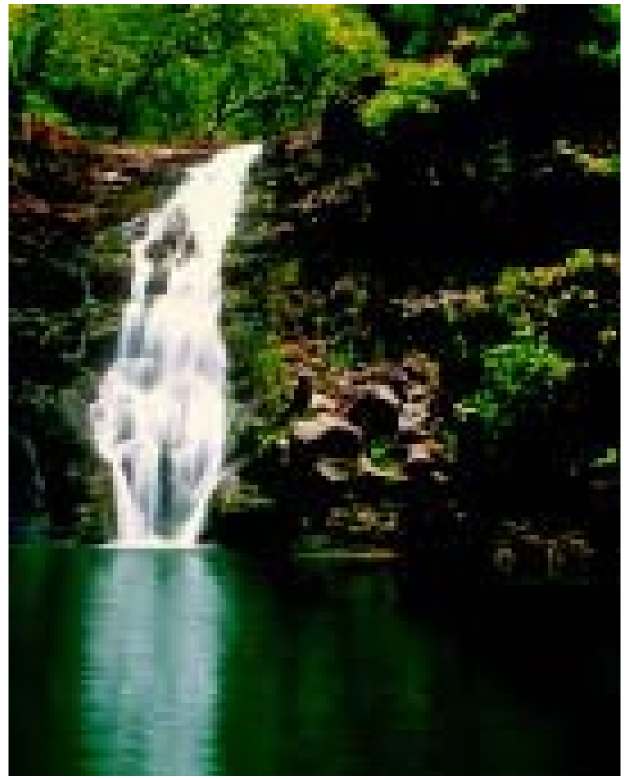
CHAPTER THREE—
CHALLENGES AND OPPORTUNITIES

The Pacific Assessment encouraged and supported exploration of climate vulnerability in the context of six activities:

- Providing access to fresh water;
- Protecting public health;
- Ensuring public safety in extreme events and protecting community infrastructure;
- Sustaining agriculture;
- Sustaining tourism; and,
- Promoting wise use of marine and coastal resources.

These activities were identified in discussions at the 1998 Workshop and subsequent meetings of the steering and organizing committees, and chosen based on their sensitivity to climate, their role in maintaining the well being of island communities, and/or the special values attributed to the activities by island people. Also explored during the Assessment were the linkages and interactions among these activities, and the extent to which interdependencies might ameliorate or exacerbate vulnerability to climate change and variability. The following sections summarize insights into climate-related vulnerability in the Pacific Islands; these insights emerged from the March 1998 and November 2000 Pacific Assessment Workshops, as well as individual small-group discussions with representatives of key stakeholder groups, and from analytical studies that supported the Assessment.



Evolution and geology have provided certain Pacific Islands with abundant sources of fresh water. Most, however, are not so bountifully endowed, and must manage their water with great care, especially in light of the growing impact of climate variability on this vital resource.

Providing Access to Fresh Water

As one participant in the March 1998 Workshop noted, "Water is gold." Water's value is even greater in island settings where surface water is limited if it exists at all, aquifers are small and fragile, and potable water may be available only from rooftop catchment systems. Given the precarious state of island hydrological systems, climate change or protracted anomalous conditions can have extreme effects on water supply. For example, during the 1982–83 ENSO warm event, Majuro's reservoir held 6 million gallons (Mgal) on January 1. By January 17, the water had dropped to 4.8 Mgal. By May 1983, total storage had dwindled to 0.8 Mgal, most of which was being reserved for the hospital (Republic of the Marshall Islands, 1999).[5] Similarly, during the 1997–98 ENSO warm event, all islands in the North Pacific experienced a rainfall deficit, and water managers were forced to ration municipal water supplies. The Marshall Islands again suffered the most extreme water shortages; at the height of the drought, municipal water on Majuro was only available for seven hours every fourteen days.

The problems of limited water supply are intensified by increasing demand for water. Population growth rates in some Pacific Islands are quite high. The Northern Marianas, for example, have an estimated annual population growth rate of 5.6%. The Marshall Islands are estimated to grow at a rate of 4.2% per year and American Samoa at 3.7% (SPC, 2000).[6] Further, domestic and international migration has contributed to the rapid

[5] *Report from the Republic of the Marshall Islands presented at the Workshop on ENSO Impacts on Water Resources in the Pacific, held in Nadi, Fiji, October 19–23, 1999.*
[6] *Secretariat for the Pacific Community. 2000. "Selected Pacific Economies— A Statistical Summary"*

growth of urban centers throughout the region. If the habitability of small islands and atolls is threatened by environmental change, migration to urban centers and high islands is likely to increase even more.

In addition to population pressure, economic development throughout the region also presents new demands on water resources. Tuna processing plants in American Samoa, for instance, require tremendous amounts of fresh water daily. Tourism, the premier industry in many island economies, is also water intensive. The island of Guam, for instance, had 8,119 hotel rooms in 1997, and the hotel occupancy rate for that year was 82% (Osman, 1999a).[7] This suggests that on any given day, Guam's water supply supported 6,650 visitors, roughly 4.4% of Guam's population in 1997.

Maintenance of golf courses, a popular tourist attraction, places additional pressure on precious local water resources. On several islands, disputes over access to limited water supplies have divided communities and entangled state agencies, private industries and citizens' groups in lengthy legal battles. On some islands, availability of water is the major problem, while on other islands, distribution is the focus of disputes. Long-standing institutional arrangements for managing water are challenged to adapt to the combined pressures of dwindling supplies and increasing demands. The search for alternative water supplies continues in earnest with research and development into desalinization projects such as reverse osmosis systems.

After the 1997–1998 ENSO warm event, the islands of Saipan, Majuro, Yap and Palau all made significant improvements in water storage and delivery systems. These initiatives have been complemented by efforts to reduce demand and promote efficient water use; new legislation in CNMI, for instance, imposes fines for wasting water. Water management institutions, whether based on traditional arrangements or administered by municipal, territorial or state agencies, have already benefited from climate information in their efforts to predict water supply and demand and allocate water supplies.

Findings and Recommendations

Discussions during the Pacific Assessment reinforced the importance of addressing the adequacy and long-term stability of island water resources. They also highlighted the importance of effects on fresh-water resources as an underlying factor in determining the consequences of climate variability and change for most activities considered in the Assessment. During the November 2000 Workshop, for example, the importance of understanding climate-related changes in fresh-water resources was seen as particularly central to agriculture, including subsistence farming and fishing as well as cash crops; to fish processing and trans-shipment; to domestic use of water; to tourism and other commercial uses; to public health; and to maintenance of natural ecosystems. Exploring the implications of competition for this limited resource can be as important as understanding the effects of climate variability and change on any activity individually.

Along with these differences, Pacific Islands share a number of common characteristics that influence their ability to respond to the effects of climate variability and change on their fresh-water resources. For example, Pacific Islands share a general reliance on rain-fed sources of fresh water—whether groundwater, surface water or rainfall catchment systems— and this reliance on rainfall makes them particularly sensitive to climate extremes like prolonged droughts. Furthermore, a reliance on multiple sources of fresh water imposes a variety of requirements for water quality and treatment.

Pacific Islands are experiencing increasing development and population pressures, which are reflected in land use changes that affect water quality and quantity.

CLIMATE MODERATORS

A number of Pacific Island characteristics influence the effects of climate on fresh-water resources, including:

- Island type, most notably the differences between "high islands" with greater groundwater and surface-water assets, and "low islands" with limited freshwater lenses and very little (if any) groundwater sources;
- Demographics, including population growth, overseas immigration and emigration, and internal migration into urban centers from smaller communities in more remote, low-lying islands and atolls;
- Remoteness, which is related to the population issues described above, and to distance from potential sources of fresh water during emergencies;
- Access to technology, including issues related to the ability to acquire new technology and maintain existing or new facilities;
- Economic activity, including reliance on water-intensive industries like tourism, agriculture and fisheries as dominant sources of national income; and,
- Social and cultural characteristics, including issues related to land tenure and resource management.

[7] *Bank of Hawai'i. Guam Economic Report, October 1999.*

The Ahupua'a Resource Management System used in Hawai'i is a model of integrated management— it combines science with traditional Hawaiian knowledge and practices to optimize use and conservation of resources "from the mountains to the sea."

Storage capacity and water distribution systems in the islands are already stressed; while some improvements (like fixing leaks in distribution pipelines) may be relatively easy, major improvements to infrastructure will require substantial economic investments. On many islands, much of the water distribution infrastructure is old and needs to be replaced. It is estimated, for example, that water and wastewater improvements on Guam could exceed $250 million. As is the case with all activities discussed during the Assessment, addressing these basic infrastructure concerns will be an important first step in improving the ability to cope with climate variability and change, as well as other stresses on water resources.

Discussions about how to enhance the resilience of Pacific Islands to climate-related stresses on fresh-water resources focused on responding in three categories: natural systems (surface and ground water, watersheds, wetlands, near-shore waters); human and institutional systems (including urban centers, rural communities, government agencies and regulatory regimes) and specific economic activities (e.g., agriculture, tourism, fish processing, domestic use/personal consumption). Table 3.1 summarizes key recommendations in each of these areas.

One of the common themes that emerged throughout the Pacific Assessment involved exploration of how traditional knowledge and practices can be applied to today's climate-related problems and to planning for the future. In the case of fresh-water resources, this discussion focused on the specific example of the ahupua'a resource management system used by early Hawaiians. Ahupua'a, the ancient Hawaiian geopolitical land divisions, ran "from sea soil to the mountainside or top," providing the chiefs and the people all that was needed to thrive on the most remote archipelago on the planet. As one author describes:

> *"A principle very largely obtaining in these divisions of territory was that a land should run from the sea to the mountains, thus affording to the chief and his people a fishery residence at the warm seaside, together with the products of the high lands, such as fuel, canoe timber, mountain birds, and the right of way to the same, and all the varied products of the intermediate land as might be suitable to the soil and climate of the different altitudes from sea soil to mountainside or top." (Hawai'i Supreme Court, 1879)*[8]

The ahupua'a system evolved in a virtual fresh-water oasis in the largest saltwater desert on earth. It has survived for close to two thousand years while undergoing numerous changes and adaptations. A modern version, the Ahupua'a Resource Management System (ARMS), is receiving widespread attention today because of growing awareness that globalization and global warming pose serious threats to the fragile natural and cultural resources of Hawai'i. By integrating ancient wisdom and modern science, resource managers are finding that the ahupua'a system addresses such major challenges as watershed management, ecosystem restoration, integrated land and water-use planning, and integrated coastal zone management. Although consideration of the ARMS arose initially in discussions about fresh-water resources, this resource management approach also can be used to improve resilience in agriculture as well as coastal and marine resource management. Because the ahupua'a system is also a place-based economic system, it offers a framework for diversifying the economy of Hawai'i and other Pacific Islands, and opens up unlimited potential for workforce development as we seek adaptive strategies to meet the challenges of globalization and global warming.

One of the characteristics of the ARMS is the involvement of experts and stakeholders from all walks of life in discussions and decision-making. This concept of engaging multidisciplinary, multisectoral teams of experts in the development of effective adaptation strategies was a recurring theme throughout the Pacific Assessment.

[8] *Hawai'i Supreme Court. 1879. Re: Boundaries of Pulehunui, 4 Haw. 239, 241.*

Underlying such an approach is a fundamental requirement: the need to build trust and establish long-term, collaborative relationships among the diverse stakeholders. Participants in the Assessment recommended that the Pacific Assessment process be continued as a mechanism for establishing such partnerships through a sustained dialogue on the challenges and opportunities of climate variability and change.

Table 3.1. Enhancing the resilience of Pacific Islands to climate-related stresses on fresh-water resources

Natural Systems	Protect and restore watersheds
	Conserve, recover and reuse water
	Integrate water- and land-use management
	Evaluate existing assets (from all systems) and develop unused/alternative sources
Human and Institutional Systems	Improve infrastructure and increase capacity
	Explore traditional and customary practices for water resource management to supplement/adjust existing management regimes (e.g., AhupuaÔ a Resource Management System in HawaiÔ i)
	Plan for the long term, emphasizing self-sufficiency
	Recover, treat and reuse wastewater
	Promote water conservation
	Review and revise permit and regulatory regimes to enhance resilience and reduce vulnerability to climate variability and change
	Use climate forecasts and information in decision-makingÑ establish targeted climate information systems building on examples like PEAC
	Improve climate and water resource monitoring (including socioeconomic data)
	Address population and demographic issues
	Promote education and awareness
Economic Activities	Provide economic incentives for water conservation, recovery and reuse
	Plan for extremes (particularly droughts)
	Develop public/private partnerships especially among large-scale users (including the military)
	Develop businesses targeted at water resource management systems
	Use climate forecasts and information in decision-making
	Promote public awareness and conservation in hotels, restaurants and other gathering places
	Promote information exchange and dialogue

Protecting Public Health

Closely related to fresh-water resource issues are concerns about the consequences of climate variability and change for public health. Several recent initiatives aim to evaluate the effects of climate and extreme events on health. Though temperature extremes can have direct impacts on human health, and several reports attempt to draw direct relationships between climate and emotional health, it is climate's impact on pathogens and disease vectors that may pose the greatest threat to the most people. In Pacific Island communities, the impact of droughts on subsistence agriculture and food supplies can also pose a significant climate-related health risk.

A number of infectious diseases in Pacific Island communities are climate-sensitive, including dengue, leptospirosis, malaria, filariasis, cholera, Ross Valley fever, influenza and other upper respiratory infections, gastroenteritis and cryptosporidiosis. Increases in global travel and trade are increasing the risk that these and other infectious diseases may spread in Pacific Island communities.

Preliminary research on the relationship between climate variability and dengue fever (a mosquito-borne viral disease) suggests that the risk of dengue fever may increase during dry periods in which a tropical storm or cyclone brings a brief period of heavy rainfall. It also appears that in some parts of the Pacific, the risk of dengue is higher during normal years and La Niña years than during El Niño years. Rainfall clearly has an impact on mosquito populations, and other research has shown that increases in temperature increase the risk of dengue outbreaks. Understanding these links between climate and dengue fever is important because, among vector-borne diseases, dengue is second only to malaria in numbers of people affected worldwide (Gubler et al., 2001). The relationship between climate variability and dengue fever, diarrheal disease, cholera, leptospirosis and ciguatera will be explored in a research

REDUCING VULNERABILITY TO CLIMATE-RELATED HEALTH RISKS

- Improve hospitals and other healthcare facilities, especially infrastructure related to acute care
- Improve water resource and sanitation infrastructure
- Improve the communication of climate information to the health sector and enhance the capabilities of local meteorological services and climate research programs in the Pacific
- Enhance public health surveillance systems in the Pacific
- Enhance healthcare education and training programs
- Improve emergency services delivery systems
- Update and implement comprehensive emergency management programs that address preparedness as well as response
- Update and implement healthcare plans that emphasize preventative care
- Integrate existing climate information (e.g., ENSO forecasts) into healthcare and emergency-services planning on a regular basis
- Enhance efforts to integrate traditional knowledge and practices into discussions of climate and health, including the engagement of traditional leaders and teachers
- Integrate information on climate variability and change into planning and decision-making in key sectors, most notably water resource management and agriculture
- Pursue community planning and economic development programs that encourage a shift toward sustainability, particularly in water usage and agriculture
- Enhance education and training programs, including technical training for healthcare practitioners and climate scientists, as well as public awareness and outreach programs at the local level
- Improve the ways in which information about climate and health is provided, in part by adopting traditional language(s) to convey improved information about local climate and health conditions

project proposed for the Cook Islands, FSM and Fiji over the next three years (Hamnett and Lewis, personal communication).

Climate change affects ecological conditions that influence both human pathogens and the habitats of disease vectors. Climatic and environmental perturbations can create new conditions for infectious diseases. In the aftermath of Typhoon Nina, which struck in November of 1987, the Chuukese suffered an increase in amebiasis, a parasitic disease associated with fecally contaminated water (FEMA, 1992). Similarly, outbreaks of cholera may be associated with climate variability and extreme events (Pascual et al, 2000). Cholera outbreaks can have severe consequences for any community. In calendar year 2000, FSM attributed 19 deaths and 709 hospital admissions in Pohnpei State to cholera.

Understanding the vulnerability of human populations to climate-sensitive diseases and disease vectors is improved by the use of models that integrate epidemiological methods with models of complex systems dynamics. For instance, Martens (1999) suggests that, based on “first generation” models of complex interactions, malaria and dengue will enjoy warmer environments, while temperature increases would be less conducive to schistosomiasis. Such findings are even more useful when they incorporate sociocultural variables that may provide information about the distribution of vulnerability within populations.

In addition to these vector-borne diseases, there are a number of synergistic relationships that increase the vulnerability of Pacific Island communities to climate variability and change. There is a strong relationship between both drought and flood and diarrheal diseases related to contamination of water supplies, although the exact nature of those impacts will differ from island to island (e.g., impacts on high islands with significant reservoirs of freshwater will be different than the impacts experienced on low islands with limited storage capacity). In this context, Assessment participants gave priority to understanding and addressing the health-related consequences of extreme events such as prolonged droughts, floods, or hurricanes and typhoons.

Another risk involves the potential for nutritional problems caused by the effects of climate on agriculture— most notably the effects of drought on subsistence crops and the effects of increasing ocean temperatures (and other climate-related changes) on subsistence fish species. In addition to enhancing the risk of a number of specific conditions such as anemia and low birth weight, malnutrition also tends to decrease the collective immunity of affected populations. In general it should be noted that geographic isolation, as well as social, economic and political inequalities, greatly exacerbate health problems and the delivery of healthcare.

Vulnerability to climate-related health risks is affected by sociocultural practices and beliefs as well. Certain behaviors (such as regular water treatment) or values (regarding health, well being and prevention) can be influential in reducing exposure. Public information campaigns are credited with reducing the incidence of diarrheal disease in Palau and Pohnpei during the 1997 ENSO-related drought (Hamnett, personal communication). Public health in

FOCUS: INTEGRATION OF TRADITIONAL KNOWLEDGE AND PRACTICE

Regardless of the topic being discussed at gatherings for the Pacific Assessment, there emerged a strong call for the integration of traditional knowledge and practice into more contemporary methodologies of climate observations, research, assessment and response being considered for the region. This call was particularly clear in discussions of how Pacific Island communities might better adapt, or reduce their vulnerability, to climate variability and change. For example, in discussions about possible changes in coastal resource management, repeated emphasis was placed on the importance of evaluating historical experience through the prism of traditional practices, as well as through more recent, "western" management paradigms.

In this context, the oral histories of indigenous peoples were put forward as a valuable source of knowledge applicable in the context of climate assessment. The oral traditions of Native Hawaiians, for example, include the intergenerational transmission of ancient resource management practices encoded in stories (moʻolelo), chants (mele) and dance (hula). Demonstration of these multisensory expressions of ancient wisdom by contemporary practitioners is a powerful testament to their survival over time, and underscores the claim that traditional knowledge was intended to continue forever (a mau a mau). Such nonwritten forms of communication can be effective tools for public education that transcend not only generations, but also barriers of culture and language. Along these lines, it was recommended that more be done to enhance the historical record of climate events and adaptations by integrating oral histories with observations of climate from instrumented records.

Furthermore, traditional leaders and teachers were identified as critical sources of insights into the vulnerability of Pacific Island communities to climate variability and change, and as important actors in the development and implementation of adaptation and mitigation strategies. The importance of engaging these traditional experts was highlighted in discussions about adapting the Hawaiian institution of an ʻaha council, in which all affected parties work to resolve resource management concerns through sustained dialogue and shared decision-making.

Traditional leaders and teachers were also identified as important information brokers in Pacific Island communities, with a vital role to play in increasing public awareness of the challenges and opportunities of climate variability and change. In this role, these leaders could facilitate the development and acceptance of effective response options that respect cultural considerations, as well as economic and environmental ones. Discussions of public education and awareness furthermore emphasized the valuable role that local experts can play in presenting climate information in local languages.

Another process considered appropriate for infusion of traditional knowledge and practice was implementation of long-term, proactive approaches to climate adaptation, a common theme that emerged throughout the Assessment. For example, in early discussions of how best to sustain agriculture, participants recommended embracing the concept of meninkairoir – a Carolinian word that means "looking ahead" or "taking the long view."

Yet others expressed serious interest in an ahupuaʻa approach to watershed and resource management, providing another strong example of the value to many of exploring traditional approaches to resource management. Such place-based, historical interpretations of the environment can significantly enrich contemporary understanding of the local consequences of climate variability and change. In addition, when we develop a better appreciation for how early Hawaiians and other indigenous peoples used their comprehension of climate to support decision-making, we gain valuable insights into how we might better integrate climate observations and information into our daily decisions.

For example, during the November 2000 "Workshop on Climate and Island Coastal Communities," Kumu Hula John Kaʻimikaua spoke of the importance of people becoming more aware of the environment around them by using their senses and naʻau (gut instinct, or intuition), as well as their intellect, to understand their relationship to the climate system. To illustrate, Kaʻimikaua described how early Hawaiians characterized the many types of winds on Molokaʻi in terms of direction, strength, scent or feel; he added that each of these descriptions conveyed an understanding of important corresponding conditions such as the availability of certain fish in coastal waters, or the timeliness of planting certain crops.

In her 1992 book *"Laʻau Hawaiʻi, Traditional Hawaiian Uses of Plants,"* Isabella Abbott noted, for example, "Early western observers were impressed with the bounty that the Hawaiians took from the land and the expertise they showed in manipulating their crops. Hawaiian understanding of their plants and the handling of plant varieties to suit the different ecological niches available on each island enabled them to reap an abundant harvest from limited cropland with considerable certainty."

By exploring traditional knowledge, people and institutions in the Pacific today can perhaps relearn the value of greater personal intimacy with the environment that sustains us— and thereby respond more holistically to the cues it continuously provides.

general is supported by the direct intervention of healthcare providers, whether they are traditional healers, medical professionals, public health officials or international aid workers. Through various organizational and institutional arrangements, these healthcare providers may be responsible for designing and implementing programmatic responses to public health problems. These projects are likely to be enhanced by the use of climate information.

Findings and Recommendations

The current state of public health in the Pacific Islands is sensitive to climate variability and change largely through climate-related effects on infectious diseases, fresh-water resources and food supplies. The following characteristics of healthcare, demographics and socioeconomic conditions in the Pacific Islands affect the region's vulnerability to climate:

- variations in availability of and access to healthcare facilities, especially for communities in remote outer islands;
- a high proportion of substandard facilities;
- a general shortage of doctors, healthcare providers and medicine;
- variations in cultural acceptability (and hence use) of healthcare facilities;
- remoteness from emergency response providers;
- vulnerability to epidemics and diseases introduced to the islands through movement of goods and services from other places;
- high population growth rates in some islands (e.g., the Republic of the Marshall Islands) with consequent implications for limited island resources;
- varying and interrelated status of socioeconomic development, poverty, nutritional status and sanitary conditions; and,
- varying levels of education, including health and environmental education.

It is important to note that climate variability and change impose added pressures on a public health infrastructure that is already stressed in many Pacific Island jurisdictions.

While the entire population of island communities is exposed to public health risks associated with climate variability and change, there are a number of groups that are particularly vulnerable, including the elderly and the very young; individuals with limited access to resources; rural communities with limited water storage, drainage and sanitation; and communities with limited access to immunizations and general health support.

Current understanding of the effects of climate variability and change on health in the Pacific (and globally) is constrained by a number of factors; these include:

- limitations on the availability and quality of climate data, and access to it, on a scale (resolution) compatible with health studies, as well as the absence of healthcare statistics and information on local or subnational scales;
- limited research on specific climate-health connections, such as multidisciplinary case studies that explore the potential for effective use of climate forecasts and information to reduce health risks in the Pacific;
- the need to develop new methodological approaches, as current statistical methods and modeling techniques do not always work for climate and health studies;
- the absence of focused exploration and integration of indigenous knowledge and practices into response options; and,
- the absence of information and research on synergistic relationships like that between public health and the effect of climate on agriculture and water resources.

As a result, one of the principal recommendations that emerged from the Assessment was that support be increased for scientific efforts to address these factors. In thinking about additional ways to reduce the vulnerability of Pacific Island communities, a number of actions were recommended to strengthen infrastructure and enhance the capabilities of the communities.

In all cases, participants in the Pacific Assessment recommended building on the capabilities of existing institutions and programs such as the Pacific Islands Health Officers Association (PIHOA); health surveillance programs through the Pacific Community and similar programs of the WHO; the national meteorological and hydrological services, and the PEAC as a critical first step.

Furthermore, participants in the Assessment encouraged collaboration between sectors and communities within individual jurisdictions, as well as among Pacific Island nations in the pursuit of these recommended actions. Cooperation between islands and among island communities, for example, could prove useful in leveraging resources such as investments in disease control infrastructure and drugs. Similarly, participants emphasized the importance of ensuring that individual government agencies provide a consistent message regarding climate and health conditions. As noted earlier, climate variability and change may increase or decrease the likelihood of a given infectious disease but there are many other factors involved, including human behavior. As a result, underlying all of the recommendations that emerged from the Assessment was a call for continuous dialogue and enhanced cooperation among healthcare officials and practitioners, scientists, governments, businesses and community leaders, as part of a regional effort to understand and address the consequences of climate variability and change for Pacific Islands.

Extreme events such as tropical storms can have a dramatic effect on lives, property and ecosystems in the Pacific Islands; these consequences make clear the importance of collaborative efforts to reduce vulnerability to such events.

Ensuring Public Safety in Extreme Events and Protecting Community Infrastructure

Island coastal communities have a long history of weathering extreme events. Typhoons, heavy winds, torrential downpours, tidal surges and floods have taught past generations about the shear force of nature. Buildings are collapsed, trees are uprooted and airborne debris becomes lethal projectiles. Unfortunate souls caught in powerful storms can be injured or even killed. In December 1997, Typhoon Paka hit Guam with sustained winds of 150–160 mph. At least 17 injuries were reported and scores of homes were destroyed. FEMA provided more than $109 million of recovery assistance, but total damages on Guam exceeded $600 million (Guard, 2001, personal communication). Following Typhoon Paka, Guam enhanced enforcement of building standards (among the strongest in the U.S.) and changed insurability standards.

Though there are few major rivers in the region, flash floods can be swift and deadly. The likelihood of extreme flooding and mudslides is increased dramatically when deforestation leaves the already fragile island soils even more vulnerable to the effects of heavy rains. The incidence of coastal inundation is expected to increase in the islands in coming years, with variations in sea level experienced as both extreme events and gradual encroachment on coastal areas.

On the other end of the hydrological extreme, droughts can pose threats to public safety, for instance, by increasing the risk of wildfires. Smoke from these fires not only leads to respiratory ailments and skin and eye irritations, it also dramatically reduces visibility and has been blamed for plane crashes, boating accidents, and uncounted motor vehicle fatalities.

The tragedy of extreme climatological events is softened only by foresight and preparedness in vulnerable communities. All of the U.S.-affiliated islands have some official agency responsible for preparedness, and for response to damage from extreme events. Emergency management and civil defense agencies develop disaster response plans and conduct public information campaigns. And the National Weather Service, thanks to advances in meteorological monitoring and prediction, can give advance warning of tropical storm events. Unfortunately, responsibility for mitigation is spread among several agencies and is not as well organized as preparedness and response. The built environment, whether concrete and steel or bamboo and pandanus, is susceptible to the forces of nature. Since World War II, government and the private sector have made a tremendous investment in homes, public buildings and tourism facilities. In many areas, however, current building standards leave buildings and infrastructure vulnerable to high winds, flooding and coastal erosion. In this situation, if the frequency and severity of extreme events increase, greater losses can be expected in the future.

In Hawai‘i, the Army Corps of Engineers conducted a survey of the vulnerability of energy and lifeline facilities to hurricanes or tsunamis (Army Corps of Engineers, 1992). They found that numerous electrical power plants and substations were located within coastal inundation zones. Similarly, petroleum and gas storage facilities are mostly located at sea level, within the commercial harbor areas of all the Hawaiian Islands. Kaua’i’s experience during Hurricane Iniki provides a compelling example of the importance of reducing the vulnerability of energy systems; the disruption of Kaua’i’s electrical system by Iniki shut down operation of the island’s water distribution system even though water was available. The situation on the island of Lana‘i is particularly instructive because, although its terminal facilities are not subject to flooding, storm damage to the breakwater allows waves to enter the harbor, thus preventing fuel barges from entering to off-load fuel; similar scenarios might be envisioned for other critical shipments.

Also at risk are lifeline facilities, including communications, telephone offices, fire and police stations and wastewater facilities, thus exacerbating the potential threats to public health and safety already associated with extreme events (such as hurricanes and storm surge), as well as the potential long-term implications of sea-level rise.

Table 3.2. Vulnerability to Climate-Related Natural Hazards in Selected Pacific Islands					
Country	**Cyclones, Hurricanes, Typhoons**	**Coastal Flooding (Sea-level variability)**	**Mud and Landslides (heavy rains/ floods)**	**River Flooding (heavy rains/ floods)**	**Drought**
FSM	Medium	Medium	Medium*	Medium	High
RMI	Low	High	Low	Not Applicable	High
Republic of Palau	Medium	Medium	Low**	Low** (Not applicable)	MediumÐ High (Medium)
American Samoa	High	Medium	Medium	Low	Medium
Guam	High	Medium	Low	Medium	MediumÐ High
CNMI	High	Medium	Low	Low	High
HawaiÔ i	Medium	Medium	Medium	High	MediumÐ High

Source: adapted from a table in Natural Disaster Reduction in Pacific Island Countries: Report to the World Conference on Natural Disaster Reduction, 1994, Section 2.2, p.9.

Vulnerability estimates for American Samoa, Guam, the Northern Mariana Islands and HawaiÔ i have been added; non-U.S.-affiliated states were not included in the original 1994 report.

Identification of a range of estimates indicates that the views of participants in the Assessment differed from the authors of the original table; estimates from the original table are provided in parentheses.

**FSM's vulnerability to mudslides was raised from low to medium based on mudslides on Chuuk during Typhoon Pamela, mudslides on Pohnpei in 1997, and the practice of planting sakau (kava) at higher elevations.*

***Palau's vulnerability to both mudslides and flooding may change as Babledaob, the second largest island in Palau, is developed.*

Findings and Recommendations

In considering the challenges of ensuring public safety and protecting community infrastructure, a number of climate-related hazards of concern were identified, including droughts; fires (as a secondary hazard often associated with drought conditions); typhoons, hurricanes and severe cyclones (with wind, wave, and rain/flooding hazards); floods and heavy rains (with mud and landslide hazards); episodic high surf conditions; sea-level variation (on various time scales) and long-term sea-level rise (with coastal inundation hazards). Table 3.2 provides estimates of the current vulnerability of Pacific Island jurisdictions to some of these hazards.

ENSO events play a critical role in this region, so participants in Assessment discussions about ensuring public safety and protecting community infrastructure decided to focus specifically on four possible futures: (1) continuation of the current pattern of El Niño events (dry one year and wet the following year); (2) more frequent or "persistent" El Niño (dry) conditions; (3) more frequent heavy rain/ monsoon-like events; and (4) an increase in temperature and general intensification of the hydrological cycle. Table 3.3 provides a summary of how those four potential conditions might affect the climate-related hazards of concern to those charged with ensuring public safety and protecting community infrastructure.

Setting these possible future scenarios in the context of existing experiences, the following conclusions were drawn about the capacity of Pacific Island jurisdictions to respond to the public safety challenges of climate variability and change:

- The capability of Pacific Islands to cope with climate-related hazards and natural disasters is already limited.
- There is great dependence on outside assistance during disasters, and this dependence increases with the severity of an event.
- Recovery from severe disasters is slow and difficult.
- Should the frequency and/or intensity of individual extreme events increase, islands may be less able to absorb and recover from disasters.

Table 3.3. Effects of Climate Scenarios on Public Safety Hazards

Climate-related Hazard or Event	Status Quo (current patterns of El Ni– o)	More Frequent or "Persistent" El Ni– os	More Frequent Heavy Rains (monsoon-like events)	Temperature Increase; Enhanced Hydrological Cycle
Drought	On large scale during strong El Ni– o	More west of dateline; Less in equatorial regions east of dateline	Between El Ni– o years	Wet areas wetter; dry areas drier; small change overall
Floods / Heavy Rains	Highly variable; can be El Ni– o-related	Highly variable during wet years; fewer in dry years	Increase in floods, erosion, mudslides and landslides	Wet areas wetter; dry areas drier; small change overall
Tropical Cyclones, Hurricanes, Typhoons	Highly-variable; can be El Ni– o-related	Shift toward dateline and Central Pacific; possibly more intense	Little or uncertain effect on intensity or frequency	Relatively small change in intensity; may be higher frequency
Sea-level Variability and Change	Multi-year, El Ni– o-related variability	More episodes of low sea level west of dateline and high sea level east of dateline	More frequent westerly winds and accompanying coastal flooding	Slow sea-level rise; by itself significant over the long term
Fires	During El Ni– o, west of dateline; otherwise poleward of 10¡ west of dateline	More fires west of dateline	Little change and possibly a decrease	More in dry areas; less in wet areas

- Resource-restricted islands find it particularly difficult to absorb a series or combination of disasters, and it is not clear how or under what conditions emergency response and recovery systems might reach a breaking point.
- There are significant differences within the region in the expected impacts of future climate scenarios, and in the capabilities of specific jurisdictions to respond to those impacts.
- While information on standard adaptive techniques such as setbacks, seawalls and flood-reduction measures is fairly readily available, care should be taken to ensure that designs are appropriate to specific jurisdictions, and that the impacts of those response options on other aspects of a community's vulnerability are assessed; and,
- Appropriate responses depend on a better understanding of current conditions and on development of more reliable climate scenarios and site-specific information.

Underlying specific recommendations for enhancing the adaptive capacity of Pacific Island jurisdictions was a call to move from today's more reactive disaster-response systems to systems that are more anticipatory, encompassing disaster prevention and preparedness as well as emergency response, recovery and mitigation. Such a proactive approach was viewed as the most economical over the long term, and would also produce near-term benefits to individual jurisdictions and the region as a whole. Similarly, implementing incremental, near-term adaptive measures that respond to today's patterns of natural variability (most notably ENSO events) can result in near-term savings and provide valuable insights into designing strategies for effective response to long-term climate change. Iterative, incremental changes represent a more likely scenario for adaptation to climate change than large, instantaneous changes.

Other recommendations were also made to enhance the ability of Pacific Islands to ensure public safety and protect infrastructure in the face of climate variability and change; these include:

- Improve efforts to monitor and predict climate conditions and changes.
- Integrate existing information about climate variability and change (e.g., ENSO forecasts) into emergency preparedness planning.
- Continuously monitor sea-level changes and use data to evaluate inundation and flooding maps and planning assumptions.

- Shift to more sustainable systems of water usage and agriculture.
- Integrate disaster management policies and enhance the flow of information across all levels of government by creating interagency, cross-jurisdictional bodies such as the government-wide task forces established in a number of Pacific Island jurisdictions to respond to the 1997–1998 El Niño event.
- Conduct island- and country-level assessments of climate-related vulnerabilities, and identify priorities for response options.
- Develop and/or update island and multihazard national emergency management plans.
- Embed emergency preparedness and response needs in a sustainable development planning context designed to improve environmental, educational, public health and living standards, as well as to promote economic development.
- Implement and enforce existing hazard mitigation measures and policies.
- Increase integration of traditional knowledge, adaptation strategies and cultural practices into contemporary disaster management strategy.
- Take greater advantage of new technologies like laser mapping techniques and computer-assisted decision-support systems like GIS and visualization tools.
- Improve ties between scientists and decision-makers.
- Strengthen education and outreach programs that are responsive to local needs, and broaden public awareness and involvement in decision-making.

Table 3.4. Examples of Climate Effects on Pacific Island Agricultural Systems

Drought	Irrigated agriculture in HawaiÔ i is at risk from drought because of dependence on surface water
	Dryland, rain-fed agriculture on some high islands is at risk from severe droughts (often associated with El Ni– o)
	Some atolls near the equator are subject to droughts that have resulted in loss of trees and other crops
	Mangrove forests on some islands have experienced die-back that may be related to drought-induced stress
Erosion/ Saltwater contamination	Taro pits on some islands and atolls in the FSM, RMI and Palau have been contaminated by salt water associated with a depletion of fresh-water lenses, extended droughts and saltwater inundation/intrusion
	Some islands have experienced erosion in coastal areas and this has increased the risk of saltwater inundation into low-lying agricultural areas
Plant disease/ Insect pests	Taro blights and leaf-rot in some island areas may be the result of droughts and other environmental stresses
	There has been an increased threat of insect pests as a result of droughts, particularly white flies that affect breadfruit and other crops
Invasive species	Important island ecosystems have been stressed by droughts as well as alien invasive species; disturbances such as storms and extended droughts can often favor invasive species over indigenous species
Wildfire	Wildfires are a major problem during severe droughts in some jurisdictions

From the perspective of ensuring public safety and protecting community infrastructure, nearly all island communities, systems and activities are affected by climate variability and change. However, it was agreed that effects on fresh-water quality and availability are particularly critical over the near and long term, and should receive priority in efforts to reduce vulnerability. As a result, immediate repair of infrastructure problems was strongly encouraged, as was local assessment of available water resources (including surface, groundwater and rainfall catchment systems) and water storage and distribution systems.

Sustaining Commercial and Subsistence Agriculture

Agriculture, both commercial and subsistence, remains an important part of the economies of many of the islands addressed in this Assessment. Climate-related changes in rainfall and tropical storm patterns present problems for agriculture in island communities, as evidenced by the effects of the 1997–1998 El Niño event in the Pacific. Agriculture throughout the U.S.-affiliated Pacific Islands in 1997 and 1998 suffered from the droughts, except on Guam. There, farmers used public water for irrigation, and the delay of heavy rains toward the end of the drought

Commercial and subsistence farming in the Pacific Islands are subject to the same climate-induced problems, including drought and salinization of fresh-water sources due to sea-level rise.

resulted in one of the most productive harvests in recent history. In the CNMI, citrus and garden crops were most affected, forcing the local hospital to buy imported fruits and vegetables. On Pohnpei, serious losses of both food and cash crops were sustained, with significant stress evident in more than half the banana trees, and significant losses in the kava (sakau) crops (Hamnett, Anderson and Guard, 2000).

The greatest percentage of the most productive agricultural land on these islands is located in low-lying coastal areas that are at risk from climate-related changes in sea level. In addition to problems associated with inundation, saltwater intrusion caused by sea-level rise would also present challenges unless salt-tolerant species could be utilized.

Agriculture in the Pacific Islands is characterized by heterogeneity, which results from differences in local climatic, soil and hydrologic conditions, and from variations in the mix of subsistence and cash crops. Interisland differences can be seen in:

- the cultural context for agriculture;
- economic and market conditions such as proximity to markets and the availability of transportation;
- the relationship of agriculture to other relevant sectors, such as water and energy; and,
- the institutions that set and implement agricultural policy, as well as those that support research and develop and disseminate information such as weather and climate forecasts.

This heterogeneity highlights the importance of research and assessment that focuses on local conditions, institutions and cultures when considering climate-related vulnerabilities in agriculture, including the development of response options. This report provides some regional insights and general guidelines that could be useful in pursuing such local efforts. For example, the Ahupuaʻa Resource Management System (ARMS) described earlier in this chapter represents a place-based approach that integrates local variability in climate and resources.

Findings and Recommendations

Two categories of vulnerability were identified for the agricultural sector; the first includes vulnerabilities related to the physical environment, including climate-related risks, and the second includes social, political and institutional practices. As is the case with all activities addressed in the Assessment, the most critical of these risks are extreme events that can have severe impacts on local and regional agricultural production. Droughts, for example, can reduce yields, with specific impacts dependent on characteristics such as duration and timing. Storms can affect agriculture in a number of ways, including crop damage from high winds and/or flooding, as well as degradation of soil quality and crop damage from sea-water inundation caused by storm surge. Natural climate variability, even when it is not manifested in the form of extreme events, poses a variety of challenges to the agricultural sector. Most notable is variation in the timing and amount of rainfall available for crop production. Agriculture on Pacific Islands is also affected by a number of pests (plant, animal, fungal and microbial) that can have a range of effects on crop production and are particularly important in areas with little crop diversity. Table 3.4 summarizes some of the effects of climate on Pacific Island agricultural systems.

Finally, agriculture must compete with a number of other uses for limited fresh-water resources. In their August 2000 decision on the Waiʻahole Ditch case, for example, the Hawaiʻi Supreme Court used the Public Trust Doctrine to outline a hierarchy of uses for water distribution during shortages. Maintenance of trust resources, including public health, safety and cultural practices, was held to be paramount, with private sector interests such as agriculture bearing the burden of proof that their uses would not cause irreparable harm to the trust. Like pests, fresh-water resources themselves are affected by climate variability and change.

Island governments and citizens are encouraged to develop more resilient agricultural systems that are less susceptible to damage from storms, drought and salt-water contamination. Specific actions in this context include planting of

A traditional staple food in the Pacific Islands, taro (kalo) is often grown in coastal plots that are susceptible to climate-related problems such as saltwater contamination. Possible solutions to this vulnerability include elevating plots and developing salt-resistant varieties.

traditional famine foods and food-banking crops used as famine foods; introduction of drought- and salt-resistant crops; development of emergency preparedness and disaster management plans that minimize disruptions to agricultural production; and shifting away from monoculture to greater diversity in crop production. Conversion of forest land to mono-crop agriculture and pasture, and shifts in low-lying areas to mono-crops such as sakau (kava), were identified as examples of current trends that may be increasing the vulnerability of Pacific Island agriculture to climate variability and change. More diverse agricultural systems would provide an important buffer against disasters, and increase economic resilience in the face of major disruptions to single crops. As a result, diversification was advocated as a general strategy to make agricultural systems less vulnerable. Traditional practices such as the Ahupuaʻa Resource Management System can provide insights into approaches that use diversification to enhance individual communities' self-sufficiency and resilience to climate variability and change. This is because the ARMS approach encourages development of agriculture that is in concert with the soils and climate within "micro-regions" as small as individual valleys on single islands.

Addressing climate variability and change in the context of comprehensive emergency management plans could reduce the effects of extreme events on Pacific Island agriculture. For example, the new drought mitigation and response plan in Hawaiʻi may make agriculture and ranching in the state less vulnerable to droughts— so encouragement was given throughout the Assessment to consideration of similar plans and programs in other island jurisdictions.

Adaptations to the problem of saltwater contamination of taro patches already have been developed in some areas, and these techniques should be shared; they include construction of elevated (above ground) taro patches made of coral rubble or concrete and filled with soil and compost; shifts on some islands to dry-land taro; and planting drought- and salt-resistant varieties of taro.

In the second category of agricultural vulnerabilities (social, political and institutional practices), one of the most critical issues is a significant information gap between those who produce information about climate risks and those who use (or could use) that information to make decisions in the agricultural sector. It was noted that scientists, governments, businesses and community leaders could narrow this information gap by enhancing awareness of available climate information; by improving the scientific community's understanding of decision-makers' information needs; by improving the usefulness and usability of climate information that addresses specific needs; by establishing and sustaining enhanced trust and credibility in forecasts, assessments and other information products; and by providing sufficient resources to support both science and a sustained dialogue between scientists and decision-makers.

Participants in the Pacific Assessment also repeatedly and strongly encouraged the development, provision and use of improved climate information, and highlighted two examples of institutions working to reduce the information gap. One was the PEAC, whose work during the 1997–1998 El Niño was described in Chapter 2. The second was Land Grant Colleges in the Pacific Islands, which help governments and farmers minimize the effects of extreme events and recover more quickly from natural disasters. An example of this assistance from the Land Grant Colleges is their cultivation of disease-resistant varieties of crops and tissue cultures, used to produce planting materials following a disaster; continuation and enhancement of such efforts was encouraged.

Also noted is the frequent mismatch between the timescale of climate events and that of political and individual decision-making. The need for policymakers to respond quickly to current problems can make it difficult to engage them in discussions of potential future problems, such as climate change. It was noted that there is a problematic tendency toward reactive decision-making instead of proactive planning, and that long-term, strategic approaches to problems of climate variability and change should be developed. The Carolinian word "meninkairoir"[9]— which means "looking ahead" or "taking the long view"— captures the essence of this management strategy, which considers the long-term sustainability of agriculture and provides greater flexibility to respond to extreme events and potential surprises in the climate system.

Land use management policies and practices were identified as another contributor to vulnerability in Pacific Island agriculture. There is tension between the need for government regulation of land use to minimize potential climate-related threats, and the prerogatives of individual property rights and traditional land tenure systems. In some cases, climate-related threats, particularly those associated with extreme events, may require regulation of land use practices. An over-exploitation of limited land resources and degradation of terrestrial and coastal ecosystems could be associated with the trend toward increased commercialization of agriculture and globalization of agricultural industries, for example. These conditions can increase the vulnerability of Pacific Island communities to the risks of climate variability and extreme events. Addressing increasing erosion problems may require changes in land use policies. Also needed are enhanced policies and procedures to stop the introduction of alien invasive species, so as to reduce the threat to native ecosystems and agricultural systems— a threat that may increase following extreme events and other disturbances, when invasive species often have a competitive advantage.

Another institutional aspect of reducing the climate-related vulnerability of Pacific Island agriculture involves the need for greater cooperation across levels of government and among various interests. Given the multi-scale nature of agriculture (from global markets to individual producers and consumers) and the multi-scale nature of climate phenomena (from global processes to local effects), coordination across different levels of government (from international to local) is necessary. Greater coordination would minimize inconsistency in decision-making at different government levels, which sometimes results in issuance of conflicting incentives. An example is a national farm policy that provides incentives for local farmers to grow crops that are inappropriate given the constraints on that area's water resources. Similarly, coordination among different agencies and interests would facilitate understanding of the links between different issues, such as hydrological processes and soil quality; this in turn would lead to more consistent decision-making (e.g., water and energy policies that are consistent with agricultural policies and vice-versa).

Beautiful beaches and weather are among the Pacific Island characteristics that drive tourism, yet both are already subject to stress from pollution and growing coastal populations. Climate change could generate additional risks for the industry by causing sea-level rise and compromising fresh-water supplies.

Sustaining Tourism

Tourism remains a significant contributor to the economies of Hawai'i, Guam and the CNMI, and is considered to offer economic growth potential for most of the jurisdictions addressed in the Assessment. Unique terrestrial and marine ecosystems are among the natural assets that draw tourists to the islands of the Pacific. These natural assets are already under stress from pollution and the growing demands of an increasingly coastal population. Sea-level rise associated with climate change could exacerbate those stresses in a number of ways: by reducing the extent and quality of sandy beaches through both inundation and storm-surge erosion; by inundating low-lying areas and threatening key infrastructure, including airports and roads; by increasing the risks of tropical storm damage (particularly damage associated with storm surge); and by threatening coastal water supplies through intrusion of salt water into the fresh-water lenses of small, low-lying islands.

Other climate-related changes of concern to tourism

[9] *The potential value of the concept of meninkairoir to reducing vulnerability to climate variability and change was initially offered by Salvatore Iriarte (FSM) during discussions of climate and agriculture at the March 1998 Workshop on the Consequences of Climate Variability and Change for Hawai'i and the Pacific.*

Irrigation for golf courses and resorts is one among the many demands tourism places upon limited fresh-water resources in the Pacific Islands; growing populations, agriculture and processing industries are other elements that must be balanced in the complex task of water management.

include:

- changes in rainfall patterns, particularly those that might bring more frequent and/or severe drought conditions, thus affecting the adequacy of water resources that support this water-intensive sector;
- changes in tropical storm patterns, which would have direct consequences for facilities and infrastructure and could exacerbate water-resource problems in certain areas;
- changes in temperature and rainfall patterns with attendant consequences for terrestrial as well as coastal and marine ecosystems; and,
- changes in ocean temperature, circulation and productivity, which could affect important marine resources like coral reefs and the fish they support.

Findings and Recommendations

During the November 2000 Workshop, the tourism working group introduced its report to the closing plenary with the following statement: "Tourism is an extremely climate sensitive industry and should provide leadership to the larger community through its response to climate variability and change." Examples of the sensitivity of tourism to climate, cited throughout the Assessment, include:

- the effects of ENSO-related drought on the availability of water for hotels and resorts, which often are located on the leeward (dry) side of islands;
- the vulnerability of the industry to hurricanes and typhoons, and the need for advance planning and preparation to protect visitors, as well as facilities and infrastructure; and,
- the dependence of the industry on marine and coastal resources like coral reefs, which in themselves are climate-sensitive.

According to industry representatives, these examples illustrate how climate variability and change affect the foundation of a sustainable travel and tourism industry: ensuring safe, healthy conditions for visitors and providing adequate infrastructure to support their needs.

It was noted that the consequences of climate change for tourism could be both negative and positive. For example, increased intensity or persistence of El Niño conditions could lead to prolonged drought in many islands with adverse consequences for tourism. Climate-related changes in environmental conditions at alternative destinations could increase the number of visitors interested in traveling to Pacific Islands. Changes in climate-sensitive resources like coral reefs, fisheries and tropical forests could jeopardize the tourism business. A change in sea level poses risks for transportation infrastructure like airports and roads, as well as hotels, restaurants and other facilities in coastal areas.

It was recognized that, to understand the vulnerability of tourism to climate variability and change, there should be discussions about response options as well as climate impacts. In this context, they noted that significant increases in the cost of diesel and airline fuels, which might arise as part of a global strategy to mitigate climate change, could reduce the number of visitors who choose to travel to Pacific Islands; nevertheless, they agreed that this possibility should not be used as an excuse to avoid consideration of important mitigation measures.

In the past, extreme events have galvanized public will and government and corporate action to reduce the sensitivity of tourism to climatic conditions. In Guam, for example, the losses associated with a Class 5 typhoon in 1962 helped pave the way for changes in building codes, for the imposition of a 20% tax for development in low-lying coastal areas, and for government subsidies and tax exemptions for developers who choose to build inland. Today, new insights and capabilities are generating opportunities to further reduce tourism's sensitivity to climate; we know more about the relationship between the ENSO cycle and extreme events such as prolonged droughts or changes in hurricane and typhoon tracks, and we are better able to predict ENSO events months in advance. Taking advantage of such advances to reduce vulnerability to climate can also have near-term benefits for the industry. Clyde Mark (then-employed as a risk manager by Outrigger Hotels, Hawai'i) cited the experience of the general manager of an Outrigger property in Australia, who used advance information about climate to anticipate and prepare for the conditions that spawned a cyclone that caught other facilities unaware. As a result, guests at the Outrigger hotel were well-informed and prepared for the event, and hotel management had time to ensure that power and water supplies were maintained by acquiring additional generators and water purification systems (Mark, 2000, personal communication).

Discussions of the vulnerability of tourism to climate variability and change should take into account all stakeholders, including foreign and domestic visitors; employees and labor unions; hoteliers and restauranteurs; transportation operators (primarily planes and ships in the Pacific Islands); activity owners and operators; government and industry policymakers and planners (including agencies responsible for water, energy, transportation, communications, sanitation, economic development and emergency management); convention and visitors bureaus; chambers of commerce; tourism industry associations; developers and construction businesses; scientists; and the community at large. To make this process manageable, the Assessment suggests that discussions should be organized around three basic systems: community infrastructure; natural resources and ecosystems; and governance systems.

In the area of community infrastructure, the recommended focus would be improving resilience to climate-related extreme events. For tourism, the overarching goal would be to improve the ability of Pacific Island communities to adapt to the ENSO and other aspects of year-to-year climate variability, and to integrate considerations of climate change into long-term facilities planning. The 1999 FSM National Communication to the United Nations Framework Convention on Climate Change notes that "the tourism sector can place significant demands on water resources and supporting infrastructure" (FSM, 1999). Of particular interest to tourism would be reducing climate-related vulnerability in water resources, sanitation, public health and safety, transportation, energy, communications, visitor accommodations, and sports and recreational activities.

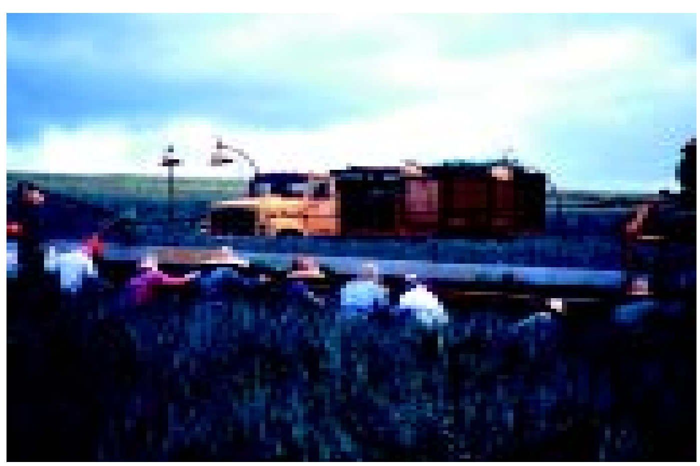
It was recognized that the tourism industry depends on the health of the islands' natural resources, most notably their coral reefs, forest ecosystems and beaches. The FSM 1999 National Communication notes that "many tourism opportunities involve capitalizing on marine and coastal resources and, therefore, are likely to place demands on coastal areas and infrastructure already under pressure" (FSM, 1999). The industry, therefore, has a responsibility to consider the effects of climate variability and change not only on its own businesses, but also on the natural systems that sustain it. Detailed discussions of the vulnerability of these systems are provided later in this chapter. As noted earlier, however, these critical natural resources are already being subjected to a number of stresses, and businesses and government agencies that support travel and tourism should collaborate in development and implementation of effective measures to reduce those stresses.

With respect to governance systems, discussions of climate and tourism focused on four key areas:

- facilities siting decisions;
- facilities design and construction;
- land management policies; and,
- emergency management/disaster preparedness.

Proactive, anticipatory approaches were universally encouraged, echoing calls for win-win or "no regrets" policies in the discussions of adaptation to climate change. One specific example often cited was reducing the risks associated with sea-level rise through proper planning for new facilities and infrastructure. Also encouraged were considerations of alternative approaches to infrastructure planning and governance, including the use of economic instruments (such as tax exemptions and subsidies) and innovative business-government partnerships as well as regulatory measures.

Discussions about governance also highlighted the importance of recognizing local cultural considerations and traditional approaches to land ownership, property rights and resource management. The phrase "one size does not fit all" was echoed throughout the Assessment, cautioning us to recall that what works in one island jurisdiction might not be appropriate in another. Similarly, the importance of incorporating traditional land ownership and stewardship practices reinforces the need to involve



Like tourism, commercial agriculture in the Pacific, in this case pineapple cultivation in Hawai'i, is among the economic activities most directly affected by climate variability and change.

local communities and indigenous peoples in discussions of how governance might be changed to reduce the vulnerability of Pacific Islands to climate variability and change.

The importance of improving climate information and communication systems was noted throughout discussions of the climate/tourism nexus, and calls were made specifically for:

- improved forecast and warning systems for extreme events and other aspects of year-to-year climate variability;
- enhanced efforts to translate, interpret and disseminate information on climate variability and change in a form useful to the tourism industry and government agencies charged with infrastructure planning and support;
- baseline information on the consequences of current patterns of climate variability for the tourism industry;
- baseline information on critical resources and infrastructure from which to measure/monitor the effects of climate change over the long term;
- improved information on the specific regional and local impacts of climate change projections; and,
- education and public outreach programs to enhance public awareness and participation.

Underlying all of these recommendations was a call for more dialogue and interaction among the communities, businesses and government agencies affected by the consequences of climate variability and change for tourism in the Pacific Islands.

Promoting Wise Use of

Critical, low-lying infrastructure in the Pacific islands, like Weno Road in the Federated States of Micronesia, is particularly vulnerable to rising sea levels and related consequences of climate change (photo by Joseph Konno).

Marine and Coastal Resources

Coral reef ecosystems are considered highly vulnerable to long-term climate change. Yet, because they provide shoreline protection and habitat for important coastal and pelagic fish species, healthy reefs are important assets not only for tourism and fishing industries but also for residents of many islands. Unfortunately, significant coral bleaching events have been observed in association with recent ENSO events, and there are suggestions that such patterns might continue or increase with increased ocean temperatures. Climate variability and change pose other challenges for coral reefs, including increased water depth caused by sea-level rise, and the possibility of increased risk from tropical storms and hurricanes.

Changes in sea level present a number of challenges to island coastal communities, ecosystems and facilities. Sea-level variations associated with El Niño events can cause increased aerial exposure of coral reefs in some western Pacific jurisdictions, and flooding in low-lying areas toward the central and eastern equatorial Pacific. The consequences of accelerated sea-level rise have been the focus of most climate-change assessment efforts; they include increased risk of shoreline erosion, inundation of low-lying areas, damage from storm surge, and saltwater intrusion with its effects on important coastal ecosystems like mangrove forests, fresh-water resources and low-lying agricultural areas.

Also affected by climate variability and change are coastal and marine fisheries, which are integral to the culture and economies of many Pacific Islands. Numerous near-shore and reef-dwelling fish species are important components of the subsistence diet in small island communities, and climate-related changes in the habitats that support these fisheries would have consequences for those communities.

Recent scientific studies have revealed an important link between patterns of natural climate variability, such as the ENSO cycle, and the migratory patterns of important pelagic species like tuna. Hamnett, Anderson and Guard (2000) for example, suggest that the eastward expansion of warm water in the Pacific during an El Niño is associated with an eastward displacement of some commercially important tuna stocks such as skipjack. For many of the Pacific Islands in this Assessment, development of a viable tuna industry is considered an important component of their economic future. For example, in the FSM, the

EFFECTS OF CLIMATE VARIABILITY AND CHANGE ON COASTAL AND MARINE RESOURCES:

- Changes in intertidal environments and species composition caused by sea-level rise
- Increased salinity in coastal estuaries caused by sea-level rise and periodic inundations from extreme events
- Changes in water quality in lagoons, with increased potential for red tides identified as a specific concern
- Changes in sea level, salinity and sediment loads (from erosion) that can affect mangrove forests (although the net effect of sea-level rise and climate change on mangroves is not well understood)
- Threats to seagrass beds from storm damage and increased sedimentation
- Changes in temperature, salinity and sea level that can have direct effects on coral reefs, which also are susceptible to siltation associated with storms and coastal erosion
- Changes in temperature and circulation in coastal and marine waters, which can alter spawning and foraging habitats for culturally and economically valuable species

tuna industry within its Exclusive Economic Zone (EEZ) is currently the primary focus for economic development in the country; access and license fees from distant-water fishing nations catching tuna in the EEZ are already a significant source of revenue (FSM, 1999). Starkist Samoa and Samoa Packing are the largest private sector employers in American Samoa, and are among the largest tuna canneries operating within U.S. territory (Hamnett and Anderson, 1999). Changes in the ENSO cycle or other climate-related changes in ocean circulation and productivity could bring significant changes to the location of tuna stocks, thus providing opportunities for jurisdictions that find themselves close to commercially-important stocks, and problems for jurisdictions that find themselves too far away.

Findings and Recommendations

The effects of climate variability and change on Pacific Island marine and coastal resources can be categorized in two ways— effects on human populations and effects on the natural/biological resources upon which they depend. The most obvious effects on people are caused by extreme events. Heavy rains, winds and waves associated with hurricanes and tropical cyclones, for example, can threaten public safety and damage homes, businesses and infrastructure. Drought can reduce access to safe fresh-water resources, with implications for public health. Saltwater intrusion into fresh-water lenses, whether associated with periodic events or long-term sea-level rise, can further jeopardize fresh-water resources, and saltwater inundation can threaten low-lying agricultural crops. Storm surge and sea-level rise can exacerbate coastal erosion— which is already significant in some areas— further endangering community infrastructure and homes. Human migrations to escape these risks can present significant challenges for both migrant populations and host communities; cultural differences and contrasting interpretations of traditional property rights and land ownership are among the potential difficulties.

Similarly, on islands where subsistence fishing is important, climate-induced changes in the productivity of marine and coastal ecosystems could alter carrying capacities. Food security issues could be particularly troublesome if declines in marine resources used for subsistence coincide with declines in agricultural productivity. And the economic viability of related industries such as mariculture could be affected by climate-related alterations in marine and coastal environments.

Marine fisheries represent an important element of Pacific Island economies. The pelagic or highly migratory tunas and billfishes of the Pacific are the basis for an extremely valuable fishery. About 70% of the world's tuna catch comes from the Western Pacific, and changes in ocean temperature associated with El Niño can significantly change the migratory patterns of commercially-important tuna stocks. The access fees that fishing companies pay Pacific Island jurisdictions to fish in their EEZs often represent a significant portion of the country's annual income. Even when a fisheries sector comprises only a small part of current GDP, as in the FSM, this sector is recognized along with tourism and commercial agriculture as providing long-term growth potential (FSM, 1999).

Pacific Island coastal waters support subsistence and commercial fisheries as well as valuable non-consumptive activities like recreational diving. Fish and other marine resources are important sources of protein for many Pacific Islanders. These resources can be affected by changes in water temperature and coral reef habitats, and by increased sedimentation associated with storms, floods and coastal erosion caused by climate variability and change. In addition, coastal ecosystems often have unique and important ecological and cultural value. (see boxed text for a summary of climate-induced effects on coastal resources.)

Recent scientific research also suggests that changes in ocean chemistry associated with increasing atmospheric concentrations of CO_2 may be at least as important for

The dynamic nature of climate variability and change demands a flexible approach to coastal resource management that can address long-term trends such as sea-level rise, and accommodate year-to-year changes like those associated with El Niño.

coral reefs as projected changes in ocean temperature and sea level. As increasing amounts of CO_2 infiltrate seawater, the carbonate saturation level of the water decreases. Preliminary findings suggest that increasing CO_2 levels could change seawater carbon chemistry sufficiently to affect the calcification rates, and hence growth, of coral and coralline algae; this in turn would affect the production of carbonate detritus, the source of sand necessary for beach building and shoreline maintenance.

In addition, insular marine ecosystems in the Pacific Islands have a great number of endemic species that have adapted to unique coastal conditions. Climate variability and change can alter the local environment and stress these endemic species, creating opportunities for invasion by alien species. Similarly, threatened or endangered species in critical island habitats could be further stressed by climate change. The endangered Hawaiian monk seal, for example, relies on unique nesting beaches and foraging habitats at the northern end of the Hawaiian archipelago. The added stresses of sea-level rise and storm-related impacts on these areas could be sufficient to move the seal (and other endangered species) closer to extinction. Marine ecosystems and species that are already heavily stressed due to over-harvesting or habitat alteration, for example, may be less resilient to climate variability and change. In this context, protected marine areas might be a useful tool for reducing fishing stress and enhancing resilience.

Many ways were identified to enhance the resilience of Pacific Island communities and resources to the effects of climate variability and change. The first set of options focuses on development of flexible resource management approaches that accommodate climate variations. Central to these options is a commitment to routinely integrate information on climate variability and change into planning and regulatory regimes, as well as into resource harvesting decisions. In addition to improving the flow of information among scientists, governments, managers and businesses, this commitment requires sustained climate and ecosystem monitoring programs, improved research on climate/ecosystem interactions, and development of new modeling and assessment tools (e.g., fisheries and ecosystem forecast systems).

Emphasis was given to the importance of planning for extreme events and climate variability rather than just changes in mean conditions, and to evaluating projections of future conditions in the context of past events and historical data. Coastal managers encouraged the use of climate information, and identified some specific applications, including: use of ENSO-based rainfall forecasts to establish conditions for construction permits in areas subject to flooding and mudslides; incorporation of ENSO forecast information in decisions about the timing of restoration projects; integration of climate considerations in design of habitat-monitoring programs; and integration of climate information in growth-management plans. Island-specific case studies were recommended to help augment existing information on the consequences of climate variability and change. Also encouraged were targeted pilot projects such as development of sea-level data sets and hazard assessment tools for coastal managers and community planners. Finally, it was suggested that scientists and decision-makers supplement global analyses and regional forecasts with data on local indicators of changing climate. The value of programs like PEAC was acknowledged in the November 2000 Workshop, leading to general support for expanding regional abilities to develop and disseminate climate information.

Flexible resource management approaches require the development of policies that recognize that ecosystems are dynamic. Since climate variability and change produce considerable ecosystem change, management strategies that handle variations in fishery yields while protecting spawning potential will be necessary. Flexible resource management policies should be able to accommodate relocation of fishermen between fisheries, and respond rapidly to changes in resource abundance. In this context, a policy is encouraged that incorporates risk, or a precautionary approach that recognizes the possibility of surprises and sets harvests at conservative levels. In addition to responding to changing climate and ecosystem conditions, such a policy would also evolve in response to changing social and cultural conditions.

Integrated resource management approaches can also be used to control risk when responding to the challenges of climate variability and change. For example, Kaluwin and Smith (1997) discuss integrated coastal zone management (ICZM) as a component of an effective response to the effects of sea-level rise and climate change. According to the Noordwijk Guidelines promulgated by the World Bank, the purpose of ICZM is "to maximize the benefits provided by the coastal zone and to minimize the conflicts of harmful effects of activities upon one another." This same document refers to ICZM as a "governmental process" consisting of "the legal and institutional framework necessary to ensure that development and management plans for coastal zones are integrated with environmental (including social) goals and are made with the participation of those affected." (World Bank, 1993)

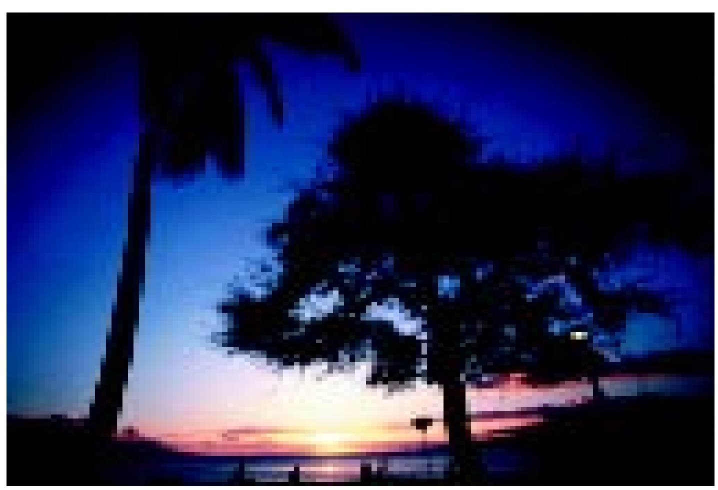
It was agreed in the November 2000 Workshop that ICZM could provide a valuable framework for climate adaptation in Pacific Islands. In addition, emphasis was placed on the idea that "all those affected" should participate in development of an ICZM process; these include resource managers, government agencies, traditional knowledge sources, policymakers, community leaders, businesses, and scientists from various disciplines. Collaborating to combine the insights and interests of these parties was seen as essential to development of any such integrated resource management approach. Participants in the Pacific Assessment also reiterated the suggestion by Kaluwin and Smith (1997) that the general concept of ICZM will require some modification to accommodate the "Pacific Way." Specifically, Kaluwin and Smith recommended a Pacific ICZM approach that recognizes:

- a high level of community involvement in coastal resource use and management;
- a high level of subsistence economic activity based on coastal resources and, therefore, an intimate involvement with the resource;
- strong customary land and marine tenure systems;
- Existence of strong indigenous cultures with traditional (and widely accepted and appropriate) decision-making and management mechanisms for natural resource management;
- cultures and communities that are closely attuned to the concepts of family and community and the need for sharing resources;
- a consensus approach to decision-making; and,
- customary resource management practices that are largely of an integrated nature, not sectoral.

In this latter context, Hawai'i's traditional ahupua'a management system was identified as an example of such a customary management practice.

Reducing the risk of economic losses is another aspect of responding to the effects of climate on Pacific Island marine and coastal resources. It was suggested, for example, that in responding to the effects of the ENSO cycle on important tuna stocks, island states might consider regional agreements that rely upon revenue sharing to reduce variation in income from fishing access fees; this would assure that annual income for any one EEZ would be better insulated from fluctuations in fishing in that EEZ. Variation in resource abundance could result in overcapitalization during periods of great abundance, which should be avoided to minimize economic and management difficulties during a decline. To reduce this and related risks, island states were encouraged to reduce their dependence on single fishery sectors; corporations were encouraged to diversify their areas of operation, and fishermen were encouraged to diversify their target species and fishing techniques. Also suggested was development of aquaculture, mariculture and enhancement techniques for wild stocks, although it was recognized that these activities might also be affected by climate variability and change.

It was recommended that effective policies and procedures be developed to control the introduction of alien species, thereby reducing the vulnerability of marine and coastal resources. This could include, for example, procedures to



Participants in the Assessment noted that the consequences of climate change for the Pacific Islands could be both negative and positive— but in any case should be anticipated and addressed through collaborative planning and mitigation.

The health of marine and terrestrial ecosystems in the Pacific Basin is dependent to a large degree on climate. Continued research and collaborative planning will enhance the ability of Pacific Islanders to anticipate and respond to the effects of climate variability and change— and maintain the health of their ecosystems.

evaluate introduction of species for trade or mariculture, and consideration of the possibility that climate change can alter local environments, making it easier for exotics to become established.

It was agreed that successful integration of climate information into routine decision-making will require development of local cadres of knowledgeable individuals. Educational outreach was encouraged to increase the public's awareness and understanding of the consequences of climate variability and change and to increase the availability of useful and usable climate information. Outreach efforts should be designed to provide climate information that is simple, unambiguous and culturally appropriate; to expand the availability of climate curricula, particularly for K–12 classrooms; and to develop and disseminate climate information tailored specifically for target audiences such as local planning bodies, government agencies, industry groups and communities.

Common Themes

In addition to the findings and recommendations aimed at reducing climate-related vulnerability in individual sectors, a number of common themes emerged from Pacific Assessment discussions of the consequences of climate variability and change.

For all activities, current patterns of climate variability (most notably ENSO events) already present significant challenges for Pacific Island communities, and significant benefits can accrue from enhancing capabilities to anticipate and adapt to those events.

To respond effectively to climate variability and change, an information-intensive endeavor, there is a need for timely, useful and usable information derived from a continuing dialogue among scientists and decision-makers.

When thinking about climate-related vulnerability, it is important to consider the effects of climate on multiple, interacting sectors or activities, as well as within specific sectors or activities (e.g. the effects of climate change on fresh-water resources has implications for public health, agriculture, tourism and coastal resources). Effective responses can only be developed after consideration of all these interactions. In addition to considering interactions among sectors, there is a need to promote consistency in planning and policy formulation at different levels of government, from local to regional, and with sponsoring or donor agencies outside the region.

In all topical areas addressed by the Pacific Assessment, participants highlighted the absence of reliable baseline information and the lack of island-specific vulnerability studies. Addressing this gap was identified as a high priority for continuing climate assessment activities in the Pacific.

There is a need for more formal and informal education, training and public outreach to strengthen efforts to anticipate and respond to the consequences of climate variability and change.

And finally, there is a need for proactive, forward-looking approaches to responding to climate variability and change— precautionary approaches that allow greater flexibility in response and reduce the adverse effects of surprises, as well as the costs of responding. This approach was characterized earlier in this Chapter by the Carolinian word "meninkairoir," which means "taking the long view."