Chapter 2

Global Warming and Biodiversity

Chapter 1 explained that global warming, attributable to the increase of human-caused GHG emissions, is most likely to adversely and extensively change the global environment. This chapter focuses on biodiversity, with a view to clarifying its significance in supporting human life in its role as a foundation of human life itself, while also discussing the impacts to the Earth's biodiversity that human activities are incurring, resultant changes in ecosystems and their influence upon our way of life, with the emphasis on their relation to global warming,

Section 1: Geological Activity and Biodiversity

Over a long history of about 4 billion years, various species have evolved on Earth by adapting to diverse environmental conditions. These diverse manifestations of life, along with inanimate factors, have interacted with the atmosphere, water and soil. These interacting natural systems, referred to as "ecosystems," represent nets of natural elements woven together by way of their close interrelationship.

For example, most life inhale oxygen and exhale carbon dioxide. Green plants produce oxygen through photosynthesis and release it into the atmosphere. Carcasses and excreta of animals and plants are decomposed by microorganisms in the soil, and are transformed into inorganic nutrients that will be taken into plants again to be used for photosynthesis. Animals acquire energy by eating other life. Some plants benefit from insects carrying pollen for them as part of the pollination process, and others benefit from animals expanding their habitat by carrying their seeds to remote places.

Thus, there are interdependent relationships among diverse life in the Earth and the atmosphere, waters and soils; and such close relationships create diverse local ecosystems that are well-balanced. Such mutual interactions are so complicated that some of them are still not fully understood. However, it is understood that biodiversity, consisting of diverse life and their diverse ecosystems, constitute the basis of living for individual animals, plants and other organisms. This applies to human beings too, who are also part of terrestrial ecosystems. In the modern human society, people often forget their dependence on ecosystems in the biosphere, but we could not survive without respecting biodiversity in the Earth's ecosystems. And, our human activities have influences on mutually interacted constituents of ecosystems.

1. Ecosystem Services

Biodiversity is not only precious in and of itself, but it is also of great value to humankind, as we gain extensive benefits from these ecosystems that are supported by diverse life.

This relationship between biodiversity and the benefits we receive from the richness of nature had not been studied systematically until 2005, when a report from the Millennium Ecosystem Assessment used the concept "ecosystem services" to explain the said relationship in an accessible way (Figure 2-1-1). The Millennium Ecosystem Assessment is a scientific work initiated by the United Nations to make global comprehensive assessments of the status of biodiversity and conservation and the sustainable use of ecosystems. The core process of the Millennium Ecosystem Assessment took four years between 2001 and 2005, and it had the participation of about 1,360 researchers and scientists from 95 countries. Findings of the Assessment explain that biodiversity constitutes the basis of ecosystem services and that the richness of ecosystem services has a strong relationship with the human well-being. Here, biodiversity is regarded as the source of all ecosystem services.

The Millennium Ecosystem Assessment report published in 2005 classifies ecosystem services into the following four categories and explains the significance of biodiversity.

(1) Provisioning services

"Provisioning services" allow people to obtain essential resources for living, such as food, fuel, wood, fiber, biochemicals and fresh water.

For example, people eat animals and plants to survive, use hides and fibers to make clothes, and use wood, minerals and their processed products to construct buildings.

In addition to those existing, recognized benefits, there may be potential values, from which we may benefit in the future when the development of biotechnologies or commercialization of advanced technologies makes it possible for us recognize a potential and cultivate it for our well-being.

Biodiversity in this category is quite important in terms of the potentials of resource-utilization. In this light, the loss of certain life, regardless of whether they have already been recognized as resources that have a trade value or are unknown at this moment, would mean lost opportunities for us to utilize existing values or cultivate their potential values as a resource. Some researchers also point out that the wider the variety of flora, the higher "primary production" would be.

(2) Regulating services

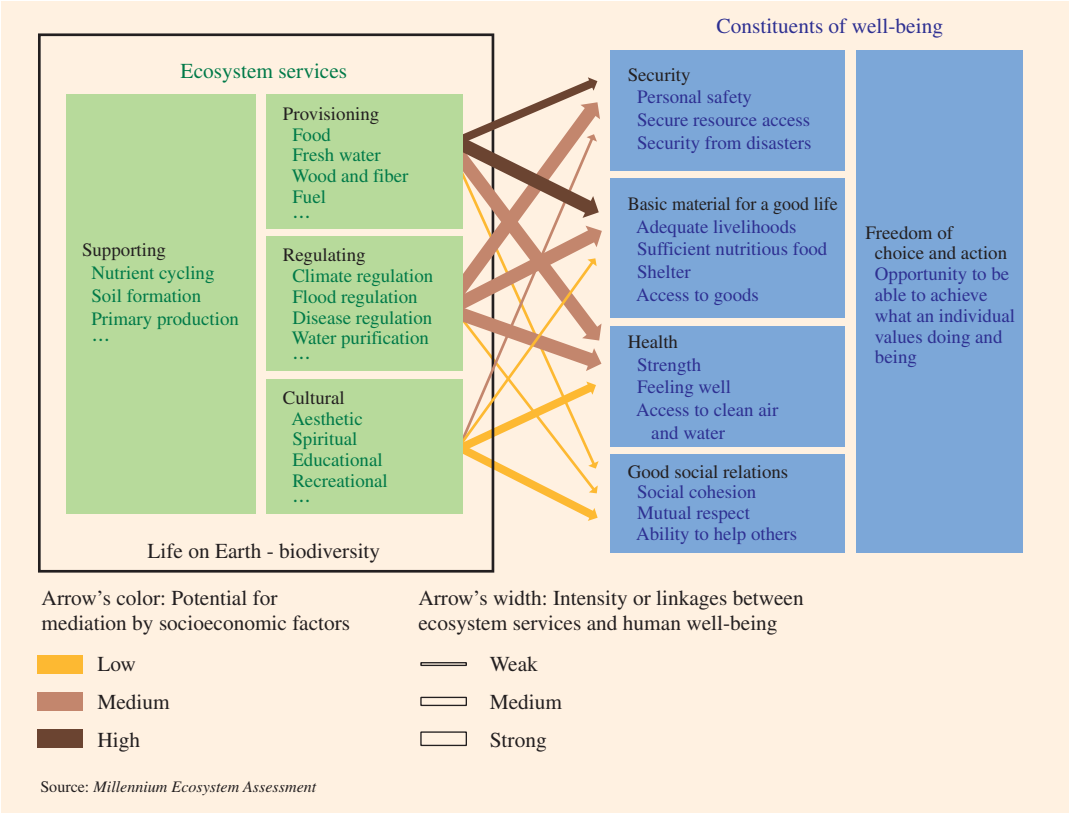
"Regulating services" allow people to obtain natural control of the environment, such as the ability of forests to mitigate climate change, to control flood, to purify water, etc. Such environmental control services, if artificially operated, would amount to enormous costs for us.

For example, forests store a vast amount of carbon. If all of the stored carbon happens to be released into the atmosphere at one time, it would cause strong greenhouse effects, most possibly resulting in the deterioration of the ecosystem balance.

Regulation of human diseases and pest control are also part of those services. There exist vulnerable species or genetically homogeneous creatures that are extremely susceptible to a certain specific disease or pest. They can be easily damaged when such diseases or pests happen to rapidly increase and spread. However, in normal natural ecosystems with rich biodiversity, explosive proliferation of a certain specific organism would not usually occur.

In this category, biodiversity contributes to the enhancement of enhancing the stability and recoverability of the ecosystem, in case of the entry of any invasive factors or any contingencies. Given a sufficiently rich biodiversity, there is a possibility that species with high levels of resistance or adaptability to certain diseases, pests, alien species, climate change, forest fires etc. will remain within the ecosystem, thus maintaining its stability. Also, areas of rich biodiversity often feature fast-growing species, which help the ecosystem recover from disturbances.

Figure 2-1-1: Ecosystem services and their links to the human well-being



Source: *Millennium Ecosystem Assessment*

Column : Monetary Evaluation of Ecosystem Services

Robert Costanza, an American researcher, attempted to put monetary value on seventeen different ecosystem services. According to his paper, published in Nature magazine in 1997, the total value is estimated to be between 16 trillion and 54 trillion dollars per year (with a mean value of 33 trillion). This is one to three times as large as the global GDP of about 18 trillion dollars at that time.

Costanza added that this calculation could only be said to represent a minimum estimate due to nature's many uncertainties, and he also mentioned that this value could well increase in the future as more facts about nature come to light.

(3) Cultural services

"Cultural services" allow people to obtain mental satisfaction, aesthetic pleasure, a basis of religious or social systems, opportunities of recreation, etc.

In most cases, locally-grown religion and culture have close relationships with local biota and ecosystems in that region.

In East Asia, which belongs to the monsoon climate zone, civilization based on rice farming and related production activity evolved. This has created a traditional belief in the sacredness of forests and all of the life contained therein in the societies of the region due to the large reserves of water contained in forests. On the other hand, in West Asia and countries westward, where it does not rain much in summer, wheat farming and stock-raising represent the core of civilization; people are not negative about deforestation and such lifestyle influences their attitudes toward nature.

Some Japanese names for colors, especially traditional ones, are etymologically related to animals or plants, such as the "color of toki" (safrano pink) and the "color of moegi" (kind of onion with young buds). This tells of the close relationship between human culture and the natural environment as well as the significant contribution that unique regional characteristics (of animals, plants, seasons, etc.) lend to local cultures. The enjoyment of seasonally blooming flowers is another important way of appreciating our ecosystems' gifts to our culture. "Ecotourism" is another example: it is based on recreational functions and educational effects of regional ecosystems and focuses on unique local landscapes or biota in a particular area. When we see regional cultures around the world, we realize that the local natural environment plays a significant role therein. For example, some ethnic costumes use a pattern of a native animal or plant and some regional food culture are greatly influenced by the nature in that region.

Thus, many regional cultures and religions are supported by ecosystems and biota in their region, and in this light, biodiversity constitutes the basis of the cultures. In other words, a loss of certain species could cause a loss of the culture to which the species belonged.

(4) Supporting services

"Supporting services" can be defined as the services that are necessary for the production of all other ecosystem services mentioned above from (1) to (3). For example, the supporting services include oxygen production through photosynthesis, soil formation, food chains and the water cycle.

Thus, services being provided by ecosystems to human beings are quite diverse. Therefore, it can be said that biodiversity, which supports ecosystem services, provides an essential foundation for human life.

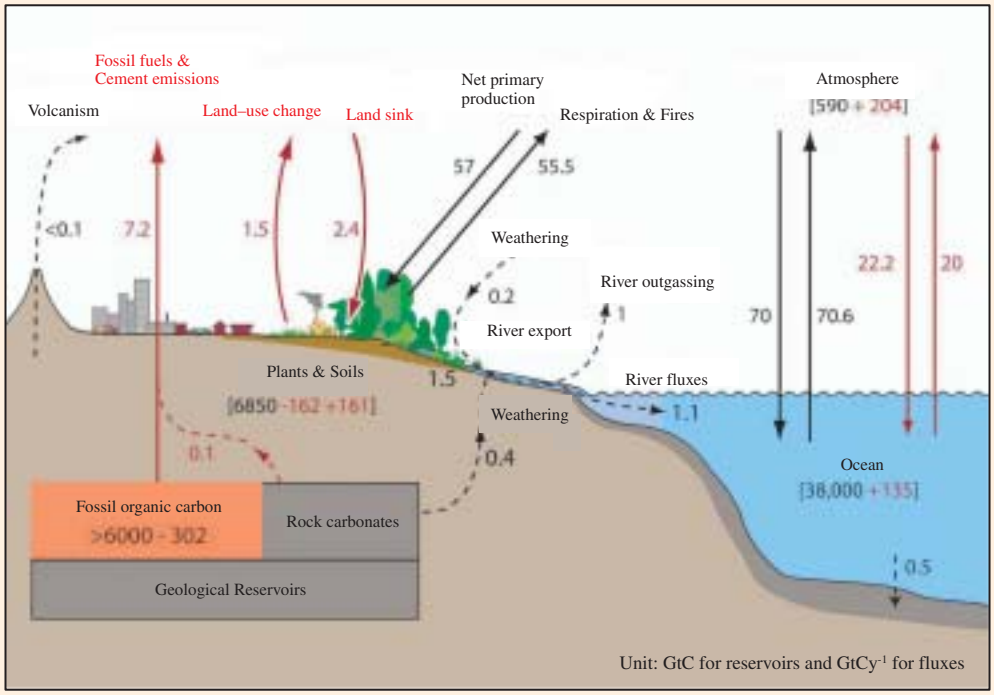
2. Material Circulation and Biodiversity that Support Ecosystem Services

As mentioned above at section 1, humans obtain great benefits from ecosystem services that constitute the basis of our life. Ecosystem services can be materialized through complicated interactions among various constituents of ecosystems (including diverse life) on Earth. Now, let's find details of those interactions and the basic roles of life in the mechanism of ecosystems.

Ecosystems consist of life and the surrounding environment, including the atmosphere, waters and soils. Every substance on Earth goes through some sort of ecological cycle. Also, solar energy flows through ecosystems as it is consumed by life at the same time.

All substances on Earth can be chemically identified as a finite set of elements, and they are consumed or used by life as they flow in a closed cycle of the geoecological system. Incoming solar energy into the Earth is always almost equal in volume to radiant

Figure 2-1-2: Carbon cycle



Note: Background or pre-anthropogenic pools and fluxes are in black. The human perturbation to the pools and fluxes are in red.
Source: "*The Global Carbon Cycle*" by the Global Carbon Project (2006)

energy released from the Earth into the space as infrared light. Life depends on certain elements of such energy flow, and actually plays an important role in the said material circulation and energy-flow mechanisms.

Recent environmental issues, such as global warming, that are attributable to disturbance of human activities can be defined as the consequences of destroyed equilibrium of those material circulation and energy flow. The following paragraphs will explain the basic mechanisms of the major material circulation (carbon cycle and nitrogen cycle), water cycle and energy flow, that constitute the basis of human life, as well as the significant contribution of biodiversity to those mechanisms.

(1) Carbon cycle

Ecosystems involving the atmosphere, waters, soils and lives of the Earth contain carbon compounds. Carbon dioxide (CO_2) is continuously exchanged between the ocean and the atmosphere through repeated dissolution into the ocean and release into the air, thus maintaining its equilibrium. Also, CO_2 is sequestrated in the form of an organic compound through the process of photosynthesis of plants. Those organic compounds are partially consumed by plants as an energy source and will be re-released into the atmosphere as carbon dioxide. Meanwhile, organic compounds stored in plants are partially consumed by animals as food, and will also be released into the atmosphere as carbon dioxide through the respiration of animals. Carcasses and excreta of animals and plants are decomposed by microorganisms in the soil and will also be returned into the atmosphere as carbon dioxide. Such carbon transformation via living organisms exists inside the ocean too. Dissolved CO_2 in the sea-surface layer is sequestrated in the form of organic compounds by photoplanktons. Some of them will sink into the deep ocean in the form of zooplanktons or carcasses/excreta of the large animals who consumed them (Figure 2-1-2).

Besides the aforementioned short-term carbon cycle, such as exchanges of carbon between the atmosphere and the ocean or transformation via living organisms, a long-term cycle also exists. Most of the carbon in the Earth is sequestrated in the form of calcium carbonate, through the process of sedimentation of carcasses and excreta of animals and plants, (including limestone of coral reef or limestone caves) or in the form of coal, petroleum, etc. that have been formed through underground transformation over the geological time of organic substances of ancient life.

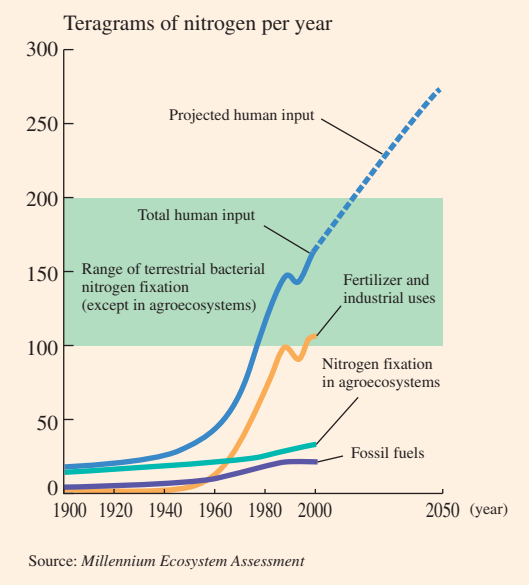
Column : Increase of Nitrogen loads Caused by Human Activities

The amount of nitrogen taken from the atmosphere and fixed through the ecosystem mechanisms is supposed to be almost equal to the amount of gaseous nitrate–nitrogen and returned to the atmosphere.

However, as a result of human activities, such as mass production of chemical fertilizers, crops and combustion of fuels, a large amount of fixed nitrogen has been accumulated and remains in ecosystems today. It is estimated that such human-produced accumulation of fixed nitrogen in ecosystems is now almost equal to the amount of naturally fixed nitrogen in terrestrial ecosystems and will further increase in the future.

According to the Millennium Ecosystem Assessment, one of the five major direct drivers of change in ecosystems and of deterioration of biodiversity is "pollution," and nitrogen is one of the principal substances causing pollution. Accumulated nitrogen in the natural environment flows into soils, ground waters, rivers and, eventually, into the ocean while it transforms itself. In this process, it causes eutrophication in lakes, reservoirs and sea areas, creates oxygen-deficient bottom water and induces nitric-acid pollution in ground water. The Millennium Ecosystem Assessment points out that such excessive accumulation of nitrogen in ecosystems could have serious, adverse impact on biodiversity.

Figure 2-1-4: Human-produced reactive nitrogen

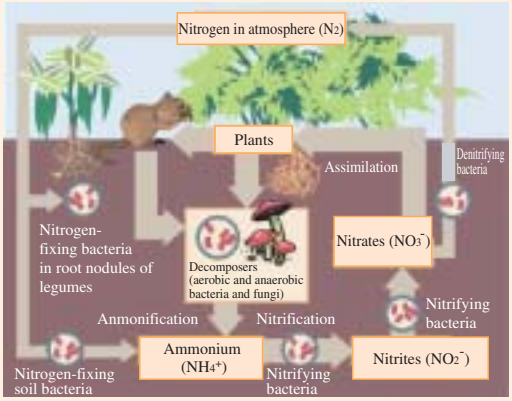


Source: *Millennium Ecosystem Assessment*

(2) Nitrogen cycle

It's not only carbon that is cycled through ecosystems. Nitrogen is an essential element for the formation of protein needed by humans and other life. Although inorganic nitrogen constitutes as much as about 78% of the Earth's atmosphere, it cannot be of immediate use for most life; it needs to be converted into forms usable by living organisms through the process of fixation, where microorganisms, etc. combine inorganic nitrogen with hydrogen or carbon. Fixed nitrogen can be taken into plants in the form of either ammonium ions or nitrate ions, and will be transformed into amino acid or protein that will be consumed by animals. This is the only way that allows animals to take in necessary nitrogen for their nutrition. Carcasses of plants or animals are consumed by other animals or decomposed by microorganisms. Then, denitrifying microorganisms will return inorganic nitrogen to the atmosphere (Figure 2-1-3).

Figure 2-1-3: Nitrogen cycle



Source: EPA (U.S. Environmental Protection Agency)

(3) Water cycle

Water is an indispensable substance for the survival of all life. To our knowledge, the Earth is the only solar planet that enjoys the presence of water, and this has much to do with the birth and existence of the Earth.

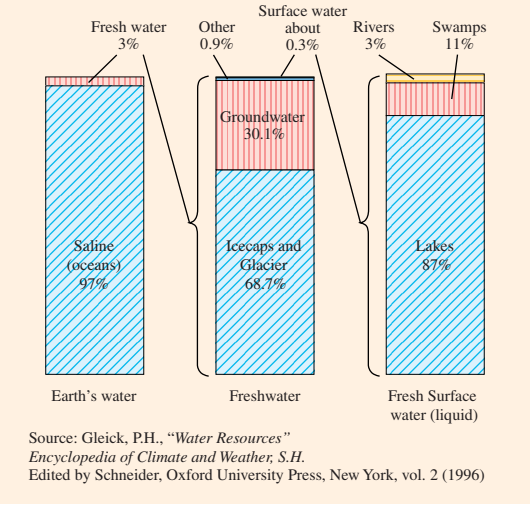
The Earth has as much as 1.386 trillion tons of water, most of which (about 97%) belongs to the oceans. Fresh water constitutes only about 3%, a large part of which takes the form of glaciers, snow or groundwater. Thus, surface-running waters such as lakes, reservoirs and rivers constitute only a small fraction of the Earth's water, but they play a central role in the lives of most terrestrial life, including human beings.

Water comes in diverse forms, including glaciers, snow, lakes, rivers, ground water and atmospheric moisture (solid, liquid or

gas), and it cycles in ecosystems. First, water in the form of vapor is released from the surface of the ocean or ground through the process of evaporation or transpiration. Vapor migrates in the atmosphere while it takes the form of cloud, fog or mist, and falls back down in the form of rain or snow. Those waters flow on the earth's surface or penetrate the ground, while heading for the ocean for the most part. In this sea-bound process, water plays diverse roles: it is consumed by life as nutrition, it mitigates climate change, it forms habitats for animals and plants, it supports biodiversity, etc.

Also, water moves long distances as rivers or sea currents, making it possible to transport various substances and energies. In addition, through the process of erosion, water functions as a determinant of geographical features of land.

Figure 2-1-5: Distribution of the Earth's waters



Source: Gleick, P.H., "*Water Resources*" *Encyclopedia of Climate and Weather, S.H.* Edited by Schneider, Oxford University Press, New York, vol. 2 (1996)

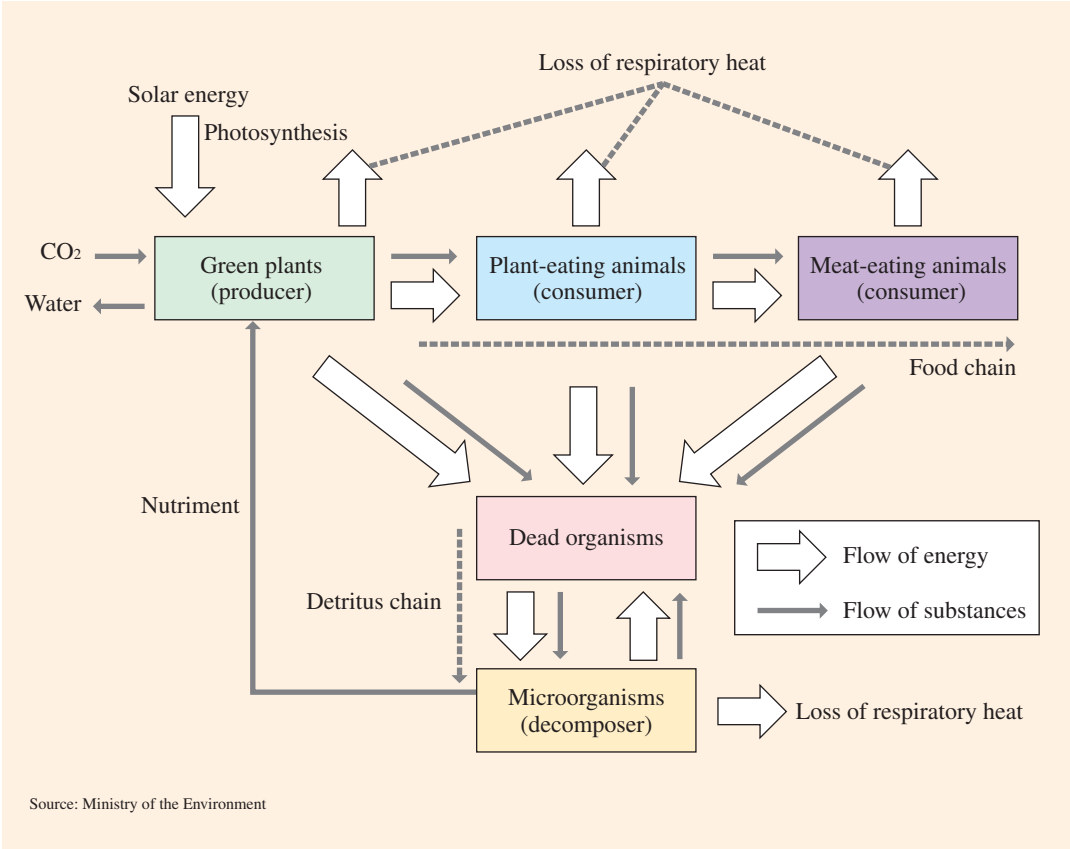
(4) Energy flow

The Earth receives solar energy from solar light coming into the atmosphere. Solar energy flows throughout ecosystems, where it is partially taken into life and supports respective lives.

As the primary producer, plants fix solar energy in the form of an organic substance through photosynthesis. More than half of that fixed energy will be consumed by plants themselves for their respiration, and will be partially stored internally in the form of starch, etc. Then, it will enter animals when they eat plants ("grazing food chain"), or in some cases will enter a "detritus food chain" where carcasses or excreta of animals or plants are consumed by decomposing organisms such as bacteria. In either case, it eventually enters the ecosystems.

In the grazing food chain, 10% to 20% of plant-fixed energy is estimated to enter animals that eat plants. Then, about 10% to 20% of the energy consumed by those animals is estimated to enter meat-eating animals, and 10% to 20% of the energy consumed

Figure 2-1-6: Energy flow in terrestrial ecosystems



Source: Ministry of the Environment

by those meat-eating animals is estimated to enter their predator animals. Thus, energy is transferred to higher-level creatures (from pray to predator). The higher the energy that is transferred, the more energy is consumed. Therefore, the remaining energy becomes smaller and smaller as it is transferred to higher-level creatures.

Thus, energy is consumed by various life at different levels, and heat generated as a result of their activities will be returned to the atmosphere. (Energy not consumed immediately is temporarily stored inside life or in the form of organic sediments, but it will eventually be released into the atmosphere, except for those organic compounds accumulated little by little underground such as petroleum and coal.) Then, heat in the atmosphere will be radiated into outer space. The amount of such heat is supposed to be equal to the incoming counterpart when the integrity of the ecosystem is maintained.

Section 2: Crisis of Ecosystems

Development of science and technology that embodies the integration of people's wisdom has provided human beings with a great fortune. Modern technology has made it possible for us to act decisively. People today receive great benefits from such activities: they take the form of artificial alteration of river flows for agricultural or flood-control purposes, deforestation, land reclamation, etc. However, today, people are sometimes unable to forecast the outcome of their activities due to unprecedented development of science and technology. We have acquired strong powers of advanced technologies, but any abuse of such high-level technology could possibly lead to an irrevocable alteration of ecosystems, including that of human beings.

The said scientific development has also brought about an increase in the world population. During the period between 1960 and 2000, the global population doubled from about 3 billion to about 6 billion. This means that we need twice as much ecosystem services, assuming that all other prerequisites remain the same as before.

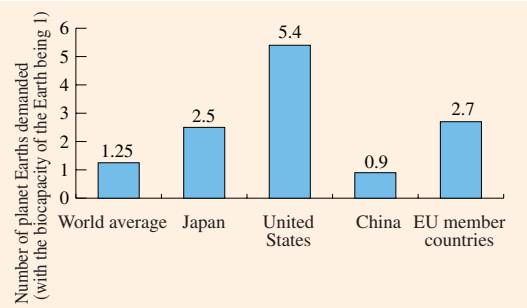
In addition, in the latter half of the 20th century, the per capita demand for ecosystem services increased dramatically, especially in advanced countries due to their economic growth and people's stronger desire to enjoy comfortable life.

There is a new analytical methodology named "Ecological Footprint" that attempts to measure human consumption of natural

Column : Ecological Footprint

The Ecological Footprint (EF) is an index developed by the University of British Columbia to represent the level of human being's dependence on the natural environment, in an easy-to-understand way. The Global Footprint Network defines the Ecological Footprint as "a resource management tool that measures how much land and water area a human population requires to produce the resources it consumes and to absorb its wastes under prevailing technology," and makes a global assessment of the EF. The analysis of the EF includes the measurement of cropland required for the production of food, etc., grazing land required for the production of stock farm products, etc., fishing grounds required for the production of marine products, forests required for the production of timbers, forests required for the absorption of carbon dioxide.

Ecological Footprint by country



Note: Figures indicate the number of planet earths in terms of the ecological footprint of specific countries
Source: Compiled from *the Living Planet Report 2006 (WWF)* by the Ministry of the Environment

According to the "Living Planet Report 2006," published by the World Wildlife Fund for Nature (WWF), the Ecological Footprint ("demand") exceeded the Earth's biocapacity ("supply") by about 25% as of 2003. If this state of demand over supply continues, ecological resources on the Earth will not be able to meet human needs in the end. Especially in many advanced countries such as the United States, EU nations and Japan, the EF shows overshooting. (CO_2 emissions caused by the consumption of fossil fuels occupy a large part of the EF.) Japan's EF as of 2003 was 2.5 times the global mean biocapacity (per capita), and the EF of EU nations (member nations as of 2006) and the United States were 2.7 times and 5.4 times respectively. This means that if the entire world adopts Japan's, the EU's or United States' lifestyles, a world population would demand 2.5, 2.7 or 5.4 planet Earths respectively.

Table 2-2-1 Global status of ecosystem services

Services	Sub-category	Status	Notes
Providing services			
Food	Crops	▲	Substantial production increase
	Livestock	▲	Substantial production increase
	Capture fisheries	▼	Declining production due to overharvest
	Aquaculture	▲	Substantial production increase
	Wild foods	▼	Declining production
Fiber	Timber	＋／－	Forest loss in some regions, growth in others
	Cotton, hemp, silk	＋／－	Declining production of some fibers, growth in others
	Wood fuel	▼	Declining production
Genetic resources resource		▼	Lost through extinction and crop genetic resource loss
Biochemicals, natural medicines, pharmaceuticals		▼	Lost through extinction, overharvest
Water	Fresh water	▼	Unsustainable use for drinking, industry and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy
Regulating Services			
Air-quality regulation		▼	Decline in ability of atmosphere to cleanse itself
Climate regulation	Global	▲	Net source of carbon sequestration since mid-century
	Regional and local	▼	Preponderance of negative impacts
Water regulation		＋／－	Varies depending on ecosystem change and location
Erosion regulation		▼	Increased soil degradation
Water purification and waste treatment		▼	Declining water quality
Disease regulation		＋／－	Varies depending on ecosystem change
Pest regulation		▼	Natural control degraded through pesticide use
Pollination		▼	Apparent global decline in abundance of pollinators
Natural hazard regulation		▼	Loss of natural buffers (wetlands, mangroves)
Cultural services			
Spiritual and religious values		▼	Rapid decline in sacred groves and species
Aesthetic values		▼	Decline in quantity and quality of natural lands
Recreation and ecotourism		＋／－	More areas accessible but many degraded

Source: *Millennium Ecosystem Assessment*

resources by converting it into the size of land/water area. (See the Column below.) According to the World Wildlife Fund for Nature (WWF), the Ecological Footprint has exceeded the Earth's biocapacity since the 1980s (in terms of ecologically productive land/water area). This overshooting status means that people are consuming resources faster than nature can recover from the damage caused thereby, and that the biocapacity can no longer keep pace with human consumption.

Japan is now experiencing population decreasing. But, the United Nations Population Division projects that the global population, currently about 6.5 billion people, will continue to increase in the future, with the estimated population as of 2050 being over 9 billion (medium variant). If the global demand for ecosystem services continues to increase, the demand is most likely to exceed the potential supply of the Earth's ecosystems, possibly resulting in the devastation of ecosystems themselves.

In particular, increased dependence of human activities based on fossil fuel since the Industrial Revolution has had a serious impact on ecosystems and their core element, biodiversity. As mentioned above in Section 1, sound ecosystems that are supported by rich biodiversity are supposed to have the ability to self-recover and correct any ill conditions by coordinating their functions. Even if any temporal malfunction happens due to the damage from drought, tsunami, cold wave, flood or other natural disasters, ecosystems are supposed to be able to recover and regain their integrity. However, the recent impacts of human activities on ecosystems are strong enough to impair the said self-recovery ability. Also, recent extensive damages of biodiversity have been generating a vicious spiral of deteriorating the ecosystem's integrity.

From the standpoint of the carbon cycle, CO_2 emissions caused by massive combustion of fossil fuels can be defined as the discharge of sequestrated CO_2 that ecosystems took a very long time to fix. This affects the water cycle too. This has changed precipitation intensity and conditions as well as the abundance and melting seasons of ice and snow, and has altered river flows significantly, and all of those changes could fatally affect water resources for future generations.

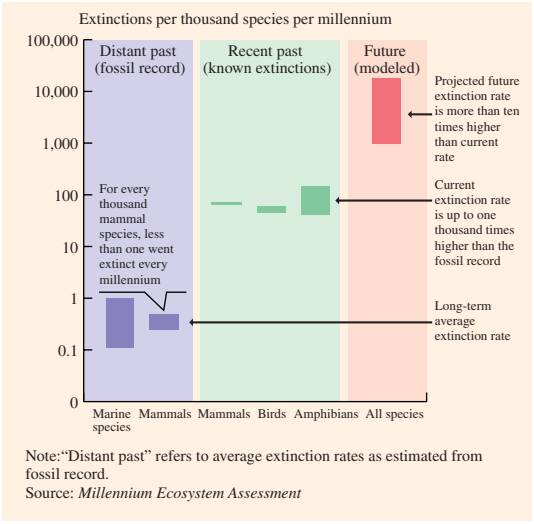
The Millennium Ecosystem Assessment (MEA) aforementioned analysis of the benefits (services) that people obtain from the Earth's ecosystems, and also evaluated the recent global state and trends of ecosystem services by focusing on twenty-four specific quantifiable services for the past several decades (Table 2-2-1). Through this evaluation, it has been found that fifteen services, including essential services such as water purification, air quality regulation and natural hazard regulation, have been degraded as a result of the human abuse or modification of ecosystems to satisfy our demand (e.g., increased demand for food) while four services

Column : Species-Extinction Rate is up 100 to 1000 Times Higher than that in the Past

The World Conservation Union (IUCN)-classified Red List of Threatened Species show endangered species at risk of extinction in different ranks under objective criteria. According to the 2006 threatened species database, which covers those species evaluated by the IUCN, endangered species are made up of 23% of all mammals, 12% of all birds, and 31% of all amphibians. This data tells us that so many species are on the verge of extinction.

In the course of evolution of life, species extinction is a natural process, as dinosaurs and many other species became extinct in history. According to the Millennium Ecosystem Assessment, however, humans have caused extreme acceleration of species extinction rates, and the rate today is estimated to be roughly 100 to 1000 times worse than the average normal rate in the past. Through researches on fossil records, it is known that there were five mass extinction events in the past, when there was a sharp decrease in the number of species in a relatively short period of time. The current status of species extinction exceeds in scale any of the past extinction events, and is therefore referred to as the sixth mass extinction event caused by mankind.

Figure 2-2-2: Species extinction rates



Note:"Distant past" refers to average extinction rates as estimated from fossil record.
Source: *Millennium Ecosystem Assessment*

During the recent Conference of the Parties to the Convention on Biological Diversity, the 2010 Biodiversity Target was established. Toward this target, which is intended to achieve a significant reduction of the current rate of biodiversity loss by 2010, the parties to the Convention have been making efforts to attain their respective goals.

have been enhanced (increased benefits for human well-being) instead.

Among those degraded services, the deterioration of fisheries landings is serious. The marine biomass has been substantially reduced in much of the world to one tenth of the levels prior to the onset of industrial fishing. Also, loss of forests and wetlands had led as loss of natural flood control basins, which means an increased likelihood of disasters such as floods, etc.

Global Biodiversity Outlook 2, which is a report released in March 2006 during the 8th Conference of the Parties to the Convention on Biological Diversity, assesses the current status and trends of biodiversity and points out that twelve out of the fifteen assessment indicators show downward trends, meaning that the accelerating deterioration of our biodiversity continues.

Millennium Ecosystem Assessment gives major direct drivers that make anthropogenic impacts on ecosystems and biodiversity. One of them is climate change with the other four including habitat change, invasive alien species overexploitation, pollution through increased nitrogen loads, etc. (See Column at (2), 2 of Section 1) .

Regarding climate change, it has been getting more and more noticeable recently, as explained in detail in Chapter 1 above. The recent phenomena, such as the reduced population of polar bears as a result of lost habitats due to sea ice melting and the coral bleaching attributed to rising seawater temperature, can be considered "warnings" sent by life to human beings.

Section 3: Global Warming-Caused Changes in Ecosystems and its Impacts on Human Beings

Section 2 explained how human activities have caused the critical conditions of the Earth's ecosystems and biodiversity. Such deteriorated biological conditions have a significant influence on the ability of human beings to survive and their living conditions.

As mentioned above, people cannot maintain sound living without the benefits we receive from our planet's varied ecosystems and the material and spiritual value that they represent. Because biodiversity supports the ecosystem services, great changes in biodiversity and ecosystems (as a result of global warming, etc.) can be interpreted as changes in quality and quantity of ecosystem

services available to humans, and they can also imply the possibility of unprecedented events or growing adverse impacts.

This section will explain the impacts that global warming-caused changes in ecosystems have on human beings.

1. Impact on the Agricultural and Stock-Raising Industries

Humans depend on animals and plants for food as energy source which means that changes in the status of inhabitation of those life could affect our food-security status enormously.

It is known that rice plants would be damaged if the daily mean temperature were to exceed 27 or 28°C during the ripening period from the time ears are formed to the full maturity stage, and that it would result in the increase of immature milky white rice kernels, including white-back kernels. It is also known that a rise of CO_2 concentration could help increase rice yields, but that the higher the temperature, the lower the yield-increasing effect ("Data on the recent climate change and its impact on the growth of farm produce" by the Ministry of Agriculture, Forestry and Fisheries). According to a simulative future estimate of rice yields, based on climate change models and atmospheric circulation models, the yield in the southern part of Japan is estimated to be reduced by nearly 40% when an atmospheric circulation model developed in Canada is applied. It is also estimated that global warming could increase the population of insects harmful to rice, such as Chilo suppressalis (rice stem borer moths), Nephotettix cincticeps and Laodelphax striatella, and also could change their habitats or activity season. Therefore, there is a concern that rice quality will be degraded in extensive areas nationwide. Actually in Kochi Prefecture, the ratio of the first-grade (top quality) rice to the entire yield, that had been maintained around 60% to 80% traditionally in this region, has already dropped to 30% to 40% ("For overcoming high-temperature damage on deepwater rice" a report by the Ministry of Agriculture, Forestry and Fisheries). Cultivation of rice requires a lot of water in the preparation stage (at the time of planting). As the recent climate change has damaged the integrity of the water cycle, leading to changes in the river flow and seasonal natural characteristics as well as reduced-irrigation water supply, those changes are likely to affect conventional cropping seasons and production patterns.

It is known that fruit trees are particularly susceptible to climate change. This is because of the low adaptability of fruit trees to adjust their cropping period to climate conditions, while on the other hand annual plants are relatively adaptable due to their adjustable seeding time, which makes it possible to obtain optimal temperatures every year regardless of climate fluctuations. Citrus unshiu (Japanese tangerine), which occupies the largest share over all Japan-grown fruit trees in terms of production, has actually been found, by a survey, to be affected by the recent global warming, resulting in the northward shifting of its optimal growing zone (having a yearly mean temperature of 15°C or higher but less than 18°C). Traditional growing regions for Citrus unshiu, which currently range over coastal regions along the Pacific Coast, the Seto Inland Sea or in Kyushu, will be most possibly found as outside the optimal growing zone by 2060s, because their temperatures will be higher.

Europe had a severe record-breaking heat wave in 2003, suffering heavy casualties mainly in Western Europe. In addition, it caused significant damage to farm produce due to high temperatures and dried weather. This year, grain production in the EU dropped by as much as about 23 million tons from the previous year. Although it is too early to conclude that global warming was a direct cause of this devastated heat wave, it can be estimated that accelerated global warming could increase similar heat waves, possibly resulting in chronic and expanded damage.

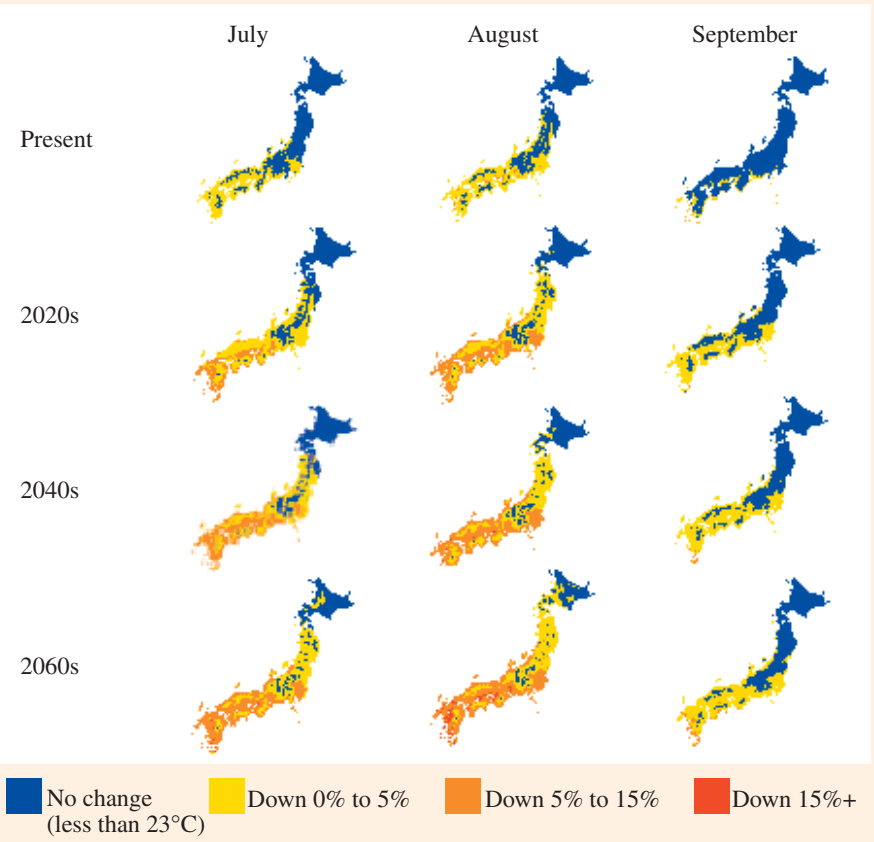
Stock farming also receives serious damage from global warming. For example, a study conducted by the National Agriculture and Food Research Organization (NARO) based on climate models shows that accelerated global warming would invite serious damage to broiler-meat production. NARO reports that it could significantly reduce chicken-meat production especially in the

Basal-white rice | White-back rice | Milky white rice

Immature white rice kernels

Photo: courtesy of Hideki Nagahata of Ishikawa Prefectural University

Figure 2-3-1: Estimated decline of broiler-meat production and projections as of today, 2020s, 2040s and 2060s



Source: "Impact of Global Warming on Broiler-Meat Production Estimated from Changes of the Mean Ambient Temperature" by Makoto Yamazaki et al, Nihon Chikusan Gakkaiho, 77 (2).

western part of Japan including Kyushu, Shikoku, Chugoku and Kinki regions (Figure 2-3-1). There is also a report showing the trend of degrading quality of farming conditions for milk cows, beef cows and pigs.

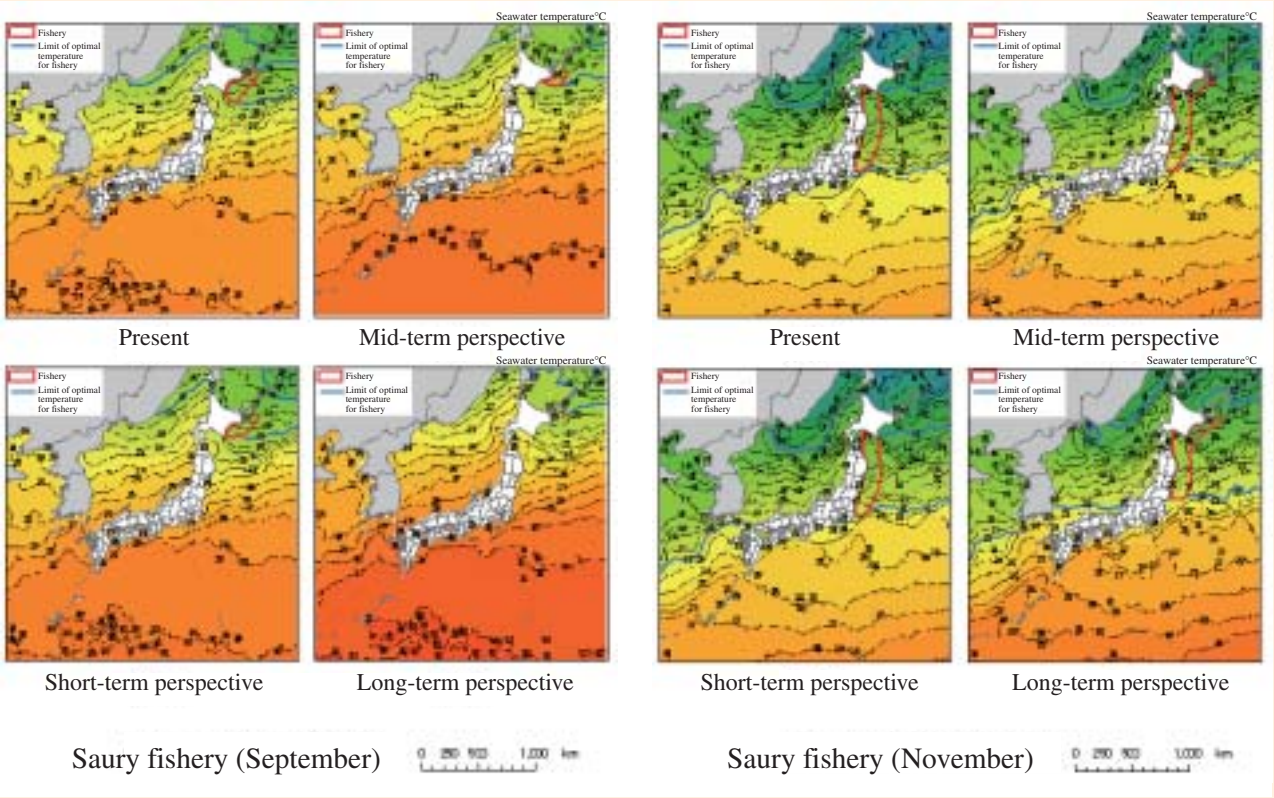
Although some impacts of global warming tend to emerge slowly, an incremental, extreme climate change, including drought and heat wave, could invite a serious sudden decline in the production of crops or stock-farm products. Such change and damage, large or small, could happen anywhere in the world. Since such damage is directly related to food supply for human beings, which is the key need for people's survival, appropriate measures should be introduced to avoid a global food crisis. Since Japan depends on imports for food (Japan's food self-sufficiency rate as of FY2005 was 40% in terms of calories), the impact of a global downward trend of food production on Japan is immense, in terms of not only food supply but also national security.

2. Impact on the Fishing Industry

Global warming is expected to invite changes in ocean currents and rising sea surface temperatures. Such changes in oceanographic conditions could have a serious influence on oceanic biodiversity, and also affect people who live close to the ocean and would otherwise enjoy rich marine-biological benefits. Japan is especially susceptible to those changes since the country is surrounded by the ocean and depends heavily on marine products for food. Therefore, appropriate measures are needed to avoid any devastating damage.

According to the results of a survey conducted by the Fisheries Research Agency, fisheries of migratory fish, such as saury, sardine, pacific mackerel and horse mackerel, are expected to shift northward in the future. For example, saury migrates seasonally, and in September they usually gather off the coast of the Nemuro Peninsula, east Hokkaido. However, the recent trend of rising seawater temperatures is expected to cause a northward shifting of the fishery, which could result in a change in distribution and fishing season in the long run. Flounder is also affected by rising seawater temperatures, and it has been reported that the southern limit of the habitat of this coastal fish could possibly make a northward shift in the future. Similarly, an optimal nursery for

Figure 2-3-2: Estimated shifting of saury fishery caused by rising seawater temperature



Note 1: "Present" shows current sea-surface temperatures measured by the Japan Metrological Agency (for future global warming trend analysis). "Short-term perspective" represents a rise of 1.0°C from the present, and "Middle-term perspective" indicates estimates based on the Agency's long-term projection (for future global warming trend analysis) (a rise of 1.4°C from the present), and "Long-term perspective" represents a rise of 1.5°C from the "Middle-term perspective" values.
Note 2: Fishery location is based on the assumption that sea-surface temperature is 16 to 20°C in August, 16 to 19°C in September, 12 to 23°C in October and 12 to 22°C in November.
Source: "Estimated Impacts of Global Warming on the Distribution of Marine Organisms in Japan" by Hisami Kuwahara et al, Chikyu Kankyo vol. 11, No. 1 (2006).

globefish, a hatchery fish, could also shift northward.

Some marine creatures that are a nuisance to the fishing industry also seem to be moving northward. Aetobatus flagellum (longheaded eagle ray), whose habitat ranges over the subtropics from the Indian Ocean to the East China Sea and tropical coastal areas, is a predator of bivalves such as clams and pen shells, and thus interferes with fishermen. Since 1989, when this ray was first discovered in the Goto Islands (Nagasaki Prefecture), a great many of them have been located in the Ariake Sea and the Seto Inland Sea, and fishery damage in those areas has been repeatedly reported.

Also, increased acidity of seawater attributed to increased CO_2 concentration is considered to affect marine planktons, which could endanger oceanic biodiversity. In addition, a rising sea-surface temperature is expected to adversely affect the biosphere in southern water zones, although it could help to improve productivity in northern water zones. In southern waters, if surface temperatures rise, it would hamper vertical circulation of sea water because of the lowered ability of surface water to be exchanged with cold deep water. This would weaken the upwelling flow of abyssal nutritious salts, etc., which could seriously affect the distribution of phytoplankton that constitutes the basis of oceanic food chains. Consequently, it could affect marine products to be consumed by human beings.

3. Impact on Human Health

In the Earth, there are many infectious diseases that could be transmitted via vectors that convey pathogens from one host to another.

For example, malaria spreads through mosquitoes and is potentially threatening to 2.5 billion people in the world, which accounts for 40% of the global population. Every year, it causes disease in 300 million to 500 million people and kills 1.5 million to 2.7 million people worldwide. It is known that Plasmodia, malaria parasites, become active at a temperature of 15–20°C or higher, and

that Anopheleles, transmission vectors of Plasmodia, become active at a temperature of 22°C or higher. Malaria has been eradicated in Japan, but due to accelerating global warming, Japan will be closer and closer to potential malaria-vulnerable regions again.

Dengue fever is also a vector-borne infectious disease transmitted via mosquitoes living in hot regions, such as Aedes aegypti and Anepheleles. Each year, about 100 million people around the world contract this disease, and about 250,000 of them are estimated to develop life-threatening dengue hemorrhagic fever. Children in the tropical and subtropical regions are especially vulnerable to the menace of dengue fever. Historically, Southeast Asian countries and Caribbean countries used to be the center of the dengue infection, but the disease has been expanding recently to reach the southern part of China, South Pacific countries and South America. In tourist-abundant Hawaii, dengue fever spread in 2001 and 2002, registering 122 patients. Like malaria, dengue fever could also be a new menace to Japan because of global warming.

Aedes aegypti sucking human blood
Photo: courtesy of Hitoshi Kawada, Institute of Tropical Medicine of Nagasaki University

Also, due to the expanding habitats of vector mosquitoes, there is a concern that Africa-centered infectious diseases such as Rift Valley Fever and West Nile Fever could become widespread in other regions.

Prevalence of infectious diseases is dependent on multiple factors such as residential environment and public health, but it is necessary for the international society to understand that global warming could cause infectious diseases to spread and it is necessary to give attention to this matter.

4. Impact on Culture

Quantitative and qualitative changes in ecosystem services could have not only material or physical impacts but also societal and cultural impacts.

Lake Suwa in Nagano Prefecture is known for its unique natural phenomenon of a frozen upheaval of lake water surface, called “omiwatari.” It is caused by repeated expansion and contraction of ice as a result of ups and downs of temperature. Traditionally in Suwa City, a holy ceremony to appreciate “omiwatari” is held where the chief priest and a representative of the parishioners of Yatsurugi Shrine (in Suwa City) identify and certify the formation of “omiwatari.” During the ceremony, cracked water-surface conditions are observed, and the results of the observation tell the year’s fortunes, including weather forecasts, crop harvests and even the fortunes of society. As a result of warm winters, Lake Suwa has frequently missed “omiwatari” in recent years .

Cherry blossoms tell Japanese people the arrival of the spring season, and have a long history of cultural significance to the Japanese, who have celebrated this flower since ancient times. Cherry blossoms appear in many old Japanese poems. One of the six great poets in the early Heian era, Ariwara no Narihira, wrote, “If there were no cherry blossoms in this world, how much more tranquil our hearts would be in spring.” (In other words, it is because of the unpredictability of the blooming and falling of the cherry blossoms that spring is such a time of agitation and excitement.) Recently, global warming and other causes have an effect to the season of this best-loved flower. For the past fifty years, since the Japan Metrological Agency started phonological observations in 1953, the official “blooming” announcement day has come earlier and earlier, and today, cherry blossoms start blossoming about 4.2 days (national average) earlier than fifty years ago.

“Omiwatari” of Lake Suwa Photo:courtesy of Suwa CityMuseum

It has also been reported that some areas in Kyushu show an extraordinary phenomenon in which a temperature rise does not necessarily induce earlier blooming, and some researchers have pointed out that hot winters tend to detune blooming. Cherry blossoms have an internal mechanism that triggers blooming after a certain minimally-required period of dormancy in winter, and they cannot bloom when dormant low-temperature winter days are too few. If the recent rising temperatures detune the blooming of cherry blossoms to a large extent, and should it result in cherry blossoms not necessarily blooming in spring, it would upset Japanese people since the cultural significance of cherry blossoms is now closely related to the spring

season. The pleasure of appreciating the spring season with cherry blossoms would be lost, and it would affect regional traditional recreational events. It is also possible that global warming could similarly affect ume (plum) blossoms, peach blossoms, hydrangea, camellia, peony and other plants in which temperatures play an important role in forming flower buds.

5. Vicious Spiral of Global Warming

Besides the direct impacts mentioned above, deteriorating functions of ecosystems could also have indirect but serious impacts on human beings. For example, it has been reported that the weakening ability of ecosystems to mitigate climate change could invite further acceleration of global warming.

Forests, where massive carbon sequestration takes place, are also affected by global warming in the form of extraordinary loss of moisture, which actually leads to frequent occurrences of fire. Forest fires release CO_2 as a result of combustion and also accelerate the release of CO_2 and methane from tundra and frost soil. It was reported that the forest fires that occurred in Indonesia as a result of El Nino effect from 1997 to 1998 burned down trees over several million hectares. It was discovered by a survey that Indonesia's carbon emission during 1997 was as much as 810 million to 2570 million tons, which accounts for 13% to 40% of the yearly global total CO_2 emission attributable to the consumption of fossil fuels.

In addition, global warming promotes decomposition of underground organic substances, and net carbon uptake by terrestrial ecosystems is weaken or even reverse.

Consequently, GHGs stored in ecosystems would be released into the atmosphere, further promoting global warming. And it could then adversely affect ecosystems. This is how a vicious spiral could be formed.

Thus, global warming has an enormous influence on ecosystems and biodiversity. Ecosystems support geoecological integrity and biodiversity support ecosystems. Therefore, it can be said that global warming would immensely harm, human beings either directly or indirectly. Human survival depends on the integrity of the biodiversity that supports ecosystems. However, human activities after the Industrial Revolution have significantly deteriorated global environment, and have invited critical conditions to affect themselves.

Global warming is a fact, and it is accelerating without doubt. It is our responsibility to make the right decisions to promote actions to protect the nature and its integrity so that we and future generations can continue to benefit from nature. Urgent and appropriate measures are required to stop global warming now.

Forest fire at Alaska
Photo :courtesy of MODIS Rapid Response Project as NASA/GSFC
This forest fire in Alaska was observed on July 30, 2004 by MODIS (optical sensor of NASA). Ascending gray smoke was detected.