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Nippon Changes

Climate impacts threatening Japan today and tomorrow

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Summary

Observed climate change

- Mean annual temperature has increased by 1.0°C in Japan over the last century
- Increased number of hot days (days with maximum temperatures higher than 35°C)
- Average winter temperatures in Hokkaido have increased by 1.3°C over the last century
- Decrease in frost frequency and in the number of days with cold temperatures
- The number of days with heavy precipitation and the number of days with no precipitation have increased
- Significant reductions in the amount of snowfall
- Increase in the frequency and intensity of extreme weather events, such as heavy rain events

Projected climate change

- Temperature increase of 2 to 3°C over the next 100 years for all of Japan
- Temperature increase of 4°C around the Sea of Okhotsk over the next 100 years
- Increase in the number of extreme hot days (days with temperatures exceeding 35°C)
- Decrease in the number of frost days by 20 to 45 days per year
- Increase of mean precipitation by more than 10% over the 21st Century
- Increase in summer precipitation by 17 to 19%
- Increase in heavy precipitation events in Hokkaido
- Increase in the frequency and intensity of extreme weather events, such as tropical cyclones, heatwaves, and heavy rainfall events

Sea-level rise

- Accelerating rate of sea level rise of 5 mm per year since 1993 along Japan's coast
- Projected sea-level rise of 5 mm per year throughout the 21st Century
- Increasing threat to 46% of population and 47% of industrial output
- Increased likelihood of inundation and intrusion of ground water aquifers and increased erosion to coastal zones
- Loss of 90% of Japan's sandy beaches with 1 m sea-level rise
- US$115 billion in preventative costs and US$1 trillion in assets at risk associated with a 1 m rise in sea levels

Impacts to humans

- Increase in heatwave intensity and heat stress, putting vulnerable populations, such as the aged, at risk
- Increased likelihood of infectious and vector and water-borne diseases
- Expansion of dengue fever into Hokkaido
- Increased allergies and allergy-related diseases
- Increased cost of living and protection from more extreme weather events
- 67 to 70% increase in wind-related losses from more intense typhoons
- Deteriorated freshwater systems and increases in chemical nutrients affecting fish production and harvests from warming temperatures and changes in precipitation
- 1.2 to 3.2% increase in the demand for water supply (with a 3°C warming)

Impacts to humans (continued)

- Negative impacts to fruit crops and an increase in abnormal fruits
- Potential temporary increased yield in grain harvests in Hokkaido
- 40% decrease in rice yields in central and southern Japan
- Potential northern shift of some fish species and changes in the fish abundance and diversity
- Declines in snow cover and sea-ice extent will negatively impact winter-dependent tourism

Impacts to natural systems

- Significant shift in the geographic distribution and range of marine and terrestrial species
- Exacerbation of current stresses and increased likelihood of species extinction
- Elevation migration of some plant species (notably trees) and the extinction of some alpine species
- Changes in the migration pattern and breeding grounds of some species, such as Whooper swans, Steller's sea eagles, and Japanese crane
- Increased occurrence of exotic, invasive species, pests, and diseases
- Earlier flowering and later senescence of some plant species, including iconic cherry trees, with potential for ecosystem mismatches (plants, birds and insects being at greatest risk)
- Cascading ecosystem effects of sea ice decline, leading to massive ecological changes in the oceans and coastal seas

Vulnerability and adaptation

- 46% of Japan's population and 47% of Japan's industrial output are at threat from sea-level rise and associated impacts such as storm surges, typhoons, and coastal erosion
- Other vulnerable sectors include agriculture, forestry, fisheries, water resources, coastal management, natural ecosystems and their services, and human health
- US$115 billion is needed to protect Japan infrastructure against just a 1 m rise in sea-levels
- National frameworks and policies need to include climate change impacts and adaptation
- WWF has provided a 4-step resilience building strategy for natural systems
- WMO and Koike (2006) have identified additional adaptation measures for human systems

Preface

Climate change is affecting Japan today and in a wide array of sectors. This report aims to synthesize existing scientific information on dangerous climate impacts, showing the massive challenges ahead for the host of this year's G8 Summit, the meeting of the eight biggest economies in the world. When possible, the report covers specific changes in Hokkaido, the Japanese province where the G8 Summit is going to take place. Both observed and predicted impacts are highlighted in order to show how Japan has changed already and what the future may look like. Special attention is given to socio-economic and culturally significant changes. For example, every year Japanese turn their attention to the flowering of cherry trees and every year it gets earlier and earlier in the season as a result of climate change. While this change may not affect the economic wellbeing of individual Japanese people, it does impact their cultural heritage and is an iconic example for a much bigger trend that brings major threats to people and nature in Japan - from rare species to precious ecosystems and from citizens' livelihoods to the country's overall economy.

Hokkaido is the northernmost of Japan's four main islands and extends from 41 to 46°N latitude. The island itself, which covers 77,978 km2, is the second largest in Japan (Dolan and Warden, 1994). It is separated from Sakhalin, Russia, by the Soya Strait and separated from Honshu Island by the Tsugaru Strait. Hokkaido's climate is sub-arctic, with an annual average temperature of 8°C and an average annual precipitation of 1,150 mm. At Asahikawa, in central Hokkaido, the mean temperature in January, the coldest month, is -9°C, The mean temperature in August, its hottest month, is 21°C, but because of climate change, these statistics will likely change soon.

Hokkaido has a rugged interior of volcanic peaks inter-dispersed with fertile lowlands containing lakes, marshes, and wetlands, making it Japan's leading farming region. In fact, Hokkaido has 90% of Japan's pastureland and produces 90% of the country's dairy products (Dolan and Warden, 1994). Forests of deciduous and conifers also cover a large part of the island and supply Japan with lumber, pulp, and paper.

Hokkaido's urban and industrial regions are situated along the third longest river in Japan, the Ishikari, cutting across mid-western Hokkaido. The Ishikari River is also one of Japan's most fertile fishing grounds. Fishing in Hokkaido, both freshwater and marine, provides one fifth of Japan's total catch. In addition to Hokkaido's natural resources, the island is also the hotspot for tourism including winter resorts and winter sport areas.

The Ainu are the indigenous people of Hokkaido and are believed to have outnumbered the Japanese until about 1800. Currently, there are roughly 16,000 Ainu in Hokkaido, located mainly in the West and Southwest of Sapporo, Hakodate, and Otaru. Due to Hokkaido's severe winters, parts of the island, mostly the north, are still sparsely populated but that is changing.

Construction, mining and manufacturing are fast becoming important industries in Hokkaido. Industrial and residential development since the 1980s has significantly altered the environmental quality and rural character of parts of Hokkaido (Dolan and Warden, 1994). Environmental problems, such as air pollution and acidification of lakes and reservoirs, are degrading air and water quality and reducing the economically and ecologically valuable resources. Compounding these problems now is climate change, which threatens to impact the economy and the environment, and to force irreversible change on the residents of Hokkaido.

Observed climate change

Japan is warming up. The Japanese mean annual temperature has increased by about 1.0°C over the last century (Cruz et. al., 2007). Additionally, Japan has been experiencing more frequent hot days (days with maximum temperatures higher than 35°C) and less extreme cold days (JMA, 2005). Unfortunately, this change is even more defined in Hokkaido, where average winter temperatures have risen more than the national average (1.33°C warming for Hokkaido compared to the national average of 1.09°C) (JMA, 2006).

While precipitation changes for all of Japan do not appear to be as clear, it is evident that precipitation events have become more variable. Specifically, the IPCC (2007) states that overall there have been no significant increasing or decreasing trends in precipitation during the 20th Century. However, the variability (i.e., timing, seasonality, quantity, etc.) has increased for Japan. This type of change could translate into more unpredictable rainfall patterns, which would make planning for agriculture and water resource management more difficult. In some areas of Japan, significant decreasing trends in annual mean rainfall have been observed (Cruz et al., 2007). Additionally, there have been significant reductions in the amount of snowfall and the duration and extent of sea-ice in the southern part of the Sea of Okhotsk (Ishizaka 2004; Hirota et. al, 2006), including along Hokkaido's coastline (JMA, 2007a), though this is largely affected by changing ocean currents and cannot be fully attributed to climate change. Satellite images over the Sea of Okhotsk confirm that there has been 4.4% per year decline in sea ice over the last three decades (EORC, 2008). More recently, the average number of observable days with drifting sea ice during the last four years has decreased from 87 to 65 days per year (JMA, 2008).

Extreme weather events in Japan have increased in frequency and intensity. During the past 100 years, there has been an increase in the frequency of extreme rain events and these have been attributed to an increase in the number of frontal weather systems. Additionally, there has been an increase in the maximum amount of rainfall during the period 1961 to 2000 (Isobe 2002; Kanai et al., 2004)

Projected climate change

Annual mean temperature is projected to increase by 3°C by 2050 and 5°C by 2080 for all of East Asia (Lal et al., 2001; Alam et al., 2007). For Japan the temperature projections are similar, with annual mean temperatures expected to rise by 2 to 3°C within the next 100 years (MOE, 2006). In Hokkaido the increase is projected to exceed 4°C around the Sea of Okhotsk (Kurihara et al., 2005; MOE, 2006a). The rate of warming is expected to vary according to season and time of day, with more warming during the winter than during the summer and more warming during the night than during the day (Kurihara et al., 2005). The number of frost days across Japan is predicted to decrease by 20 to 45 days by 2090 with the biggest changes in Hokkaido and along the Sea of Japan (Mizuta et al., 2005). The frequency, duration, and intensity of summer heatwaves and the number of hot days are also expected to increase throughout East Asia (Gao et al., 2002; Meehl, 2004; Cruz et. al, 2007). Similarly, a large increase in the probability of extreme warm seasons in Japan is expected and the average daytime summer temperature (June, July and August) in Japan is projected to increase 3.0 to 4.2°C by 2100 (MOE, 2006a; JMA, 2007a). Furthermore, a recent Japanese study illustrates that the number of days exceeding 30°C will drastically increase from around 40 days a year currently to over 100 days a year by 2100 (CCSR, 2004). Temperature changes such as this could mean that Japan may transform from a country with four seasons to just three, which would reverberate changes throughout the culture. The oceans will likely continue to warm, with a rise in sea-surface temperatures from 1 to 6°C in the eastern equatorial Pacific, including along the east coast of Hokkaido (Murazaki et al., 2005).

Precipitation and the frequency of intense precipitation events are also projected to increase throughout East Asia (Ichikawa, 2004; Emori et al., 2005; JMA, 2005; Cruz et. al, 2007; Christensen et al., 2007). Mean precipitation in Japan is expected to increase by more than 10% over the 21st Century, especially during the warm seasons (Kimoto et. al, 2005). While regional differences will likely exist, summer (June to September) precipitation in Japan is expected to increase 17 to 19% (MOE, 2006a). Winter precipitation throughout Japan is projected to either not change or to slightly decrease.

More variability in precipitation events is anticipated across Japan; the number of heavy precipitation days (days when the daily precipitation is over 30mm/day) is expected to increase by 5 days a year and the number of days with no precipitation is expected to increase by 10 days a year (Kimoto et. al, 2005). Hokkaido is projected to have increased precipitation magnitude and frequency (Nishimori and Kitoh, 2006; Mizuta et al., 2005).

An increase in the frequency and/or intensity of extreme weather events, such as droughts, floods, and tropical cyclones, is also projected for parts of East Asia (Cruz et. al., 2007). In fact, a rise in sea-surface temperature of 2 to 4°C relative to the current temperatures may result in an increase of 10 to 20% in tropical cyclone intensities, depending on climate sensitivity (Knutson and Tuleya, 2004).

Impacts

Japan's climate is changing. Observed increases in both land and sea temperatures and precipitation have changed the environment and projected changes will lead to substantial socio-economic and natural consequences. Warming temperatures, rising sea levels, changes in rain and snowfall patterns and extreme weather events will affect Japan in many ways, for example its agriculture, human health, infrastructure, tourism, forest growth, wildlife migration patterns, fish availability, and even the nation's cultural identity. The following section highlights some of the observed and projected impacts from climate change:

i. Sea-level rise

Global sea-level rose an estimated 0.17 m during the 20th Century (IPCC, 2007). Currently, sea-levels in the coastal areas of Asia are rising at an annual rate of 1 to 3 mm (Cruz et al., 2007). Along Japan's shoreline, sea-levels have been rising at an accelerated rate of 3.3 mm per year since the mid-1980s and at a rate of 5.0 mm per year since 1993 (JMA, 2007a). The maximum rate of sea-level rise was recorded in Kushiro, Hokkaido, which rose 9.3 mm per year from 1970 to 2003 (JMA, 2004). Future climate change projections expect global sea-level to rise an additional 0.18 to 0.59 m by 2100 (IPCC, 2007), though many scientists suggest that this is grossly underestimated. In East Asia, the annual rate of sea-level rise is projected to increase to 5 mm per year over the next century (Cruz et al., 2007). An increase of such magnitude seriously threatens Japan's 34,000 km of coastline containing a large part of Japan's population and economic activity (Kojima, 2004). Compared to other countries, Japan has the sixth largest number of people (more than 30 million) living within 10km of the sea (IIED, 2007). While coastal municipalities occupy only about 32% of the total area of Japan, they hold about 46% of the total population and produce about 47% of the industrial output, and amazingly 77% of the total expenditure for retail business or market goods is spent in the coastal municipalities (Kojima, 2004). Unfortunately, sea-level rise does not occur in isolation, it can also exacerbate storm surges, typhoons, tsunamis, and beach erosion, all major threats to coastal communities and economic productivity (Kojima, 2004).

Impacts associated with a rise in sea-levels are inundation and submergence, exacerbation of flooding, saline intrusion in rivers and ground water aquifers, and erosion of Japan's coastal zone. People and wildlife species will experience the impacts of increased levels of storm surges, flooding and inundation and the encroachment of tidal waters into estuaries and river systems (McLean et al., 2001). In fact, a 0.3 m rise in average sea-levels could potentially eliminate more than 50% of Japan's sandy beaches. More than 90% of Japan's beaches would disappear with a 1 meter sea-level rise, along with many of the tidal wetlands where migratory birds feed (Hulme and Sheard, 1999; MOE, 2004; Harasawa 2006). The Japanese government estimates that the costs associated with defending the country from a 1 m rise in sea levels would cost about US$115 billion, whereas the value of assets at risk from the same amount of sea-level rise exceed US$1 trillion (Kojma, 2006).

ii. Impacts to humans

Climate change will impact humans in many ways, from direct exposures (e.g., heatwaves, floods and storms) to indirect exposures (e.g., changes in air and water quality and loss of ecosystem services), and in the form of social and economic disruption (Confalonieri et al., 2007). Regional climate models project an increase in heatwave intensity for Japan (Cruz et al., 2007) and rising temperatures may expose the fast aging population to increased heat stress and more infectious diseases (Stern, 2006). Increased temperatures may also encourage the spread of some vector-borne and water-borne diseases (WHO, 2002; MOE, 2004; Government of Japan, 2006). A survey by the National Institute of Infectious Diseases found that the habitat of mosquitoes in Japan is expanding, which could bring dengue fever to Hokkaido (NIFD, 2007). Increased temperatures can also provide better growth conditions for disease-causing organisms and parasites (Government of Japan, 2006). Based on a national health study focusing on the impacts of climate change, it was suggested that Japan has already experienced elevated levels of heat-related emergencies and increased allergies and allergy-related diseases from Japanese cedar pollen (Koike, 2006).

As Japan's climate changes and weather patterns are affected, there is an increase in the likelihood of more intense and frequent extreme weather events, such as storms, droughts and floods, which will almost certainly have a severe impact on Japan's economy. While it is difficult to attribute individual events to climate change, a study by the Organization for Economic Co-operation and Development suggests that changes in climate and several socio-economic drivers have not only increased the probability of flood events, especially urban floods, but also have increased vulnerability to floods, because of increased population density and concentration of economic assets in Japan (OECD, 2006). As a result, the probability that a flood event develops into a disaster has increased and Japan will be faced with rising costs of living and the need for increased protection from "natural" disasters.

Asia is particularly vulnerable to natural disasters and Japan is no exception. Climate change will exacerbate Japan's existing vulnerabilities to such extreme weather events as typhoons and coastal storms by potentially increasing the wind speed of Japanese typhoons by 6% (ABI, 2005). ABI estimates that insured wind-related losses from extreme Japanese typhoons could increase by US$10 to 14 billion above present-day losses of US$15 to 20 billion, representing a 67 to 70% increase, which is more than twice the cost of the 2004 typhoon season, the costliest in the last 100 years (ABI, 2005). There has also been a ten-fold increase in weather-related economic losses over the last 40 years (IPCC, 2001). Typhoons are one of the three major storm types affecting the Japanese insurance markets, which are among the three largest in the world (ABI, 2005). On average, Japan's total insurance industry losses due to typhoons are estimated at US$4 billion (ABI, 2005) and 2004 was the costliest typhoon season in a century, with losses from three typhoons totaling upwards of US$14 billion (ABI, 2005).

Water and agricultural sectors are likely to be most sensitive to climate change induced impacts in Asia (Cruz et al., 2007). Increased temperatures and more variable rainfall could have a detrimental affect on watersheds, the ecosystem services they provide (e.g., water filtration) and agricultural species (MOE, 2004). Changes in the distribution and quantity of precipitation and rising temperatures will also have significant impacts on water quality and water availability (Gitay et. al., 2002). Warming temperatures and decreased water availability may also adversely affect some freshwater lakes in Japan; specifically, water quality will likely deteriorate and an increase in chemical nutrients could be more common, affecting fish production and harvests (Gitay, et al., 2002). Changes in water resources may also impact socio-economic and environmental sectors such as health, public safety, biodiversity, agriculture, and industry (EEA, 2007).

The impacts of warming temperatures will have a substantial effect on Japan's agricultural industries (Hirota et. al., 2006). Regional temperature increases have already affected Hokkaido's agricultural sector in a number of different ways - favorably for rice farming, and unfavorably for fruits. In fact, temperature increases have negatively affected some fruit crops and occurrences of abnormal fruit have been identified throughout Japan from grapes not turning red to peaches with brown flesh. Climate change-induced increases in water temperatures will affect ecological processes, the geographic distribution of aquatic species, and may result in the decline and possible extinction of some key species from the region. Because Hokkaido is considered one of the coldest rice producing areas in the world, the rice plants are at their distribution limit. Recent research suggests that an increase in the temperature may lead to an increase of rice production (e.g., a 1°C temperature rise may lead to an increased rice yield of 6%). When other factors – such as solar radiation and wind speed – are included, water temperatures may warm anywhere from 0 to 2°C and subsequently rice yields could range from a decrease of 30% to an increase of 41%. This shows a large uncertainty in modeling climate impacts on rice farming in this part of Japan (Shimono et al., 2007). The IPCC suggests that rice yield are projected to decrease up to 40% in irrigated lowland areas of central and southern Japan, under doubled atmospheric carbon dioxide (CO_2) concentrations (Cruz et al., 2007). Hokkaido, on the other hand, may experience a temporary increase of grain harvest. With changes in precipitation and soil moisture, however, this may not last very long if it does occur at all.

Climate change will affect both freshwater and salt water fish throughout Japan and its coastal waters and threatens to change the mainstay of Japanese cuisine. One of the first studies to document a major shift in fish distributions and abundance was in the Northern Bering Sea (Grebmeier et al., 2006), but these observations can be applied for Japanese waters as well. One example is the projected shift north of Pacific saury off the coast of Japan (MAFF, 2007). Temperature affects a fish's metabolism, growth and distribution and can alter the food web effects of predator-prey balances, changing the levels of nutrients in the water. Because drift ice creates a rich oceanic environment that fosters ice algae and thus forms the primary link in the ocean food chain, a change in the timing of ice retreat will affect fish production and subsequently Japan's fishing industry (MOE, 2006a). While the waters off Japan are currently considered some of the richest fisheries in the world [largely due to the convergence of the subtropical Japan Current (*Kuroshio*) and the subartic Kurile Current (*Oyashio*) (MOE, 2006)], research suggests that Japan may face a substantial decline in some fish catches over the 21st Century.

Declines in sea-ice extent and snow cover will also likely force changes upon snow and ice-based tourism, such as the ski resort towns of Niseko, Hokkaido (JMA, 2007a). While the current decline of sea-ice extent is considered the combined effect of warming temperatures and changing ocean currents, it is undeniably an icon of Hokkaido, and without it Hokkaido will lose part of its cultural integrity. Abashiri, Hokkaido, the southernmost area of the world to experience drift ice, may be the first place where ice floes will likely disappear (Jun, 2008).

iii. Impacts on natural systems

Hokkaido hosts some of the most extensive wilderness areas in Japan, from cool temperate forests in the south to the sub-arctic ecosystems in the north, and more than 200 species of birds in the lowland deciduous forests. Additionally, it is the only region in Japan that supports a population of brown bears. However, the stress of climate change added to the already existing pressures threatens these natural areas and species. Climate change will likely have the biggest impact on to coastal and marine ecosystems, forests and mountainous regions (Alam et al., 2007). In fact, more than 20% of mammals, amphibians, brackish water and freshwater fishes, and vascular plants inhabiting Japan already face extinction, along with around 20% of reptiles and more than 10% of bird species (MOE, 2006). Climate change will exacerbate this. As temperatures continue to increase, some species that exist only at the highest elevations of Hokkaido's mountains will be most threatened. One such animal is the pika, which has been highlighted as a threatened mountain species throughout its distribution (WWF, 2008). In Japan the pika is currently listed as a threatened local population on the Red List of the Japanese Ministry of the Environment (MOE, 2008). Unfortunately, the pika has already gone locally extinct in some regions of the world (Beever et al., 2003). As temperatures increase, some forest tree species have responded by moving up in elevation and are now encroaching alpine meadows, where there has been a recent decline in the distribution of alpine plants in Hokkaido (MOE, 2004). If this trend continues, Japan may lose much of its iconic alpine meadows and the species that survive there.

Additionally, migratory species such as Whooper swans and Steller's sea eagles may also be impacted by climate change as temperatures warm up and precipitation patterns change. A third of the world's entire population of these bird species migrates to the northeast coast of Hokkaido. The Japanese crane, the national emblem and a symbol of long life and happiness, is affected in similar ways. Hokkaido is now also one of the few wintering sites for the iconic and "near threatened" white-fronted goose (*Anser albifrons*) (MOE, 2004), however, other species may have to compete for similar habitat needs and feeding requirements. Climate change can also affect the reproduction rates and timings of some species, the phenology of plants, which then cascades down to the species dependent on those plants, and insects and diseases (Root et al., 2003). For example, a northward shift of butterfly, moth, dragonfly, and cicada distribution in Japan has been observed (MOE, 2004). Many species will be forced to move pole-ward or to higher elevations (when possible) in response to climate change. This migration of species will undoubtedly change the composition of current ecosystems and wild areas (Gitay et. al., 2002).

Climate change-induced species loss and extinction also threaten agricultural crops (i.e., pollinators), medicines, and cultural identity. Increases in temperature and changes in precipitation are having an effect on phenological events of individual plant species, such as earlier flowering during spring compared to past decades (Root et. al 2003). The date of autumnal leaf tint and consequently, the date of leaf-falling have been changing as well (JMA, 2007b). Over the last 50 years, Japan has experienced an earlier average blooming date for its cherry blossoms by 4.2 days (JMA, 2007b). Phenological changes have also been detected in the Ginkgo tree and the Japanese maple, which both have a longer growing season. The Ginkgo tree now starts its growing season four days earlier and ends it about eight days later than it had during the last four decades (Matsumoto, et al., 2003). Phenological changes have also been detected in other Japanese plants, including Japanese dandelion and Japanese Wisteria. Overall, the warmer temperatures have led to earlier blooms and have therefore caused concern over the ecosystem mismatches, with birds and insects being at greatest risk (JMA, 2007b).

Vulnerability and adaptation

A large portion of Japan's population and industrial output is located near coastlines and therefore highly vulnerable to the effects of climate change. Infrastructure in Japan's heavily industrialized ports is particularly vulnerable (e.g., factories, refineries, gas liquefaction and chemical plants, steel mills, shipyards, and oil storage tanks) (Hulme and Sheard, 1999). Japan has a considerable amount of coastline, which is at risk of sea-level rise and associated storm surges, natural hazards, including tsunamis and coastal erosion and flooding (UNDP, 2007). In fact, approximately 860 km^2 of Japan's major industrial cities are below the mean high-water level and the vulnerable area would be three times larger with a 1 meter sea-level rise (Hulme and Sheard, 1999). Other vulnerable sectors to climate change include agriculture, forestry, fisheries, water resources, coastal management, natural ecosystems and their services, and human health. Unfortunately, even if we were to stabilize CO_2 concentrations at current levels, global warming will continue for decades and sea level will continue to rise for centuries.

In order to effectively cope with the inevitable increases in temperature and such associated impacts as coastal inundation and flooding, adaptation strategies should be embedded within existing national frameworks and climate change assessments should be integrated into national policies. For natural systems, WWF (2003) has outlined four basic tenets to build resilience in the face of climate change:

1. ***Protect adequate and appropriate space***
2. ***Limit all non-climate stresses***
3. ***Use active adaptive management approaches and begin testing strategies***
4. ***Reduce greenhouse gas emissions***

Adaptive measures related to social infrastructure defense, coastal zone protection, and agricultural production and cultivation methods may include deliberate withdrawal, adaptation and prevention, as proposed by the IPCC (MOE, 2006a). Fortunately, evidence is emerging in Japan that climate change impacts and adaptation measures are now being considered by the construction and transportation sectors (Shimoda, 2003) and that adaptation measures typically include coastal defense structures. However, it is estimated that US$115 billion would be needed to protect infrastructure in Japan against just a 1m rise in sea-levels (Kojima, 2004; Harasawa et al., 2005).

Additional adaptation measures identified by the World Meteorological Organization (2008) and Koike (2006):

- Education and training on post-disaster response, prevention and preparedness
- Develop and maintain effective early warning systems for extreme events
- Monitor heat stress-related emergency visits and alert aid agencies when appropriate
- Employ sea-level rise adaptation measures
- Develop risk management strategies including the construction and/or inspection of storm surge defense facilities
- Identify monitoring requirements and establish plans for communicating risk information to citizens
- Establish evacuation plans and systems
- Education and outreach on the risks of and solutions to climate change

Conclusion

This report shows that climate change is indeed already affecting Japan, for example its agriculture and fishing industry, its ecosystems and biodiversity, and its cultural heritage and identity. Changes range from symbolic examples like the early flowering of the iconic cherry trees to the life-threatening and cost-intensive impacts of sea-level rise and extreme weather events. An altering climate forces irreversible change on the residents of Japan, today and increasingly in the future according to the science synthesized for this report.

Despite Japan's high adaptive potential, the country remains vulnerable to the consequences of warming temperatures, and should urgently mitigate climate polluting greenhouse gases, while implementing adaptation strategies as soon as possible. According to Sir Nicholas Stern (2006), Head of the U.K. Government Economic Service, the overall costs and risks of climate change will be equivalent to losing 5 to 20% of global GDP each year – if we don't act now. In contrast to these exorbitant costs of inaction, Stern highlights that the costs of reducing greenhouse gas emissions to avoid the worst impacts of climate change can be limited to around 1% of global GDP each year.

Global climate change is perhaps the greatest challenge we face and because of the amount of greenhouse gases that we have already pumped into the atmosphere, we are committed to at least another 0.6°C warming in the next years. In response, we urgently need to reduce our greenhouse gas emissions and employ appropriate and effective adaptation strategies to address climate change and its impacts. The world can still avoid the worst impacts of climate change, but the window of opportunity for taking the action that is needed to keep global warming below the dangerous threshold of 2°C is closing quickly. Industrialized countries, such as Japan, need to acknowledge their responsibility to the current climate crisis and take the lead in mitigating and adapting to climate change.

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