regional mechanism to coordinate climate variability/change and human health should be encouraged. This mechanism would facilitate the exchange of information and services between National Ministries of Health, other relevant agencies, and end-users.

- Existing policies, including current initiatives at the international (e.g. UNFCCC) and regional (e.g. PICCAP) levels should be reviewed and implemented. In particular, the results of this workshop should be incorporated into the draft Pacific Islands Framework for Action on Climate Variability and Change.

- Intersectoral and interagency collaboration should be encouraged to maximize effective resource use.

(2) Research needs:

- Basic entomological research, including the distribution of vector species, their responses to climate variability, habitats and biting habits and the effectiveness of control measures.
- Social, cultural, and economic aspects of linkage between climate and health, including important modifiable factors contributing to vulnerability and adaptation should be explored.
- Development of an index of health risk that incorporates both linkages to environmental indicators, such as the Environmental Vulnerability Index and social and human dimensions of climate variability and change (SOPAC, for example) could be a resource for integrated assessments.
- Evaluation of the effectiveness of response strategies and policies related to climate/health.
- Consolidation of and improved access (via the Internet) to regionally relevant information, including water quality, air quality, climate data, GIS and remote sensing data, health outcome data, and applied research and response strategies.
- Initiation of new studies on specific climate-sensitive diseases, such as skin, respiratory, and waterborne diseases.

(3) Training and technical assistance:

General training and technical assistance falls under three general categories:

- Health information systems should be improved at all levels.
- Services should include education, training, technical assistance, and public health infrastructure (for example, water resources and sanitation).
- Community attributes should include social cohesiveness, networking for wider support systems and community response and participation.

Further recommendations for expanding information systems:

- Establishing integrated health surveillance and environmental monitoring, and include laboratory testing and clinical diagnosis methods.
- Enhancing communication skills, including coordination between clinical, laboratory and public health staff.

Further recommendations for expanding services:

- Training of health professionals in environmental monitoring methods, such as vector monitoring and water quality tests and strengthen environmental monitoring. In addition, intersectoral training, bringing together experts from multiple disciplines, is a priority.

- Improving understanding of and expertise in the use of tools, such as software tools, available to assess vulnerability of and adaptation of climate variability and change.

- Providing user-friendly climate forecasts and applications information at the national and regional levels. Accurate and simple information, translated into simple language, should include information about floods and droughts, tropical cyclones, temperature and sea level variability.

- Providing seasonal temperature and rainfall forecasts and historical graphs and trends for each island/locality.

ANNEX 1

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ANNEX 2

PROGRAMME OF ACTIVITIES

25 July 2000, Tuesday

0800 ♦ Registration

0830 ♦ Opening ceremony

- Introductory remarks by Dr Carlos Corvalán, Scientist, WHO, Geneva
- Opening prayer by Reverend Falefatu Enari
- Remarks by His Excellency Tuiloma Neroni Slade, Ambassador & Permanent Representative of Samoa to the United Nations and Chairman of AOSIS
- Remarks by Mr Henry Taiki, on behalf of Prof. G.O.P. Obasi, Secretary General, WMO
- Remarks by Dr Hiremagalur Gopalan, on behalf of Dr Klaus Toepfer, Executive Director, UNEP
- Speech by Ms Pamela Messervy, Acting WHO Representative in Samoa, on behalf of Dr Shigeru Omi, WHO Regional Director for the Western Pacific
- Opening address by Hon. Misa Telefoni, Minister of Health, Samoa

0930 ♦ Coffee Break

1000 ♦ Selection of meeting officers (Chairman, Vice Chairman, Rapporteur)

Administrative briefing by Dr Hisashi Ogawa, Regional Adviser in Environmental Health, WHO/WPRO

1010 ♦ Keynote address by Dr Jonathan Patz, WHO Consultant, on Climate Change and Health for Small Island States: Need for Integrated Approach

Objective 1: Review and share the experiences of impacts of climate variability

1040 ♦ Session on Regional Health/Climate Initiatives

- South Pacific Regional Environment Programme (SPREP) Gerald Miles
- Contributions from participants

1110 ♦ Climate Change and Climate Forecasting

- The Climate System - Nick Graham
- Climate Forecasting - Chip Guard
- Contributions from participants

1220 ♦ Lunch

1340 ♦ Climate and Health Applications

- Regional vulnerability to climate change – Alistair Woodward
- ENSO and infectious diseases in the Region – Nancy Lewis, WHO Temporary Adviser
- Case Studies in Regional Climate/Vector- and food-borne diseases - Simon Hales, WHO Temporary Adviser
- Dengue fever modelling – Dana Focks
- Leptospirosis, climate and agriculture – Navi Litidamu, Fiji School of Medicine (FSM)
- Contributions from participants

1530 ♦ Coffee Break

1550 ♦ Climate and water supplies - Rishi Raj (WMO)

1610 ♦ US national assessment on climate variability and change – Joel Scheraga (USEPA)

1645 ♦ South Pacific Regional and national assessments

- Juli Trtanj, National Oceanic and Atmospheric Administration (NOAA)
- Fiji Case Study – Atu Kalowmaira, South Pacific Applied Geoscience Commission (SOPAC)

- Contributions from participants
- Charge for remaining workshop – Mike Hamnett, WHO Temporary Adviser

1800 ♦ Close day

1810 ♦ Reception hosted by Dana Focks

26 July 2000, Wednesday

Objectives 2 and 3: Learn linkages between climate change and health, tools available for predicting climate change and the associated health impacts, possible mitigation measures and tools available on Internet

0830 ♦ Orientation and overview of workshop sessions -Jonathan Patz and Mike Hamnett

0900 ♦ Plenary Session - Determining nation/specific key climate/health issues, drawing upon data brought to meeting.

1000 ♦ Coffee break and group photograph

1030 ♦ Plenary Session (continued).

1230 ♦ Lunch

1330 ♦ El Niño forecasting and application –ChipGuard,

1430 ♦ Group exercise (3 groups)

Application of the regional climate forecast in previous session to the following three questions and determine risks across health and health related sector. Will consider: (1) seasonal wet/dry variability; (2) ENSO; and (3) cyclone effects.

- Is there a significant difference in the monthly incidence of dengue fever, diarrheoal disease, or any other major illness in the wet season and in the dry season or in the transition from one season to another?
- Has there been a significant difference in the incidence of dengue fever, diarrheoal disease or any other major illness during El Niño (1982-83, 1986-87, 1991-92, 1994-95, and 1998-98) and La Nina (1984-85, 1988-89, 1995-96, 1999-99) years?
- Has there been a significant increase or decrease in the incidence of dengue fever, diarrheoal disease or any other major illness associated with extreme weather or climate events such as cyclones, floods or droughts?

1530	♦	Coffee break
1600	♦	Group exercise (continued).
1700	♦	Close day

27 July 2000, Thursday

0830	♦	Introduction to dengue simulation modelling – Dana Focks
1030	♦	Coffee break
1100	♦	Dengue simulation and field simulation
1230	♦	Lunch
1400	♦	Integrated National-Scale Models for Climate Impact Assessment - Richard Warnick, University of Waikato
1500	♦	Coffee break
1530	♦	Report back on group exercise and discussion on current information gaps and future needs

- What were the key risks?
- What data are available at established information networks (e.g. PACNET)?
- What are key information needs?
- What are the possible mitigation/management actions?
- How can information be translated into decisions?

1700	♦	Close day

28 July 2000, Friday

0830	♦	Regional institutional resources and initiatives and international data sources (summary from day 1, with brief presentations on activities by SPREP, SOPAC, PEAC)
1030	♦	Coffee Break

Objectives 4 and 5: Develop plans and recommendations for sustainable future activities in the Region

1100	♦	Round table discussion: Recommended sustainable future activities in the Region (e.g. research needs; networking, etc.)
1230	♦	Lunch
1330	♦	Drafting of workshop conclusions by a small group consisting of meeting officers and secretariat members
1500	♦	Closing of the workshop • Adoption of workshop conclusions • Closing remarks

ANNEX 3

LIST OF DOCUMENTS DISTRIBUTED DURING THE WORKSHOP

WPR/HSE/EUD(O)(1)2000.IB1	-	Information Bulletin 1
WPR/HSE/EUD(O)(1)2000.IB2	-	Information Bulletin 2 (List of participants, temporary advisers, consultant, observers, resource persons and secretariat
WPR/HSE/EUD(O)(1)2000.1	-	Provisional Agenda
WPR/HSE/EUD(O)(1)2000.1a	-	Programme of Activities
WPR/HSE/EUD(O)(1)2000.1b	-	Timetable
WPR/HSE/EUD(O)(1)2000.2	-	Climate Change and Health for Small Island States: Need for Integrated Approach
WPR/HSE/EUD(O)(1)2000/INF.1	-	Climate Change and Variability: Regional Initiatives and Health Impacts in Pacific Island Countries
WPR/HSE/EUD(O)(1)2000/INF.2	-	Establishing an Effective Regional Climate Information and Prediction Services Partnership
WPR/HSE/EUD(O)(1)2000/INF.3	-	The Island Climate Update
WPR/HSE/EUD(O)(1)2000/INF.4	-	ENSO Impacts on Water Resources in the Pacific: A Workshop for Water Managers, Disaster Managers and Meteorological Services on ENSO Response and Mitigation Planning, 19-22 October 1999, Nadi, Fiji
WPR/HSE/EUD(O)(1)2000/INF.5	-	El Niño and the Dynamics of Vector-borne Disease Transmission
WPR/HSE/EUD(O)(1)2000/INF.6	-	Small Island States
WPR/HSE/EUD(O)(1)2000/INF.7	-	Impacts on Global Environmental Change on Future Health and Health Care in Tropical Countries
WPR/HSE/EUD(O)(1)2000/INF.8	-	The Effects of Changing Weather on Public Health
WPR/HSE/EUD(O)(1)2000/INF.9	-	Climate Research: Interactions of Climate with Organisms, Ecosystems and Human Societies

WPR/HSE/EUD(O)(1)2000/INF.10	-	(DRAFT) Pacific Island's Framework for Action on Climate Change, Climate Variability/ and Sea Level Rise
WPR/HSE/EUD(O)(1)2000/INF.11	-	Predicting High-Risk Years for Malaria in Colombia using Parameters of El Niño Southern Oscillation
WPR/HSE/EUD(O)(1)2000/INF.12	-	Hydrologic Research Center: Prospectus for an HRC Initiative – April 2000 (Regional Flash Flood Warning for Central America)
WPR/HSE/EUD(O)(1)2000/INF.13	-	Climate Change Information Kit
WPR/HSE/EUD(O)(1)2000/INF.14	-	Climate Change and Human Health. An assessment prepared by a Task Group on behalf of the World Health Organization, the World Meteorological Organization and the United Nations Environment Programme
WPR/HSE/EUD(O)(1)2000/INF.15	-	Weather, Climate and Health, World Meteorological Organization 1999, Geneva – No. 892
WPR/HSE/EUD(O)(1)2000/INF.16	-	WMO at a Glance (pamphlet)
WPR/HSE/EUD(O)(1)2000/INF.17	-	ENSO Climate Events and Human Health in the Pacific Islands, Nancy D. Lewis, Department of Geography, Michael P. Hamnett, Social Science Research Institute, University of Hawaii, Liem Tran, Pennsylvania State University, prepared for the WHO Workshop on Climate Variability and Change and Their Health Effects in the Pacific, Apia, Samoa, 25-28 July 2000
WPR/HSE/EUD(O)(1)2000/INF.18	-	Reports to the Nation: on our Changing Planet. Our Changing Planet, University Corporation for Atmospheric Research, Fall, 1997.
WPR/HSE/EUD(O)(1)2000/INF.19	-	The Pacific ENSO Applications Center and the 1997-98 ENSO Warm Event in the US-Affiliated Micronesian Islands: Minimizing Impacts through Rainfall Forecasts and Hazard Mitigation, M. Hamnett, C. Guard, C. Anderson, PEAC Progress Report, October 1999.
WPR/HSE/EUD(O)(1)2000/INF.20	-	Program on Health Effects of global Environmental Change, Johns Hopkins School of Public Health
WPR/HSE/EUD(O)(1)2000/INF.21	-	Climate Change and Human Health: Impact and Adaptation, World Health Organization, May 2000

WPR/HSE/EUD(O)(1)2000/INF.22	-	South Pacific Seasonal Outlook Reference Material, (DRAFT) Issue 3 July 2000, August-September-October 2000, Bureau of Meteorology, National Climate Centre.
WPR/HSE/EUD(O)(1)2000/INF.23	-	Climate Information Digest, June 2000, International Research Institute for Climate Prediction, Volume 3, Number 6.
WPR/HSE/EUD(O)(1)2000/INF.24	-	Strategic Action Plan: for the Development of Meteorology in the Pacific Region, 2000-2009, December 1999, World Meteorological Organization, South Pacific Regional Environment Programme, Bureau of Meteorology.
WPR/HSE/EUD(O)(1)2000/INF.25	-	The World Meteorological Organization Address at the Workshop on Climate Variability and Change and Their Health Effects in Pacific Island Countries, Apia, Samoa, 25-28 July 2000.
WPR/HSE/EUD(O)(1)2000/INF.26	-	El Niño and Health: Protection of the Human Environment, Task Force on Climate and Health, Geneva 1999, Published by World Health Organization Sustainable Development and Health Environments
WPR/HSE/EUD(O)(1)2000/INF.27	-	Setting an Agenda for Research on Health and the Environment, Workshop 1: Health and Climate Variability, Final Workshop Report, December 1999.

ANNEX 4
SUMMARY OF SELECTED PRESENTATIONS

Climate Change and Health for Small Island States: Keynote and charge to the Workshop

Jonathan Patz
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This regional workshop is extremely timely, coming on the heels of the strongest El Niño ever recorded, which caused widespread disruptions in human welfare. This reminder of current extremes in climate of today, makes such a regional workshop relevant both for improving adaptation to present risks and to best plan for risks in the future.

According to the UN Intergovernmental Panel on Climate Change (IPCC), small island states are likely the most vulnerable countries in the world to projected climate change. Many direct physical and ecological threats exist for these nations that pose risks to human health and welfare, and among the primary goals of this workshop is to inform stakeholders in the region about these health vulnerabilities and adaptive measures that can be adopted to reduce the risks.

There are three well-recognized physical consequences of climate change: 1) temperature rise; 2) sea level rise; and 3) extremes in the hydrologic cycle. These physical attributes of climate change are expected to:
- increase the frequency of heat waves and potentially air pollution episodes;
- alter the distribution and incidence of vector- and water-borne diseases;
- increase the number of extreme weather events;
- cause coastal flooding and salination of fresh water aquifers.

Potential health effects from these consequences are illustrated in figure 1.

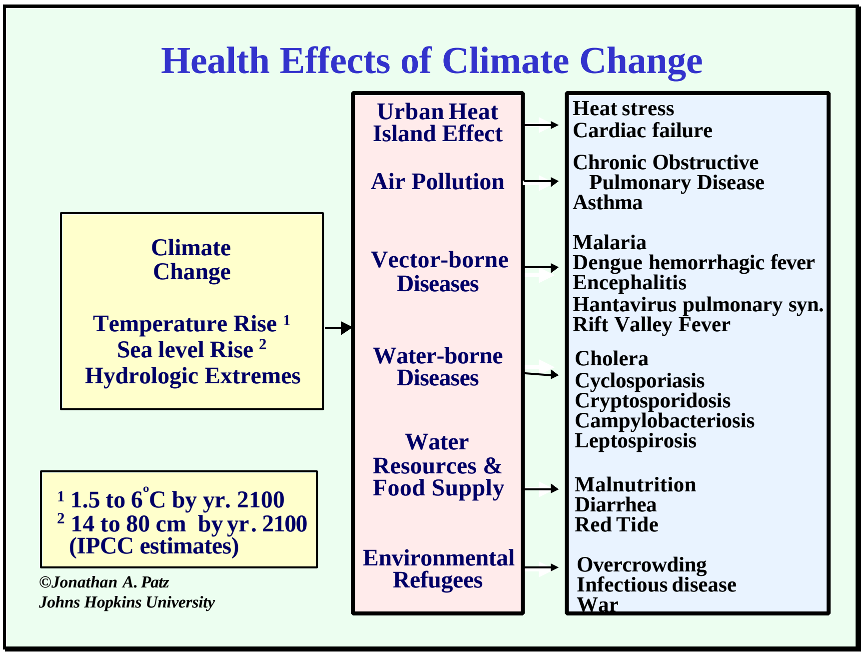

Figure 1: Schematic of public health outcomes anticipated from climate change.

Workshop objectives:

- Review & share ongoing studies in region on health and climate variability / change.
- Learn tools available for predicting regional climate variability & apply these to local health impacts.
- Assess potential for mitigation measures (e.g., case study -Dengue Fever)
- Develop plans and recommendations for sustainable future activities in the Region

Workshop themes:

- El Niño climate variability may provide window into future climate change.
- Short-term variability will be superimposed on long-term trends.
- Impacts cut across sectors and so require integrated assessments.
- Prediction better enables prevention

Many small island states rely on a single source for their water supply such as groundwater, rainwater, surface reservoirs, or shallow wells that draw from freshwater lenses just beneath the surface. Agriculture of subsistence food crops and crops for export in the tropical Pacific may be adversely affected by changes in precipitation; rising temperatures causing heat stress; salinization resulting from sea level rise; and extreme events such as cyclones, floods, or droughts. Coral reefs are likely to experience adverse effects from a range of climate change related events such as increases in sea-water temperature, sea-level rise, and changes in storm patterns and coastal currents.

Therefore, health related areas to which the workshop will link include:

- water resources, including availability and quality
- agriculture, farming practices, and fisheries
- health of coral reefs
- coastal settlement
- land use planning (related to sea level rise)
- disaster planning (related to storms)

A rise in sea level could result in saline contamination of estuaries and aquifers, direct inundation of low-lying areas, shore erosion, destruction of coral reefs and fisheries, and exacerbation of coastal flooding and storm damage. IPCC projections for climate change from 1990 to 2100 are an increase in temperature ranging from 1.5 to 6.0°C, and a rise in sea level of ranging from 14 to 80 cm. The projected rise in sea level is primarily due to thermal expansion as the ocean waters warm, but also due to increased melting of glaciers.

Sea level Rise (mid-value 49 cm)

- 13 of 20 "Megacities" are at sea level
- Doubled population at risk from storm surges, from 45 million to 90 million
- Saline intrusion of fresh water aquifers for drinking and agriculture
- Sewage contaminated storm runoff

Figure 2 Sea Level Rise

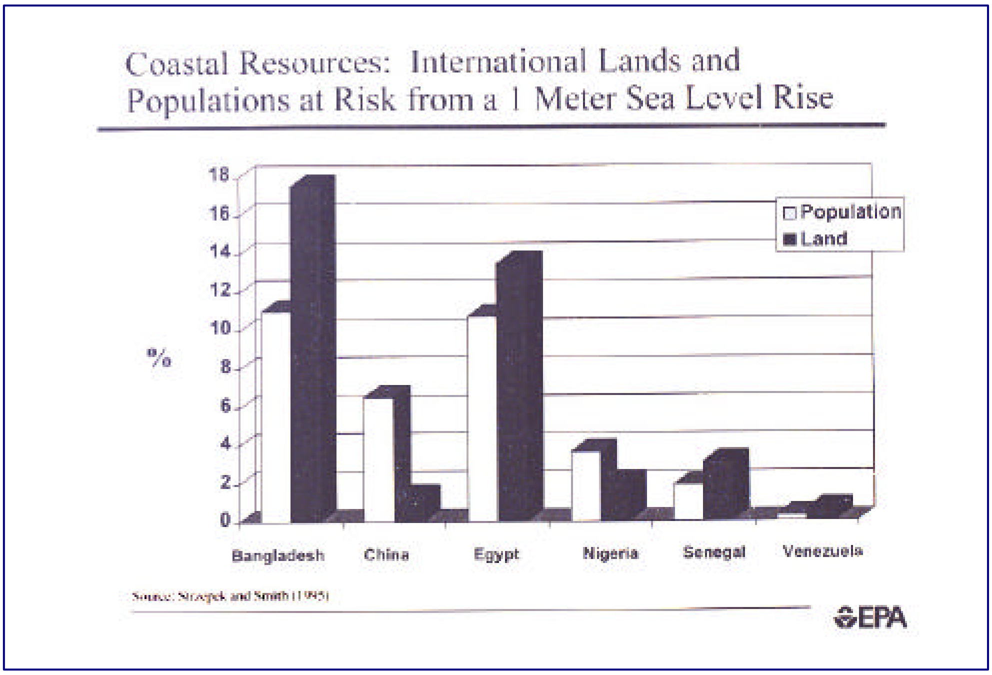

Figure 3 Population at risk of a one meter sea level rise

Figures 2 and 3 (above) illustrate some of the general consequences of sea level rise, with some examples of the proportion of populations and lands affected in other parts of the world. Source: Strzepek and Smith 1995; graph per US EPA.

Strategies for reducing more immediate health threats related to climate change include effective health education programs, improvement of health care infrastructure, disaster preparedness plans, vector monitoring and control, and appropriate sewage and solid-waste management practices. Adaptations for the longer term include decreasing human population growth and slowing emissions of greenhouse gases.

Some adaptive measures to global climate change include:

- Improve health surveillance
- Integrate climate forecasting and weather watch-warning systems with public health information
- Educate the public about climate changes and protective actions
- Develop emergency management and disaster preparedness programs

Case Studies in Regional Climate/Vector- and Food-borne Diseases

Simon Hales

Ciguatera

To investigate the relationship between ciguatera (fish poisoning) and regional climate, incidence data for fish poisoning from 1973 to 1994 were obtained from the Secretariat of the Pacific Community. Data from the International Research Institute for Climate Prediction data library were used to estimate sea surface temperatures (SST).

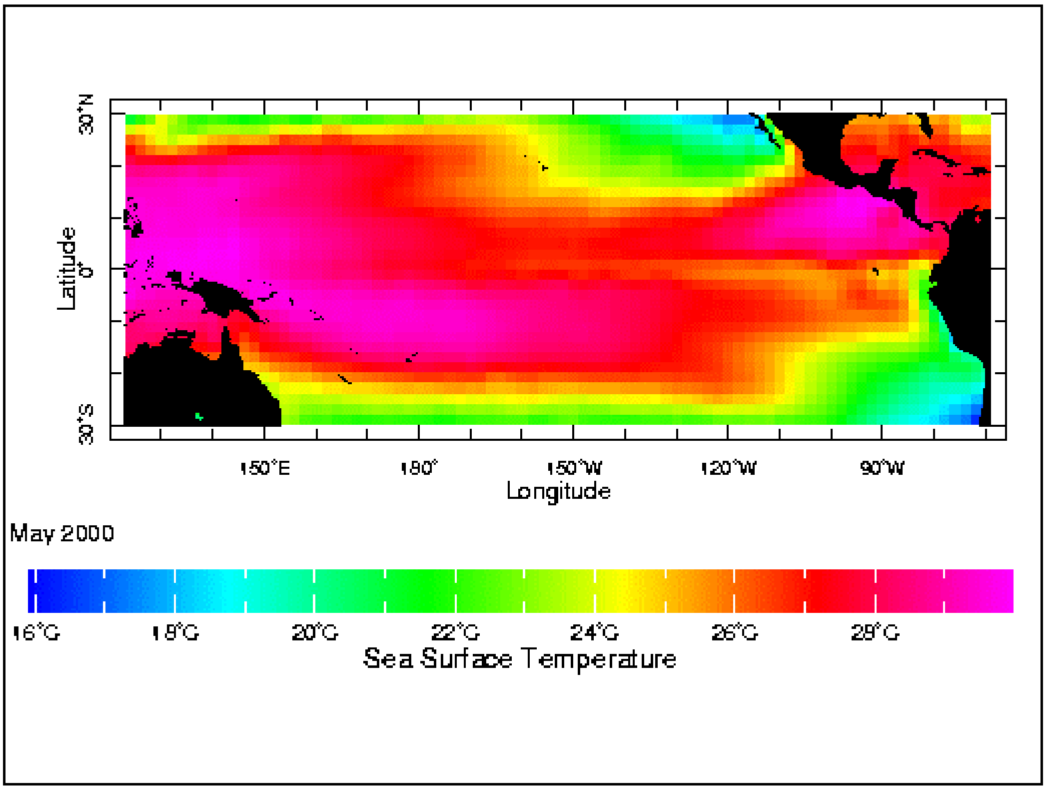

Figure 1: Maps such as this show average SSTs.
Source: IRI/LDEO Climate Data Library (http://ingrid.ldgo.columbia.edu/).

Pearson correlations were calculated using January to December annual averages of Southern Oscillation Index (SOI), sea surface temperature (SST), and ciguatera fish poisoning reports. Average fish poisoning reporting rates were calculated based on 1994 populations.

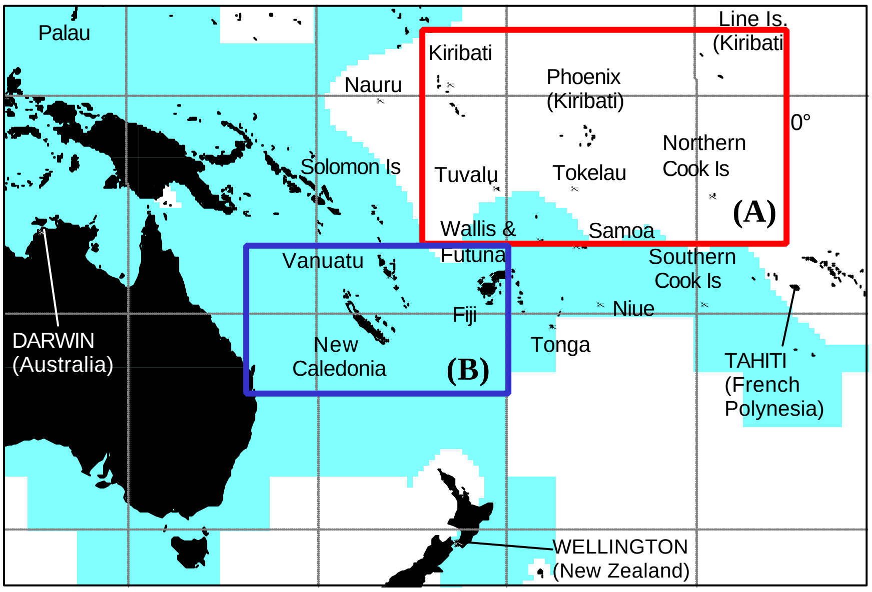

Figure 2: This map illustrates the group of Eastern Pacific islands (A) that experience warmer SST's during El Niño events and the group of Western Pacific islands that are less warm during an El Niño event (B).

Positive correlations between the annual incidence of ciguatera fish poisoning and El Niño events were found in the Eastern Pacific islands which experience warmer SST's during El Niño events. Small negative correlations were found between the annual incidence of fish poisoning and El Niño events in the Western Pacific islands that experience no warming during El Niño events.

	local SST vs SOI	fish poisoning vs local SST
(A)		
Tuvalu	**-0.76**	**0.65 *** **
Rarotonga	**-0.51**	**0.61 ** **
Kiribati	**-0.93**	**0.54 * **
Western Samoa	**-0.53**	**0.49 * **
French Polynesia	**-0.81**	**0.13**
(B)		
Fiji	**0.70**	**-0.05**
Vanuatu	**0.74**	**-0.17**
New Caledonia	**0.78**	**-0.24**

Figure 3: This table shows the correlation coefficients between local SST vs. SOI (Southern Oscillation Index) in the first column, and fish poisoning rates vs. local SST in the second column. Stars indicate statistical significance.

Dengue

To examine the possible relationship between dengue and climate, a literature search was conducted to determine the annual number of dengue epidemics between 1970 and 1998. This number was then correlated with the SOI from the same time period. Dengue epidemics, it was discovered, tend to be initiated in La Nina years. Two exceptions to this occurred in 1972 and 1997 during which time the epidemics were initiated during El Niño years.

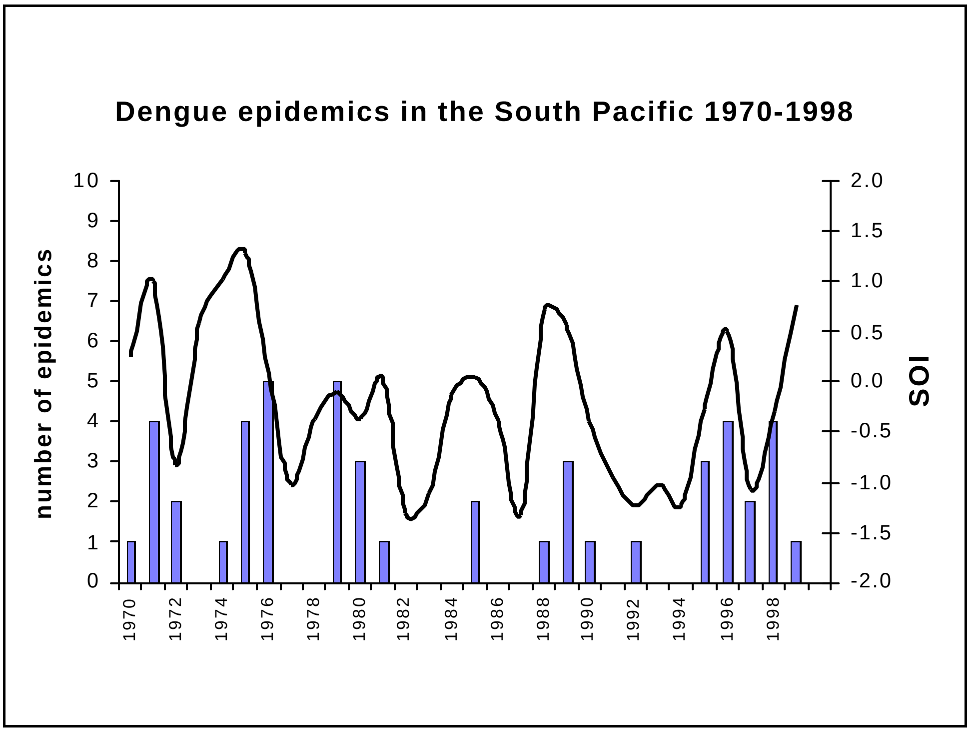

Figure 4: The line indicates SOI (higher SOI is associated with La Nina, lower SOI is associated with El Niño events) while the bars indicate dengue epidemics.

La Niña events are associated with higher rainfall than usual in some islands, as indicated in Figure 5. These islands also tend to be warmer during La Niña events. In general, the islands that were wetter and warmer during La Niña events had a greater number of dengue epidemics. There was also some evidence of island-to-island spread of dengue epidemics. Therefore, local variability also influences when and where epidemics will occur.

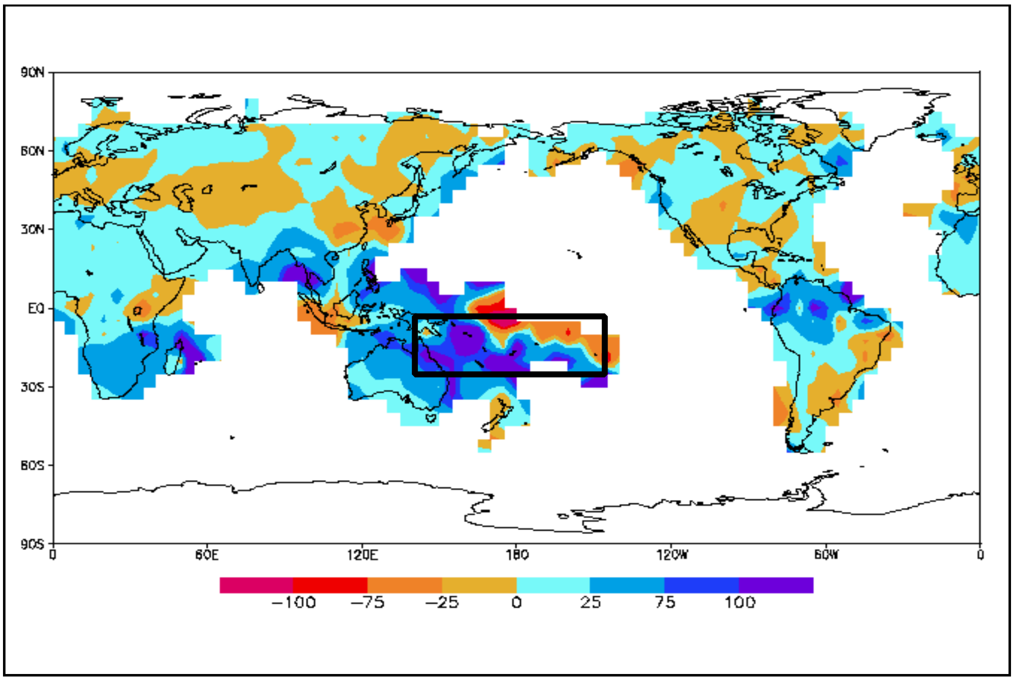

Figure 5: Shows the amount of change from normal rainfall patterns.

Diarrheal Disease

To investigate a possible link between diarrheal disease and climate, monthly reports of diarrhea in infants for Fiji were obtained for the time period from 1978 to 1989 (SPC data). National climate estimates (temperature and rainfall) were obtained. Regression analysis shows increased diarrhea at extremes of rainfall in the same month and increased diarrhea with increasing temperature in the same month, and for one month later. The findings are limited by the following weaknesses: 1) climate estimates are crude, 2) data is sparse, and 3) diarrhea data is aggregated and not disease specific, but biological mechanisms linking climate and diarrhea may not be very disease specific either.

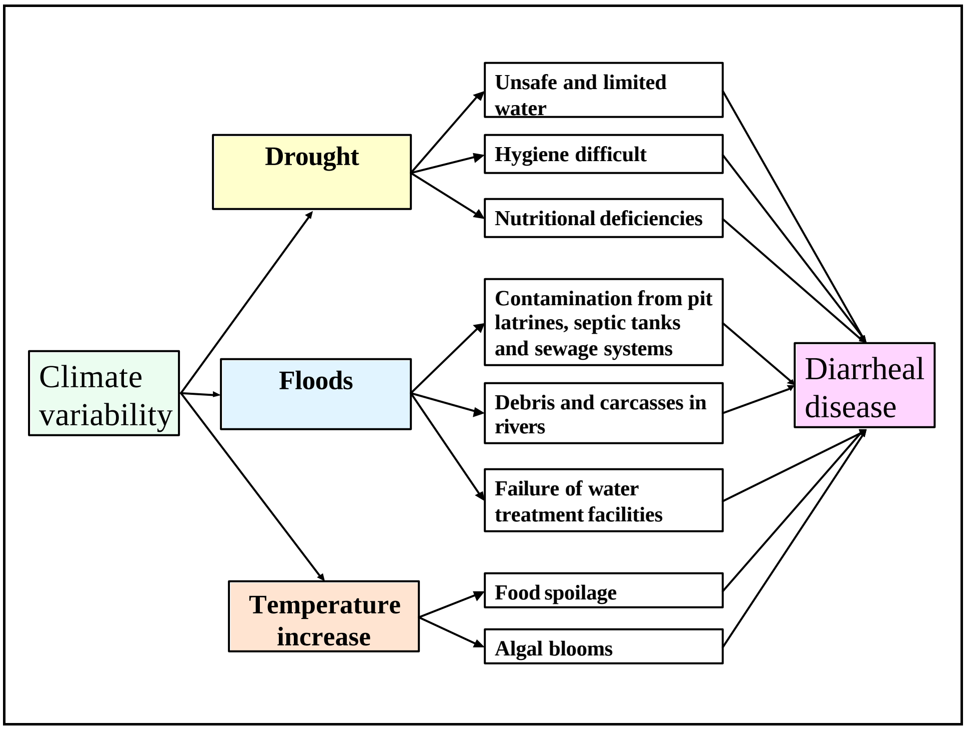

Figure 6: This diagram shows various ways that diarrheal disease may be linked to climate.

In summary, there are a variety of factors contributing to the development of disease outbreaks, including, but not limited to, climate. Climate forecasts, therefore, should be used to predict an increased *risk* of a disease outbreak such as ciguatera fish poisoning, dengue, or diarrheal disease. Accurate climate forecasting can provide valuable information to public health officials about how, when, and where to concentrate resources to avert epidemics.

Climate and Water Supplies

Rishi Raj

There is a variety of geographical attributes found in the Pacific islands. Some of the larger islands like Papua New Guinea, Solomons, and Fiji have significant elevation while others are low lying small coral atolls such as Kiribati, Marshall Islands, Tonga, and Nuie. Natural resources, including water, also range from scarce to abundant. Some islands have abundant surface water while other are completely dependent on ground water. Water requirements are just as diverse. Some islands have large commercial or industrial centers, others have extensive agricultural water needs. Social, cultural and economic settings are just as varied. Any assessment of water resources and vulnerabilities, therefore, requires a tailored approach and local information.

The Pacific islands generally experience two distinct seasons which are outlined in figures 1 and 2.

Climate and Water Supplies
CLIMATE INFLUENCE

- Tropical oceanic climate with distinct seasons:
- Two seasons
  - **warm wet season**
    - » around November to April
    - » season *infested* with tropical cyclones - abundance of water;
    - » Threats of water damage - Floods are common.
    - » Up to 80% of annual total rainfall is received
    - » Up to 25% of annual total can occur in one storm (over several days)
  - Excessive water creates other problems
    - » Taxes water treatment facilities - excessive contamination. - health risk, threat to food security, landslides, environmental damage ….

Figure 1. Climate influence (Warm wet season)

Climate and Water Supplies
CLIMATE INFLUENCE

cool and dry season

» around May to October
» rain deficient period usually leeward side of islands more deficient
» 20 to 30% of annual rain over 6 months
» Higher water demand for cultivation season, high tourist arrivals. Agricultural product processing
» Over exploitation of ground water

Water deficiency creates other problems

» depleting storage - problems with supply systems (airlocks)
» Contamination.risk increases; health risk, food production declines, forest fires and environmental damage ….
» Salinity problems with coastal ground water sources and contamination from wastes.

Figure 2 Climate influence (cool dry season)

Typically, El Niño Southern Oscillation events cause rain failures and water deficiencies in Vanuatu, New Caledonia, Fiji, Tonga, southern Cook Islands, French Polynesia, Marshall Islands and the Federated States of Micronesia. The freshwater supplies of almost all Pacific islands are threatened during times of drought. In addition to the scarcity of water during the regular dry season and times of drought, the quality of the water is also compromised. Figure 3 list factors that affect water quality during times of scarcity.

Climate and Water Supplies
SPECIFIC WATER SUPPLY ISSUES

- Quantity and Quality influenced by seasons

  Dry season

  » Domesticated and wild animals may share limited water from the same surface water source, risk contamination
  » Demand increases and minor sources deplete (including roof catchments)
  » Additional water requirements met from ground water raises the potential for saline intrusion and other underground contaminants.
  » With low volumes potential contaminant concentration rises

Figure 3. Specific water supply issues (Dry season)

Perhaps unexpectedly, an overabundance of water can also affect water quality. Factors that play a role in compromising water quality are listed in figure 4.

Climate and Water Supplies
SPECIFIC WATER SUPPLY ISSUES

- Quantity and Quality influenced by seasons

  Wet Season

  - » added contaminants - silt, debris, high bio-organic pollutants from variety of sources
  - » treatment requirements change - higher dosage of imported chemicals
  - » chlorination disinfectant may not be adequate
  - » Groundwater source contamination by storm surge, pollutants carried by overland wash

Figure 4. Specific water supply issues (Wet season)

Water may be an island's most precious resource. Global climate change may cause more frequent episodes of water supply extremes. A number of measures will be necessary to protect water resources. Timely, site-specific, reliable forecasts of impending droughts and floods that are rapidly disseminated to water resource managers and disaster planners will help. Better management of the demand for water supply, water storage, and water loss prevention will help conserve supplies during times of drought. More vigilant monitoring of water quality at all times, but especially during times of droughts or floods is imperative.

US National Assessment on Climate Variability and Change

Joel Scheraga

Climate change will pose risks to human health, some more direct than others. Direct effects include heat stress and weather-related mortality. There are other potential effects that are more indirect. Some of these are listed in Figure 1. This figure also points out the intersectoral nature of climate change impacts.

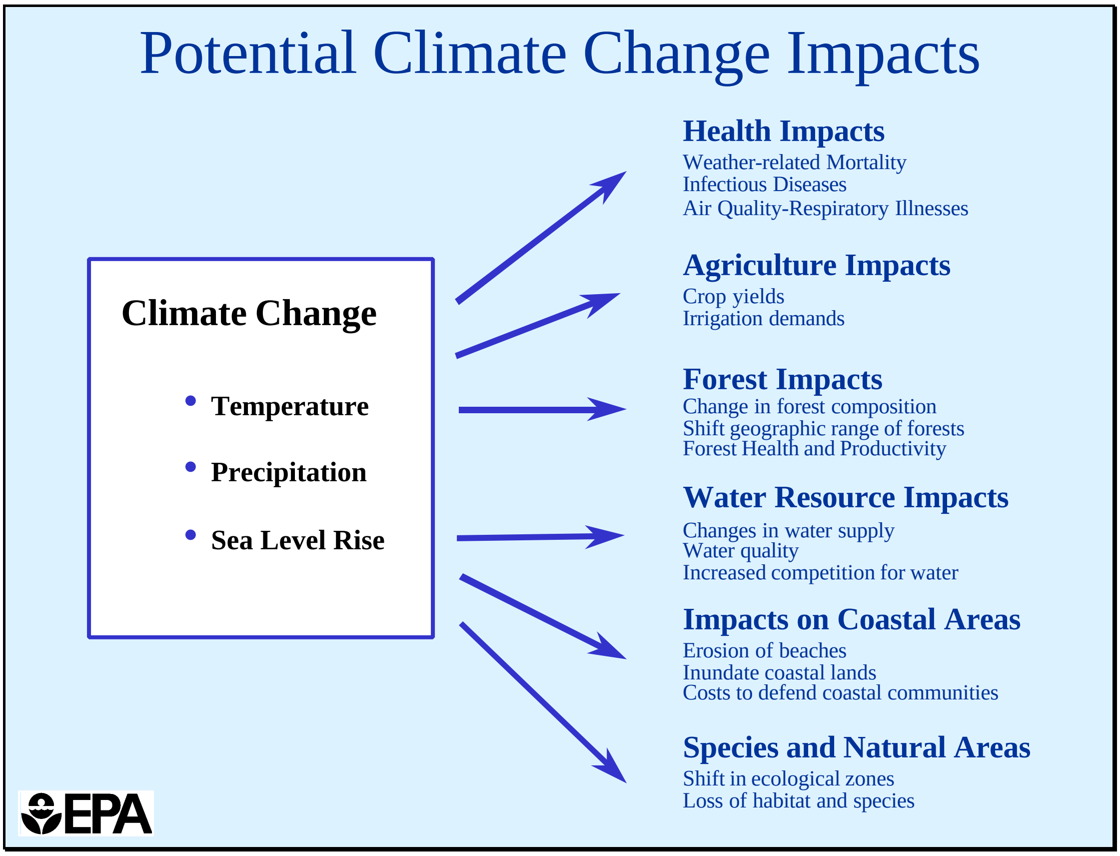

Figure 1 Potential climate change impacts

More specific ways that global change can affect human health are outlined in Figure 2. As can be seen in Figure 2, these impacts can be multiple, simultaneous, and significant. One of the many challenges to policy makers and resource managers, then, is how to cope with all of these potential impacts as they occur at the same time.

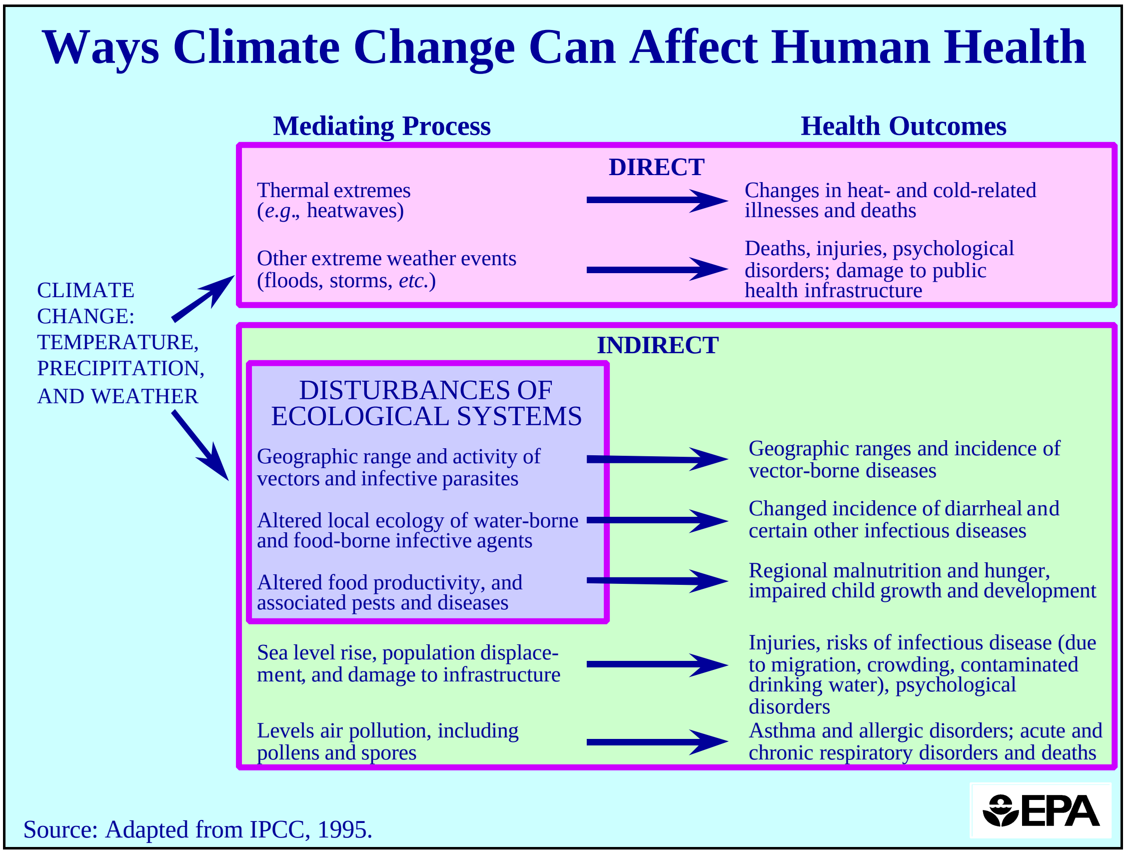

Figure 2 *How climate change can affect human health*

The United States recently completed its first National Assessment of “The Potential Consequences of Climate Variability and Change on the U.S.”. Key findings are outlined below (1):

1. *Increased warming*—Assuming continued growth in world greenhouse gas emissions the climate models used in this assessment project that temperatures in the US will rise 5-10° F on average in the next 100 years.
2. *Differing regional impacts*—Climate change will vary widely across the US. Temperature increases will vary somewhat from one region to the next. Heavy and extreme precipitation events are likely to become more frequent, yet some regions will get drier. The potential impacts of climate change will also vary widely across the nation.
3. *Vulnerable ecosystems*—Ecosystems are highly vulnerable to the projected rate and magnitude of climate change. A few, such as alpine meadows in the Rocky Mountains, and some barrier islands are likely to disappear entirely, while others, such as forests of the Southeast are likely to experience major species shifts or break up. The goods and services lost through the disappearance of fragmentation of certain ecosystems are likely to be costly or impossible to replace.
4. *Widespread water concerns*—Water is an issue in every region, but the nature of the vulnerabilities varies with different nuances in each. Drought is an important concern in every region. Floods and water quality are concerns in many regions. Snow pack changes are especially important in the West, Pacific Northwest, and Alaska.
5. *Secure food supply*—At the national level, the agriculture sector is likely to be able to adapt to climate change. Overall, US crop productivity is very likely to increase over the next few decades, but the gains will not be uniform across the nation. Falling prices and competitive pressure are very likely to stress some farmers.

6. *Near-term increase in forest growth*—Forest productivity is likely to increase over the next several decades in some areas as trees respond to higher carbon dioxide levels. Over the longer term, changes in larger-scale processes such as fire, insects, droughts, and disease will possibly decrease forest productivity. In addition, climate change will cause long-term shifts in forest species, such as sugar maples moving North out of the US.
7. *Increased damage in coastal and permafrost areas*—Climate change and the resulting rise in sea level are likely to exacerbate threats to buildings, roads, powerlines, and other infrastructure in climatically sensitive places, such as coastlines and the permafrost regions of Alaska.
8. *Other stresses magnified by climate change*—Climate change will very likely magnify the cumulative impacts of other stresses, such as air and water pollution and habitat destruction due to human development patterns. For some systems such as coral reefs, the combined effects of climate change and other stresses are very likely to exceed a critical threshold bringing large, possibly irreversible impacts.
9. *Surprises expected*—It is very likely that some aspects and impacts of climate change will be totally unanticipated as complex systems respond to ongoing climate change in unforeseeable ways.
10. *Uncertainties remain*—Significant uncertainties remain in the science underlying climate change impacts. Further research would improve understanding and predictive ability about societal and ecosystem impacts, and provide the public with useful information about adaptation strategies.

National assessments are a first step in determining vulnerability to the impacts of climate change. Perhaps some insight can be gained from the US National Assessment that might be helpful in other settings. In addition to the key findings listed above, the study concluded that there are significant regional differences in vulnerabilities to the effects of climate change; adaptive responses, therefore, must also be region-specific. When performing region-specific assessments, the four key questions listed in Figure 3 were found to be useful.

Key Questions to be Addressed by Assessments

Four Key Questions:

- What are the current primary characteristics of the region and the current stressors?
  - Ecological & health conditions
  - Socio-economic & cultural factors
- How will climate change & variability exacerbate or ameliorate stresses?
- What are possible coping & adaptation strategies?
- What is the most important missing information?

Figure 3 Questions to be addressed by assessments

With respect to adaptation, the following points of insight might prove useful (2):

- The effects of climate change vary by region.
- The effects of climate change may vary across demographic groups.
- Climate change poses risks and opportunities.
- The effects of climate change must be considered in the context of multiple stressors and factors.
- Adaptation comes at a cost.
- Adaptive responses vary in effectiveness.
- The systemic nature of climate impacts complicates the development of adaptation policy.
- Maladaptation can result in negative effects that are as serious as the climate-induced effects.
- Many opportunities for adaptation make sense whether or not the effects of climate change are realized, so called "no regrets" measures.

In summary, the potential health impacts of climate change are many, varied, and cross-sectoral. Adaptive responses will be more successful if they are designed to ensure that they are affordable, effective, and do not inadvertently lead to negative side effects that may be more severe than the problems they are trying to solve.

References:

1. Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change (Overview). National Assessment Synthesis Team, U.S. Global Change Research Program, Cambridge University Press, New York, 2000.

2. Scheraga, Joel D., and Anne E. Grambsch, "Risks, Opportunities, and Adaptation to Climate Change," Climate Research, Vol. 11, No. 1, 1998, 85-95.

Disaster Planning and Coastal Zone Management

Atu Kalowmaira

The Pacific region has developed several initiatives for disaster mitigation. South Pacific Applied Geoscience Commission (SOPAC) has assisted in the regional development of: 1) the establishment of National Disaster Management Offices, 2) National Disaster Management Plans, 3) support plans, 4) education and awareness programmes, 5) several manuals and guidelines, 6) training programs, and 7) pilot mitigation projects.

Fiji was used as a case study to describe a national strategy for drought disaster planning. Impact reduction is the main goal of disaster planning. The concept of introducing disaster planning and mitigation measures into social and economic activities to increase resilience and reduce vulnerability and loss is the base for developing national strategies. To do this, one must change national perceptions of disaster management and shift the focus from response and relief to pre-event risk reduction and preparedness measures.

As an example, the 1997-98 El Niño drought in Fiji is presented. First, the drought must be defined and perceived as a threat. A vulnerability assessment is then conducted so that problems can be anticipated and resources can be concentrated where most needed. The onset of a drought is slow and therefore good indicators and threshold criteria are needed. There is a lack of information about the past impacts of droughts. Impacts of drought may be more difficult to recognize because of the slow onset and a tendency for impacts to linger into subsequent years. Long-term social impacts are difficult to quantify as are micro-level economic impacts. Figure 1 illustrates the economic impact of the drought on sugarcane harvest.

When assessing vulnerability to disaster, multiple issues should be considered. Land use patterns, for example, can have huge impacts on the outcome of a disaster and therefore the disaster management plan. Some land use issues to consider include the use of marginal land such as steep slopes or coastal low lands. Urban issues to assess include the population density, the social structure, the standard of emergency medical services, and the general knowledge of sanitary measures. Water resources and use patterns are important for both urban and rural areas. Figures 2 and 3 illustrate water resources and waste patterns for Fiji.

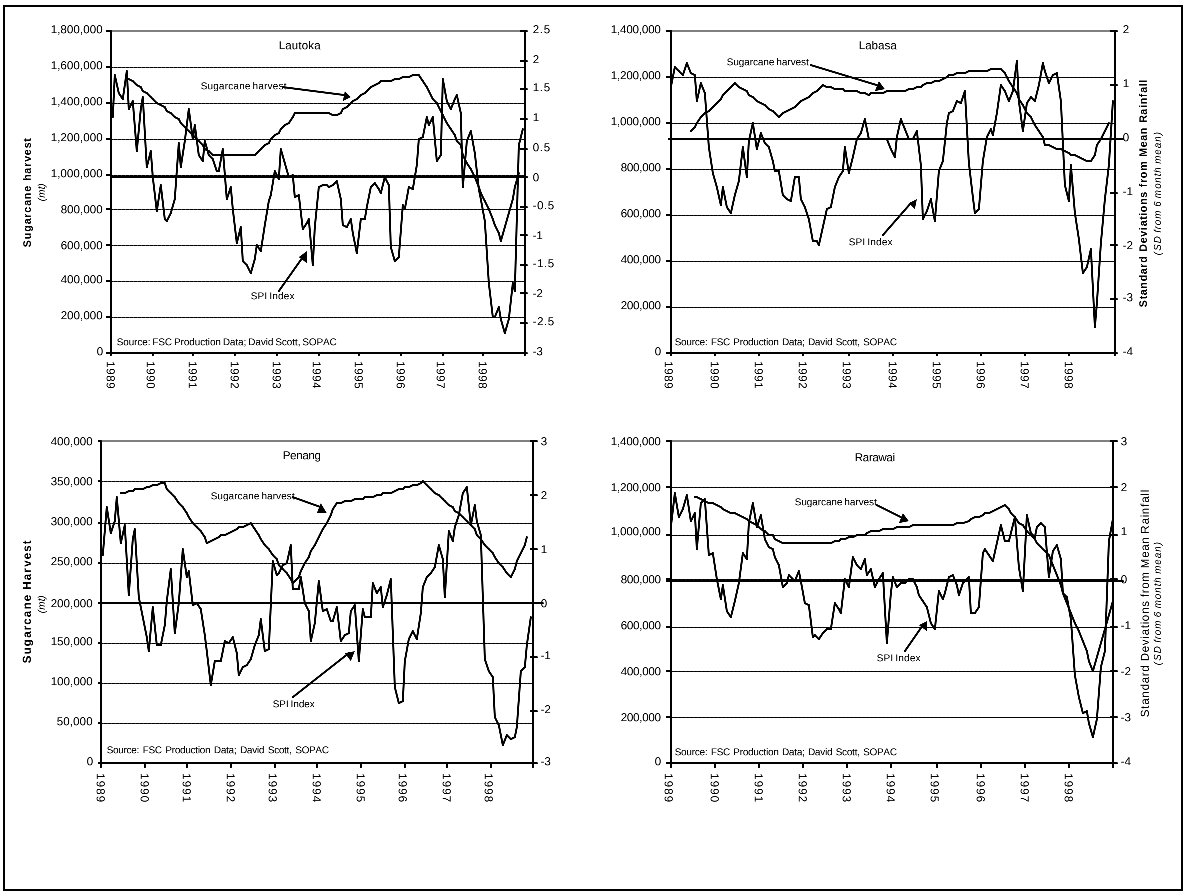

Figure 1: The top line in each chart shows the amount of sugarcane harvest from 1989 to 1999 in four locations in Fiji. The bottom line in each chart shows the number of standard deviations from average for rainfall. In all four locations, the amount of sugarcane harvested began to drop about midway through 1996 as rainfall increased, then plummeted in 1997 during the ensuing drought.

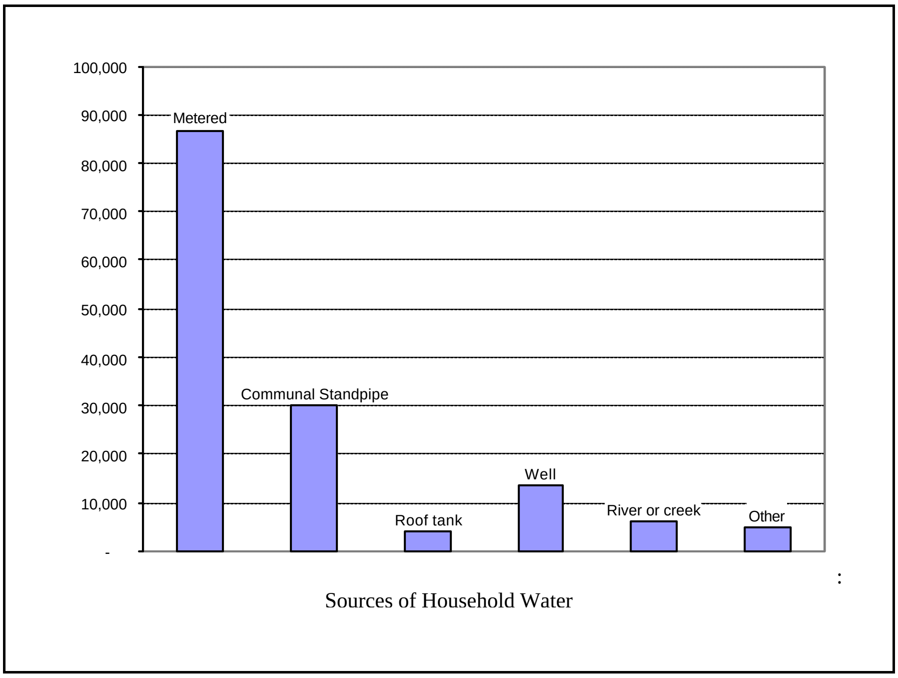

Figure 2: Shows the number of households in Fiji that obtain their water from metered vs. other sources.

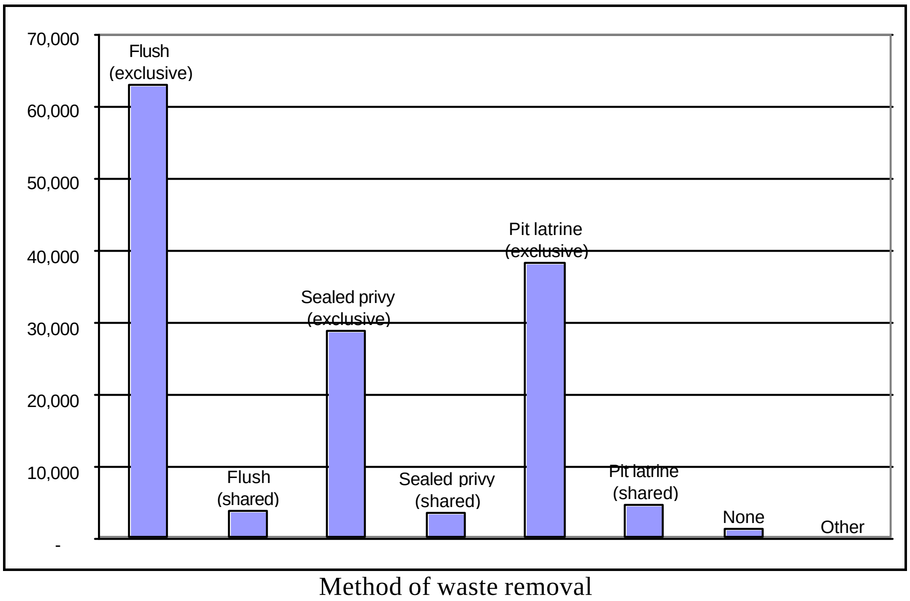

Figure 3: Shows the number of households in Fiji with flush toilets vs. other methods of waste removal.

Hazard or risk mapping is a technique that can be useful for the development of a disaster management plan. The map could include areas of important food sources, water sources, areas prone to inundation, coastal areas at risk of degradation, population centers, and other areas determined to be important or at risk.

Disasters may not be completely preventable, but with proper planning and preparedness, their negative impacts can be lessened.

Acknowledgements: Graphics from an unpublished report on "Regional El Niño Social and Economic Drought Impact Assessment and Mitigation Study" by Chris Lightfoot for the Disaster Management Unit, SOPAC.

Introduction to Dengue Simulation Modeling and Risk Reduction

Dana Focks

For a dengue epidemic to occur, must have virus present, enough *A. egypti* mosquitoes to effectively spread the virus (entomologic factors), and enough people who have not had that type of dengue virus before and are therefore not immune (seroprevalence). Dengue simulation modeling uses these factors to determine a "threshold" number (pupae/person/area), as is shown in Figure 1. Below the threshold, the risk of dengue epidemic is low; above the threshold number, the risk increases.

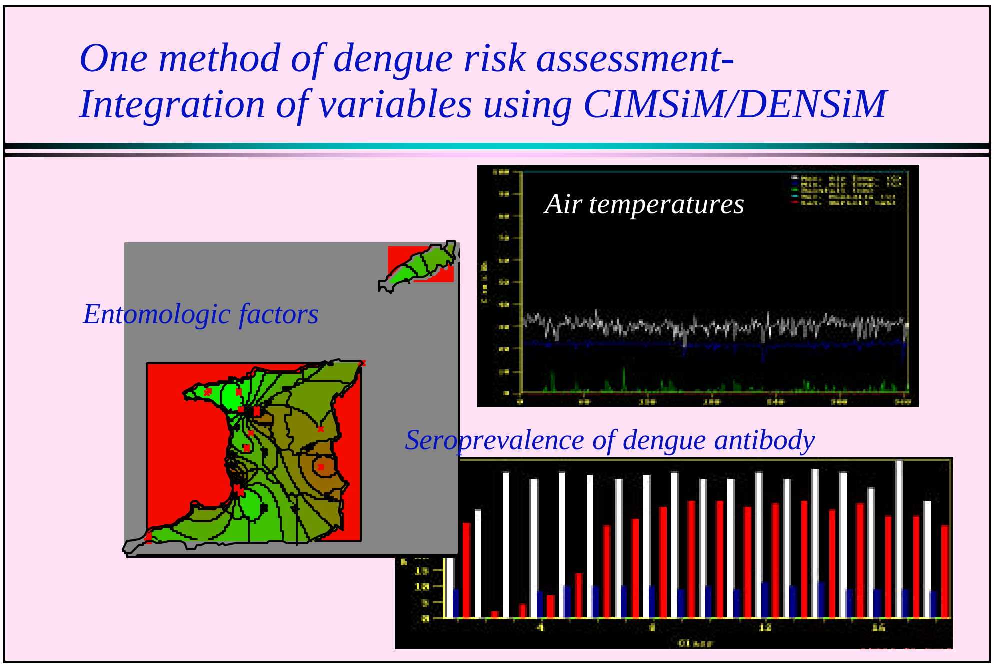

Figure 1: The Dengue simulation models look at local entomologic factors (in this case Trinidad), seroprevalence of dengue antibody in the population, and projected local air temperatures to determine a threshold number.

Temperature affects the rate at which virus develops inside the mosquito: the warmer the temperature, the faster the incubation and the faster the mosquito becomes infectious. The longer the mosquito lives after becoming infectious, the greater the transmission rates of dengue. Therefore, the threshold number decreases as temperature increases.

Note: Detailed information on dengue/modeling/threshold work can be found on the following papers:

- Focks, D. A. and D. D. Chadee. 1997. Pupal survey: An epidemiologically significant surveillance method for Aedes aegypti: An example using data from Trinidad. Am. J. Trop. Med. Hyg. 56: 159-167.
- Focks, D. A., R. J. Brenner, D. D. Chadee, and J. Trosper. 1998. The use of spatial analysis in the control and risk assessment of vector-borne diseases. Am. Entomologist. 45: 173-183..
- Focks, D. A., R. A. Brenner, E. Daniels, and J. Hayes. 2000. Transmission thresholds for dengue in terms of Aedes aegypti pupae per person with discussion of their utility in source reduction efforts. Am. J. Trop. Med. Hyg. 62: 11-18.

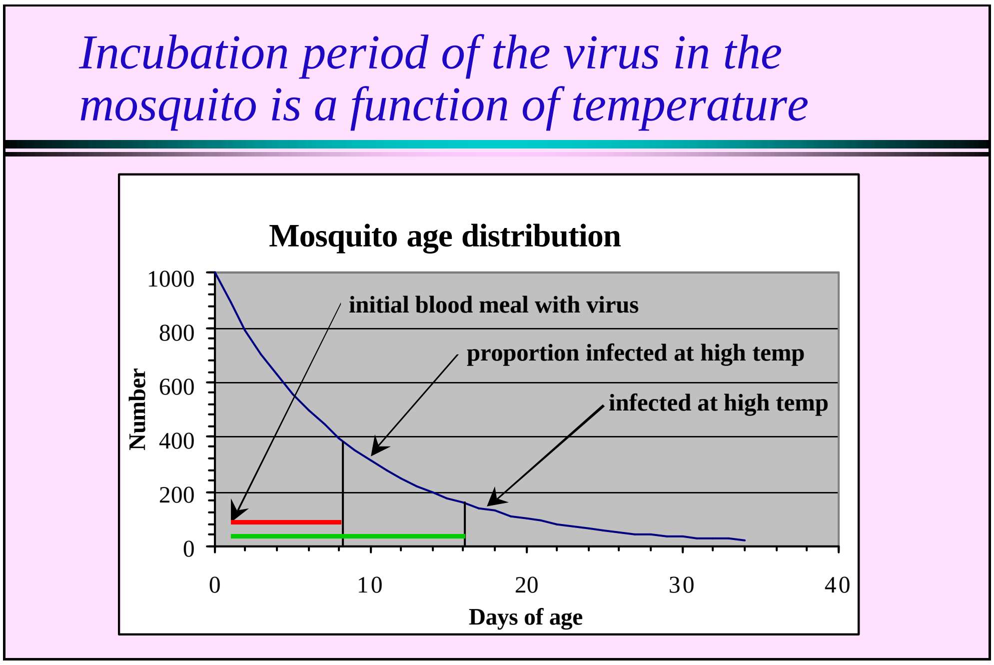

Figure 2. *Survival curve of a mosquito.*

The pupal development period, expected daily number of newly-emerged females, and associated standing crop of females of all ages for a standing crop of 100 Ae. aegypti pupae

Temp	Days	Number of adult females		Ratios of standing crops	
		New	Standing crop	Pupae/female	Females/pupa
22	4.06	10.2	88	1.14	0.88
24	3.33	12.5	107	0.94	1.07
26	2.66	15.6	134	0.75	1.34
28	2.04	20.4	175	0.57	1.75
30	1.46	28.4	244	0.41	2.44
32	0.92	45.2	388	0.26	3.88

Figure 3: Shows how much more rapidly the mosquito population (standing crop) increases as the temperature increases.

With higher temperatures, the mosquito becomes infectious more quickly, reproduces more quickly, and bites more frequently; all factors that increase transmission of dengue. Figure 4 demonstrates how the threshold numbers decrease as temperature increases and seroprevalence decreases.

Transmission thresholds assuming 12 monthly introductions of a single viremic individual by temperature and initial seroprevalence

Temp	Initial seroprevalence of antibody		
	0%	33%	67%
22	7.13	10.7	23.3
24	2.20	3.47	7.11
26	1.05	1.55	3.41
28	0.42	0.61	1.27
30	0.10	0.15	0.30
32	0.06	0.09	0.16

Figure 4: Shows how "threshold" numbers (pupae/person/area) decrease as temperature increases. This table also shows that if the level of herd immunity (seroprevalence) is high, the threshold number is also high. Below the threshold, the risk of dengue epidemic is low; above the threshold number, the risk increases.

Calculating the threshold number requires an accurate survey to determine the number of pupae/person/area. To obtain this number, Dr. Focks recommends household surveys be conducted in the following way:

1) Map out a measurable area.
2) Go into every 5th house and look for suspicious containers. Record the number of people living in the house.
3) Empty the containers by pouring the water through a screen.
4) Rinse the screen with clean water into a white basin so that the pupae can be seen.
5) Use a dropper to capture the pupae and put them into a vial.
6) Label the vial with same number as house number.
7) Allow adults to emerge and look under a microscope to see what kind of mosquito they are.
8) Count the number of pupae per person per area.

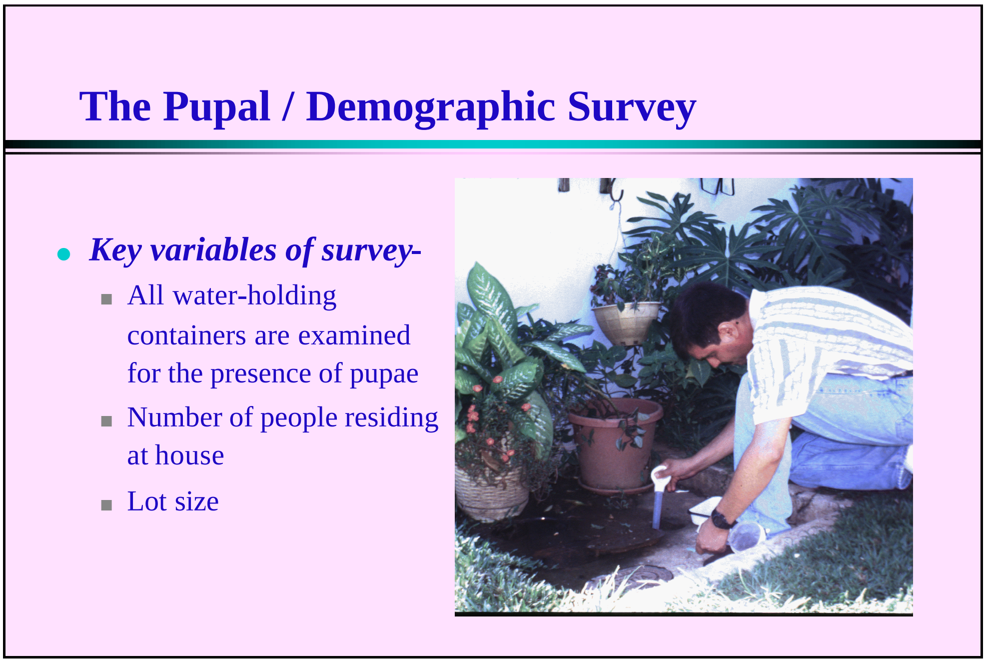

Figure 5: *Pupal/Demographic survey*

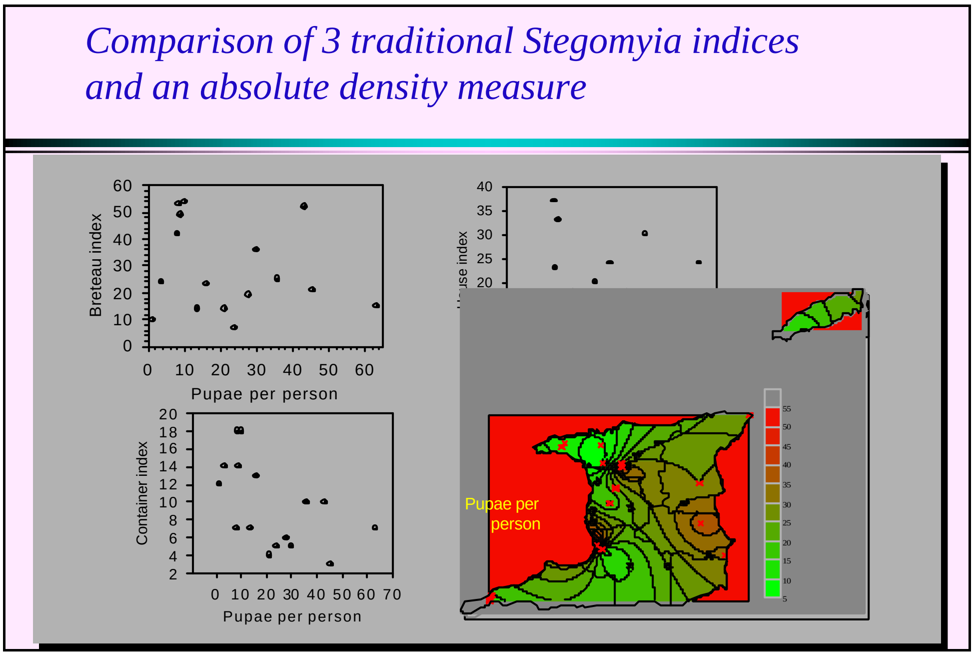

Figure 6: Shows several scales for calculating the number of pupae per person, then shows the actual pupae/person/area on a map of Trinidad. *(Focks DA, Chadee DD, 1997. Pupal survey: An epidemiologically significant surveillance method for Aedes aegypti: An example using data from Trinidad. Am J Trop Med Hyg 56: 159-167.)*

Certain types of containers have been found to regularly harbor a greater number of pupae in a particular area. In fact, in some areas less than 1% of the containers have been found to produce more than 95% of the adults. After the data from the household survey has been put into the model, Figure 7 shows how the model can be used to determine which types of containers are the most important. Since eliminating all water-holding containers would require tremendous resources and is probably not practical, resources can be targeted toward scrubbing (as in the case of household fresh water storage containers) or draining the most significant containers to get the pupae/person/area under the threshold number.

This method of targeting especially productive breeding containers has been found to be more cost effective than insecticides or more traditional source reduction. Control based on eliminating these high-production containers can be initiated in response to an epidemic or a climate forecast of higher temperatures.

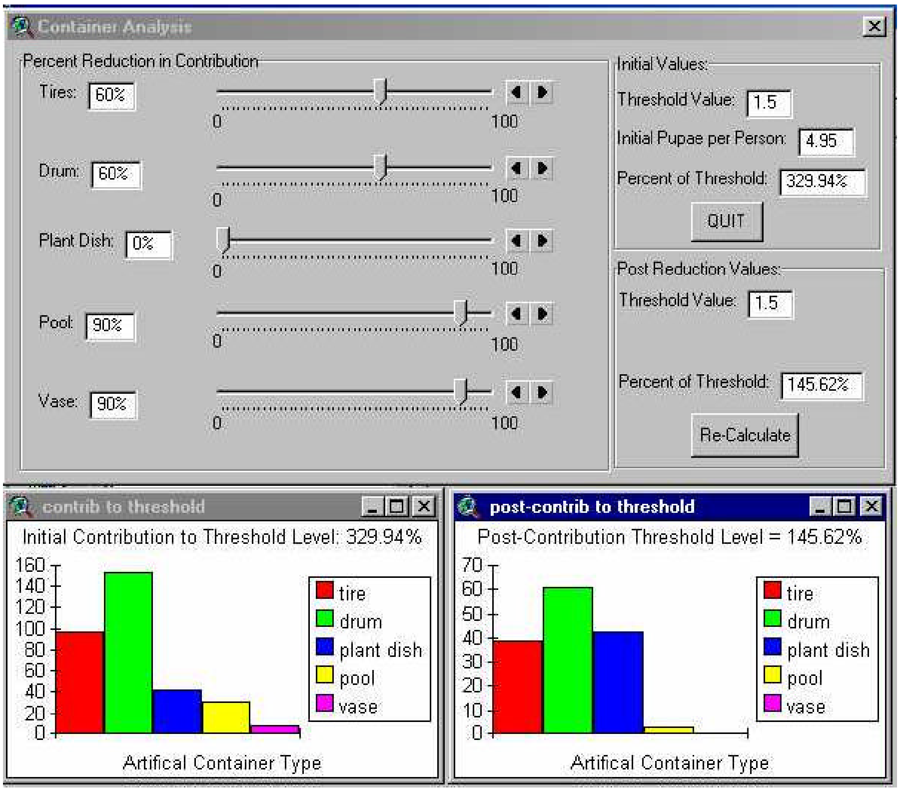

Figure 7: Demonstrates how the dengue simulation model can be used to determine exactly which containers are the most important to target for draining or scrubbing to get the pupae/person/area number below the calculated threshold number and lower the risk of a dengue epidemic.

The amount of water in a container has no influence on how many pupae will develop in that container. The temperature and the amount of food (algae) for the larvae to eat will have a greater effect. Rainfall may affect dengue transmission, depending on the area and typical seasonal rainfall patterns. The number of "small miscellaneous containers" will go up after a rain. Therefore rainfall is taken into account in the model. If most of the containers are "junk" containers in the environment, and not containers that are deliberately kept filled all of the time, then seasonal rainfall will contribute to the production of dengue. To determine the extent that rainfall contributes to dengue in a given area, do the household survey in the wet season and then do another survey at the end of the dry season.

Since the threshold number decreases as temperature increases, a climate forecast can be very helpful to alert public health officials to an increased risk of a dengue epidemic when increased temperatures are expected. Dr. Focks would like to partner with a Pacific island nation to develop and implement a dengue early warning control program based on ENSO forecasts.

ANNEX 5

OPENING SPEECH BY ACTING WHO REPRESENTATIVE IN SAMOA ON BEHALF OF DR SHIGERU OMI, WHO REGIONAL DIRECTOR FOR THE WESTERN PACIFIC

Distinguished guests, participants, ladies and gentlemen,

On behalf of Dr Shigeru Omi, the WHO Regional Director for the Western Pacific, I am pleased to welcome you to this workshop on climate variability and change and their health effects in Pacific island countries.

Climate variability and long-term climate change present special concerns to small island states. The UN Intergovernmental Panel on Climate Change, or IPCC, has identified these small island nations to be the countries most vulnerable to climate change. Temperature increase and sea level rise are occurring in the Pacific island region at a rate faster than the global average.

The most immediate threat to small islands include extreme climate variability due to El Niño which affects rainfall patterns, moisture and storm events. Such events have both direct and indirect impacts on human health and well-being. In 1997-98, for example, droughts in Micronesia, Fiji, Papua New Guinea, Kiribati and the Marshall Islands were attributed to El Niño. The climate phenomenon adversely affected taro crops and fisheries. Also, a rise in the sea level may imperil coastal infrastructures and jeopardize water resources and agriculture by salination of freshwater aquifers. A higher temperature sea level may unleash long-term trends of coastal reef bleaching, further threatening food and nutritional sources such as fisheries.

Many diseases are linked to climate variability. For example, vector-borne diseases such as malaria, dengue fever and lymphatic filariasis are on the rise in the region and some of these diseases have been linked to El Niño-driven climate fluctuation. In combination with rapid urbanization, dengue has spread throughout the region and constitutes a major health risk. Water-borne diseases, such as typhoid, remain problematic in Papua New Guinea and Tonga, and intestinal worms are still common afflictions in the region. Though cholera has not been seen in an epidemic proportion, rising sea temperatures may potentially increase the danger. Toxic algae and ciguatera have also been linked to periodic ocean warming events.

WHO has recently organized two regional meetings to address issues of emergency preparedness: a training course on health emergency management in October 1999 and a workshop on strengthening emergency preparedness in November 1998. These meetings involved participants from large countries and small island states. The meetings concluded that many countries had basic information on the occurrence of disasters, but more accurate data to evaluate health impacts needed to be collected, and access to information through the use of different media, including the Internet, needed to be improved.

This workshop will review and share the experiences of the impacts of climate variability and change, as well as control and management measures that can be adopted to reduce the risks from climate change. The workshop will also provide a training opportunity for you to learn skills for climate predictions and the associated adverse impacts on health. At the end, you will recommend a regional sustainable future plan of action to mitigate the health impacts of climate variability and change. I urge you to participate actively in the workshop and wish you a fruitful week of discussions.

Finally, I would like to express my gratitude to our host for this workshop, the Department of Health, the Government of Samoa. I would also like to acknowledge gratefully the donation WHO received from Dr Tapa, the former Health Minister of the Kingdom of Tonga, for this event. For those of you visiting Samoa, please enjoy your stay here.

With these remarks, I now declare the workshop open.

Thank you.