Circulation Program

Program Director **TANIGUCHI Makoto**

What is circulation and how does it relate to global environmental problems? Two concepts of circulation are considered in this program. One is the circulation of energy and matter at the earth's surface. Matter includes air, water, chemical components and the living organisms they contain. Such circulations of energy and matter are caused by solar radiation absorbed by the earth's surface systems. In a broad view, the migration of humans around the planet can be considered as a kind of circulation, as can the great amount of material people move from place to place. Circulation describes large-scale spatial and temporal movements that in small-scale may look like flows. The critical issue in regards to global environmental problems is that changes in the biogeochemical circulations that sustain the biosphere are happening suddenly; they may be irreversible, though this is difficult to predict, as it depends on human action, thought and culture.

The recurrent interaction between humanity and nature can also be considered as a kind of circulation. Through economic and technological development, and through its sheer numbers, humankind has gradually transformed the surface of the planet. It has altered existing environments and created wholly new environments, which have in turn become new sites of human-environmental interaction in which new societies have emerged.

Individual research projects in the RIHN Circulation Program are conceptualized and carried out within the above conceptual framework. They cumulatively improve human understanding of the ceaseless motion that composes the biosphere.

Completed Research	Leader	Title
C-03	FUKUSHIMA Yoshihiro	Recent Rapid Change of Water Circulation in the Yellow River and its Effects on Environment
Full Research	**Leader**	**Title**
C-04	SHIRAIWA Takayuki	Human Activities in Northeastern Asia and their Impact on Biological Productivity in the North Pacific Ocean
C-05	TANIGUCHI Makoto	Human Impacts on Urban Subsurface Environments
C-06	KAWABATA Zen'ichiro	Effects of Environmental Change on the Interactions between Pathogens and Humans
C-07	INOUE Gen	Global Warming and the Human-Nature Dimension in Siberia

Recent Rapid Change of Water Circulation in the Yellow River and its Effects on Environment

A complex set of interacting factors, including natural climate variation, human-caused global warming and changes in land-use, contributed to the 1997 drought crisis in the Yellow River basin. This project evaluated how land use changes affect the water cycle throughout the Yellow River drainage basin and the effect of decreasing groundwater storage on marine environments. This study may prove to be at the forefront of ecological studies of densely-populated coastal zones. In studying the Bohai and Yellow Seas we may also be able to evaluate the effects of Yellow River change on marine products in the Sea of Japan.

Project Leader: **FUKUSHIMA Yoshihiro** Tottori University of Environmental Studies (RIHN until March 2008)

Outcomes

By implementing our Yellow River Study Project (hereafter referred to as YRiS), we were able to invite young and excellent researchers from Chinese universities and institutes. We were also able to obtain good results from the exchange of information between Japanese and Chinese scientists, and from our analysis based on observations, investigations and inspections in the period of 2003-2007.

We found that reforestation works undertaken by the Institute for Soil and Water Conservation on the Loess Plateau, which occupies almost 40% of the Yellow River Basin, have increased evapo-transpiration and consequently decreased the volume of river water by 15 billion m^3. The Chinese Yellow River Conservancy Commission was previously unaware of the link between decreasing river flow and upstream reforestation. Furthermore, regulation governing use of the Yellow River water by surrounding provinces gave each province independent authority. After the severe exsiccation in the Yellow River basin, an improved "water law" was established in 2002. It granted the central government complete authority over river water use and the ability to penalize over-use. Fortunately, there has been a rather large amount of precipitation on the North China Plain since 2000, so there were no instances of the unfair use of river water.

Reforestation has decreased erosion from the Loess Plateau, but the downstream riverbed is still continuing to increase or to maintain the same level despite the completion of the Xiaolandi Dam in 1997 and its important function of flushing out sediment on the riverbed by instigating small flood events. This means that there is increased danger of a flood disaster in an area in which nearly 100 million people live.

The environment of the Bohai Sea has been changed by the shortage of inflow water from the Yellow River. Firstly, the critical condition for primary bio-production has changed from Nitrogen to Phosphorus. Secondly, the exchange of fresh and sea water has decreased remarkably. Thirdly, chlorophyll-a has decreased with the decrease of river water. These findings suggest that primary bio-productivity in the Bohai Sea is decreasing.

How changes in land use affect the atmosphere above the Loess Plateau is still being analyzed. Topographic conditions and the strength of the Asia Monsoon seem to have a larger effect on the atmosphere than do land surface conditions.

It is estimated that almost 10 billion m^3 of water is used in upstream irrigation districts such as Qintongxia and Hetao, an amount that has likely remained constant between 1960 and 2000.

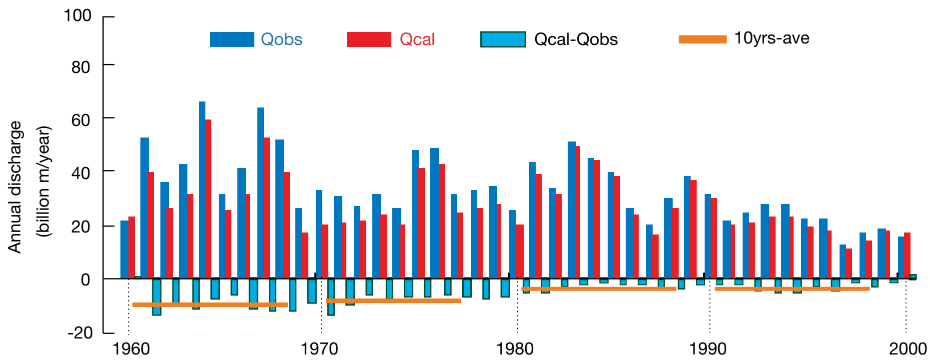
Plans for water supply using three routes from the Chang Jiang River to Beijing, Tianjin and the North China Plain may be completed soon. Whether or not water pollution, which is now a serious concern, will be resolved by this project will become a principal issue in the future because of the large cost of addressing such pollution.

Accounts of our study can be found in the YRiS Newsletters 1-8, published from September 1, 2003 to January 31, 2008 (http://www.chikyu.ac.jp/yris/newsletters.html).

Future Issues

Increased demand for food associated with present growth in the human population may lead to expansion of irrigated agricultural fields into areas where climate conditions are rather dry. Efforts to increase the efficiency of water use would appear to be too late to improve agricultural water-use given the rather small amounts of precipitation, and continued decreases in river water volume is likely to lead to salt accumulation in the Yellow River Basin. The supply of water from the Chang Jiang River to Beijing, Tianjin and the North China Plain is to be realized soon. Still many problems can be anticipated because the pollution of the Yellow River water remains unresolved; pollution in the Bohai Sea is likely to worsen.

Result of model simulation for the Loess Plateau area



Human Activities in Northeastern Asia and their Impact on Biological Productivity in the North Pacific Ocean

This project investigates qualitative and quantitative dimensions of iron circulation in heterogeneous human and natural ecological zones. It examines how dissolved iron from forests and wetlands is transported by the Amur River to the Sea of Okhotsk, and its role in supporting marine primary productivity. We also examine the effect of human activities in the Amur basin on these material linkages, and stimulate policymakers to take such large-scale and transboundary environmental circulations into account.

Project Leader
SHIRAIWA Takayuki
RIHN

Takayuki SHIRAIWA is Associate Professor at RIHN. He received his MA in Geomorphology (1989) and his Ph.D. in Glaciology (1993) at Hokkaido University. He was Research Associate (1992-2004) and Associate Professor (2004-2005) at the Institute of Low Temperature Science, Hokkaido University. He was in Antarctica (1993-1995) for field work, and was a visiting scientist at the Swiss Federal Institute of Technology (ETH; 2000-2001).

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Background

Japanese fisherfolk have long held the view that marine productivity is linked to forest conditions; their word for this linkage is *uotsukirin,* literally translated as "fish breeding forest." This project observes a similar linkage, but on a much larger scale. We use the term *kyodai uotsukirin,* or "giant fish-breeding forest" (GFBF) to indicate continental-scale ecological linkage of the Amur River basin and the Sea of Okhotsk and Oyashio area.

The Amur River basin contains extensive wetland and forest; both are important sources of dissolved iron which, when transported to the ocean, is an essential element in marine primary productivity. Dissolved iron is transported by thermohaline circulation—circulation driven by differences in water density caused by freezing seawater—in the Sea of Okhotsk. Aided by the East Sakhaline Current, dissolved iron is distributed into the Oyashio region, where it supports the fertile fisheries of the North Pacific Ocean. Our observations thus confirm that ocean ecological conditions are affected by the land surfaces in the Amur River basin.

The Amur River basin includes territories in Russia, China and Mongolia. More than 100 million people live in the basin and their livelihoods depend on agriculture, forestry and industry. Such activities impact wetlands and forests, and so the flux of dissolved iron, which in turn affects primary production in the ocean. In quantifying our description of dissolved iron transport and measuring the human impact on this process, we hope to improve coordination of the overlapping political, economic, and ecological systems that together affect the giant fish-breeding forest.

Figure 1 **Transport of iron from the Amur River to the Oyashio region**

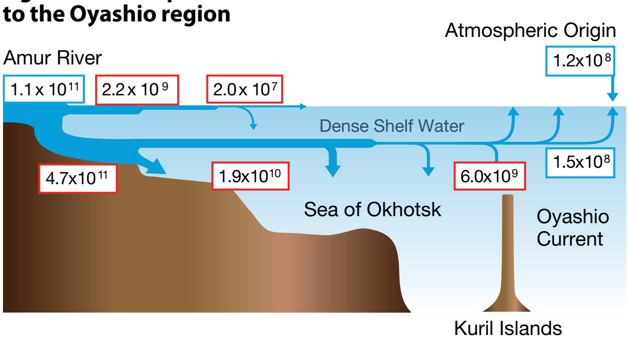


Photo 1 **A photo of the middle part of the Amur River, with musical score of the tune "The giant fish-breeding forest"**

Major results

The average annual flux of total and dissolved iron was estimated in various parts of the GFBF; these measurements confirmed the continuity of iron transport from land surfaces of the Amur River basin to surface water of the Oyashio region (Figure 1). $1.1 \pm 0.7 \times 10^{11}$ g of dissolved iron is transported to the estuarial area from the Amur River annually. Approximately 95% of the dissolved iron coagulates in the Amur–Liman estuarial area and the Sakhalin Bay. There are two pathways of iron transport from the estuarial area to the Oyashio region: 1) surface transport of total iron; and 2) transport with the dense shelf water (DSW). Both flows support primary productivity; the former in the Sea of Okhotsk and the latter in the Oyashio region. We estimate that approximately $1.2–1.5 \times 10^8$ g/yr of total iron was provided from the atmosphere and DSW in the Oyashio region. Among the iron used for the spring

Figure 2 **Estimated timber exports from the Russian Far East in 2005**

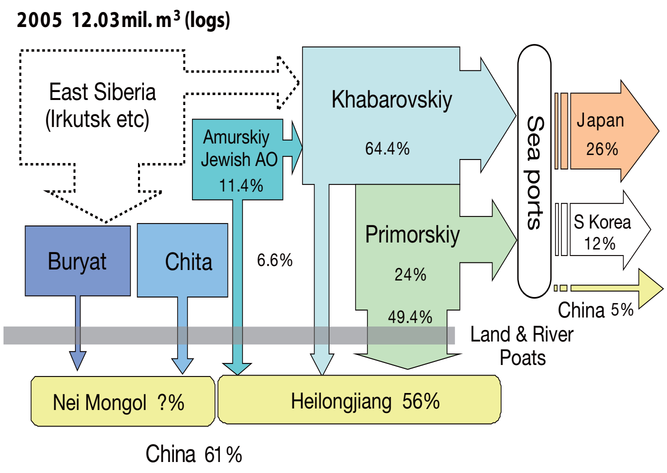


Figure 3a **Time series of dissolved iron concentration in the Naoli River.**

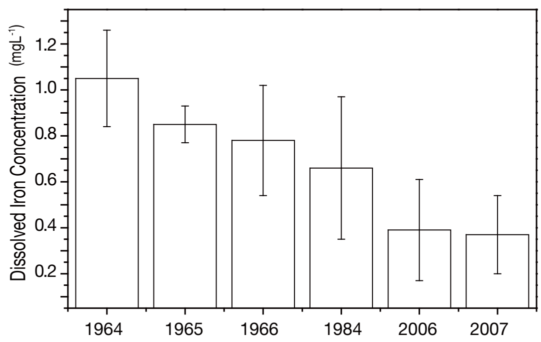


Figure 3b **Time-series of dissolved iron concentrations at Khabarovsk and Blagoveshchensk**

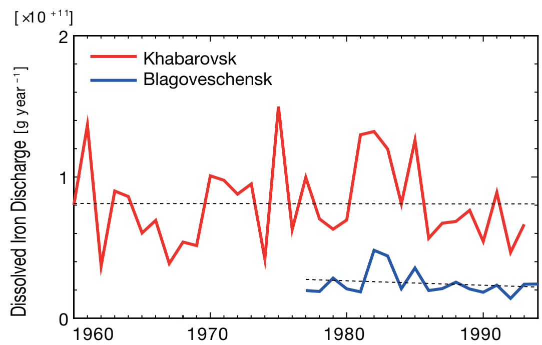


Figure 4 **Structure of the project**

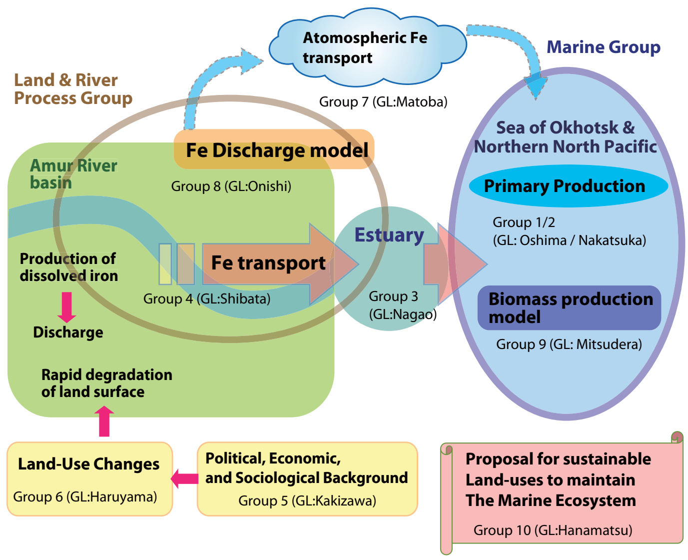
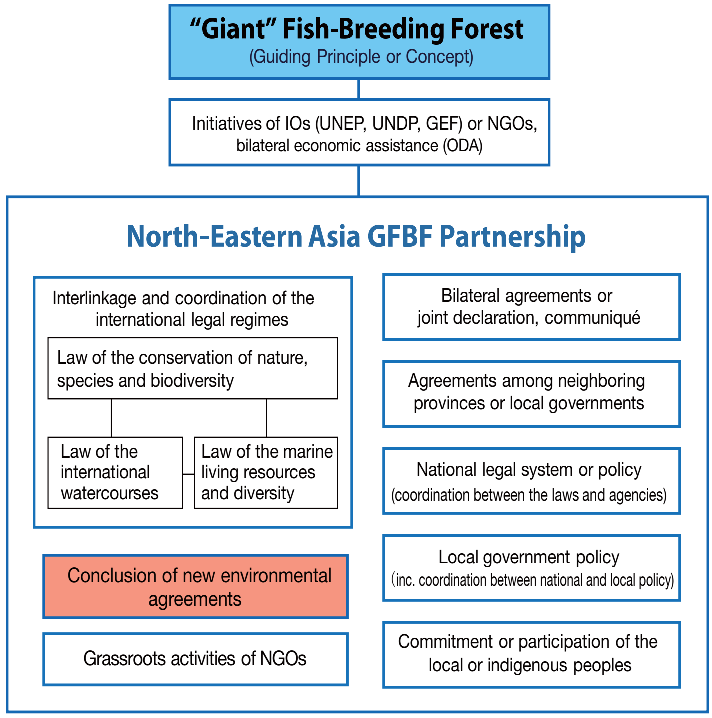


Figure 5 **Structure of Northeastern Asia GFBF Partnership**



bloom in the Oyashio region, 40% was provided by the DSW and 60% was recycled through microbial processes.

The impact of land-use changes on the concentration of dissolved iron were clear in the Sanjiang plain, where time series measurements of iron concentration in a tributary river show a decrease in iron concentration since 1964, as the area of agricultural fields expanded (Figure 3a). It was, however, difficult to find evidence of a decrease in the iron concentration in the main channel of the Amur River (Figure 3b). Time series data of iron concentration at Khabarovsk indicate that iron concentration has varied widely in the past, with no discernable long-term trend. The discrepancy will be studied intensively in 2009.

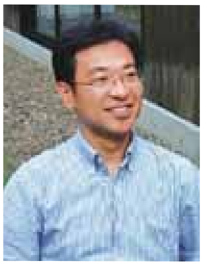
Deforestation, forest fires and poor management systems are degrading forests in the Russian Far East (Figure 2). After rapid expansion in the latter half of the 20th century, agricultural conversions on the Chinese side of the Amur River basin has stabilized, but irrigation has rapidly reducing the groundwater table of the Sanjiang plain.

Final goals of the project in 2009

On the basis of our description of the Amur River basin, we have: (1) devoted our efforts to developing the agenda for the conservation of the GFBF system; (2) realized that such an agenda should combine an ideal or general framework that suggests an international regulatory system along with a more pragmatic framework that reflects the political and economic situations in each country (Figure 5); and (3) formed a scientific board, the Amur-Okhotsk Consortium, to further discuss the futurability of the Amur-Okhotsk-Oyashio GFBF system.

Human Impacts on Urban Subsurface Environments

This project assesses the effect of human activities on urban subsurface environments, an important but largely unexamined field of human-environmental interactions. Subsurface conditions merit particular attention in Asian coastal cities where population numbers, urban density and use of subsurface environments have expanded rapidly. The primary goals of this project are to evaluate the relationships between urban development and subsurface environmental problems such as extreme subsidence, groundwater contamination, and thermal anomalies associated with the urban "heat island" effect, and to provide ecommendations of how these impacts can be addressed or voided in the seven Asian coastal cities under study.



Project Leader
TANIGUCHI Makoto
RIHN

Prof. Taniguchi earned a doctorate in hydrology from the University of Tsukuba. In addition to his work at RIHN he is a leader of the UNESCO-GRAPHIC Project "Groundwater Resources Assessment under the Pressures of Humanity and Climate Change", and vice president of the International Committee of Groundwater of the IAHS/IUGG. He has published several books and journal articles on hydrology, geophysics and environmental science.

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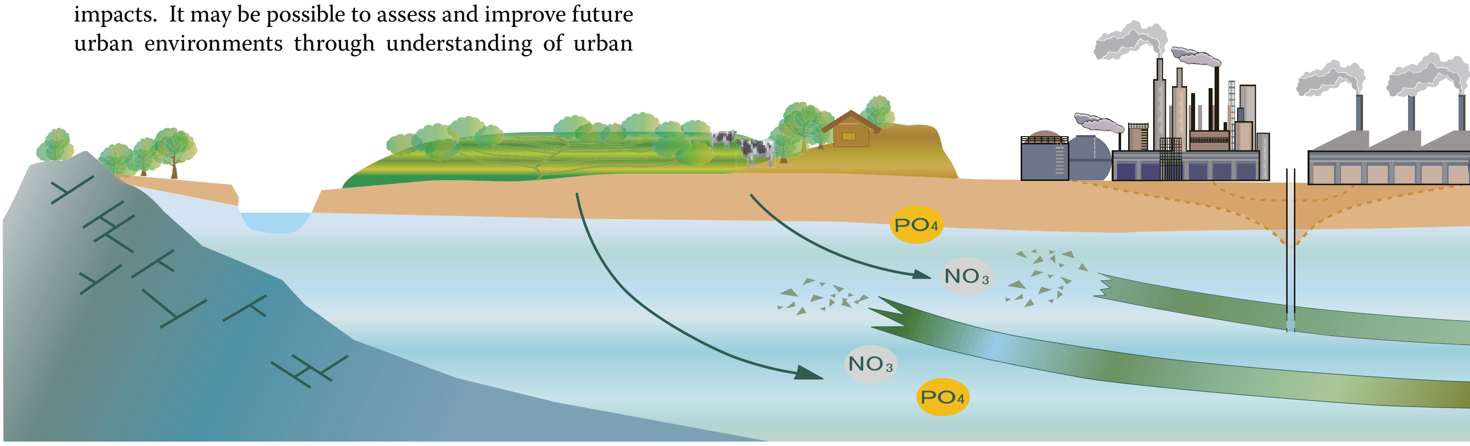
BUAPENG Somkid	Ministry of Natural Resources and Environment, Thailand
LEE Backjin	KRIHS, Korea

Project objectives

Most global environmental studies have focused on above ground environments. Subsurface environments, though they are involved in biogeochemical circulations and are critical to overall environmental quality, have been largely ignored, perhaps because of their invisibility and difficulty of evaluation. Subsurface environmental problems such as subsidence and groundwater contamination are repeatedly manifest in major Asian cities, though there is often a time lag between the "stage" of urban development and recognition of subsurface impacts. It may be possible to assess and improve future urban environments through understanding of urban areas' historical impact on surface environments.

This project investigates subsurface environmental conditions in Tokyo, Osaka, Bangkok, Jakarta, Seoul, Taipei and Manila. The relationships between these cities' historical development and their impact on subsurface environments will be assessed by socio-economical analyses and historical records. Hydrogeochemical and in-situ/satellite-GRACE gravity data will describe groundwater flow systems and changes in groundwater



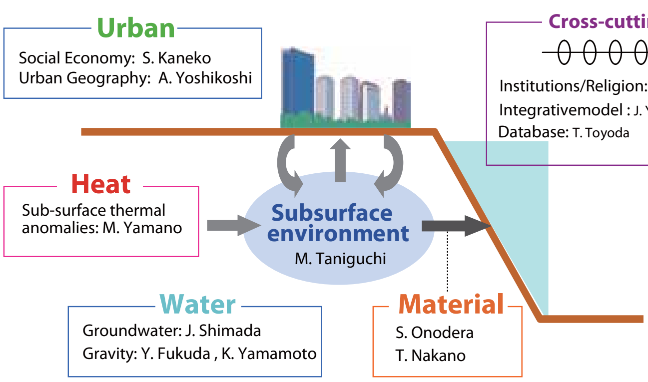
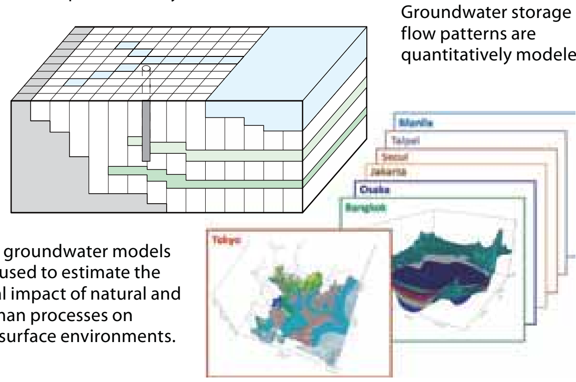


Figure 1 **Research Structure**

Figure 2 **Cross-cutting analysis: Integrated models**

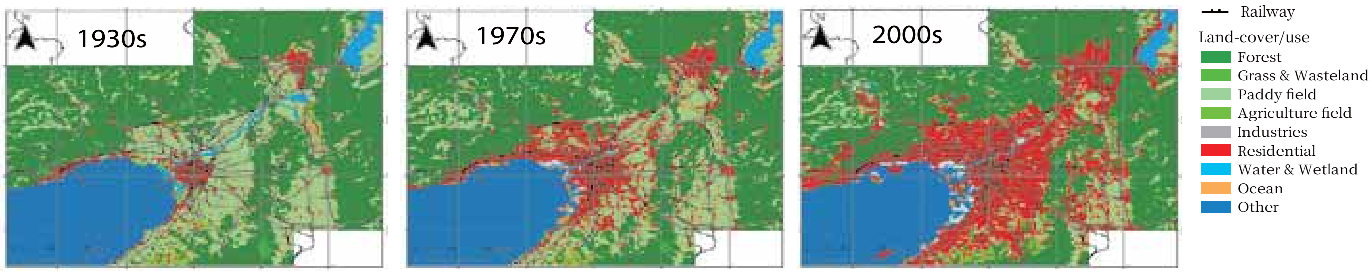
The model working group (MWG) integrates observed data and constructs a framework that allows comparative analysis of the seven cities.

Groundwater storage and flow patterns are quantitatively modeled.



The groundwater models are used to estimate the total impact of natural and human processes on subsurface environments.

Figure 3 **Cross-cutting analysis : GIS working group**



Changes in land use/cover in Osaka. Residential areas have expanded along the railway corridors.

storage, and indicate where significant problems in subsurface environments exist. Chemical analyses of subsurface waters, sediments and tracers will allow us to evaluate contaminant accumulation and their transport from land to ocean. Finally, we will use urban meteorological analyses to reconstruct surface temperature histories in the seven cities and to examine the impact of the urban "heat island" effect on subsurface thermal contamination.

Progress in 2008

Subsurface environment in targeted cities have been surveyed, and monitoring of subsurface environments in Bangkok, Jakarta, Manila, Seoul, Taipei, Tokyo and Osaka is ongoing.

Natural and social data have been assessed in each city, and compiled into a GIS database. Based on this data, land use/cover maps of 0.5 km mesh were composed for each city at three development stages (1930s, 1970s, and 2000s)

RIHN project members co-organized the international symposium, *HydroChange2008*, based on which the book "*From Headwater to the Ocean*" was published by CRC press (2008).

Several cross-cutting themes, such as the relation between groundwater and religious sites and beliefs in Bangkok and Jakarta, have been identified and investigated.

Interim results of the project were published as a special issue of the journal Science of the Total Environment (STOTEN vol. 407[9], 2009), which included an overview of the project and 15 original papers.

Future works and challenges

Analysis of water use and quality in relation to public/private water rights and the distinct regulatory histories of surface and groundwater in the various cities.

The Model Working Group has been formed in order to integrate the impacts of economics, water resources, environmental loads, and policy on subsurface environments.

Land use/cover data taken at three dates (1930s, 1970s and 2000s) in the study cities will be used to evaluate the rate of groundwater recharge, thermal storage in aquifer, and subsurface contamination.

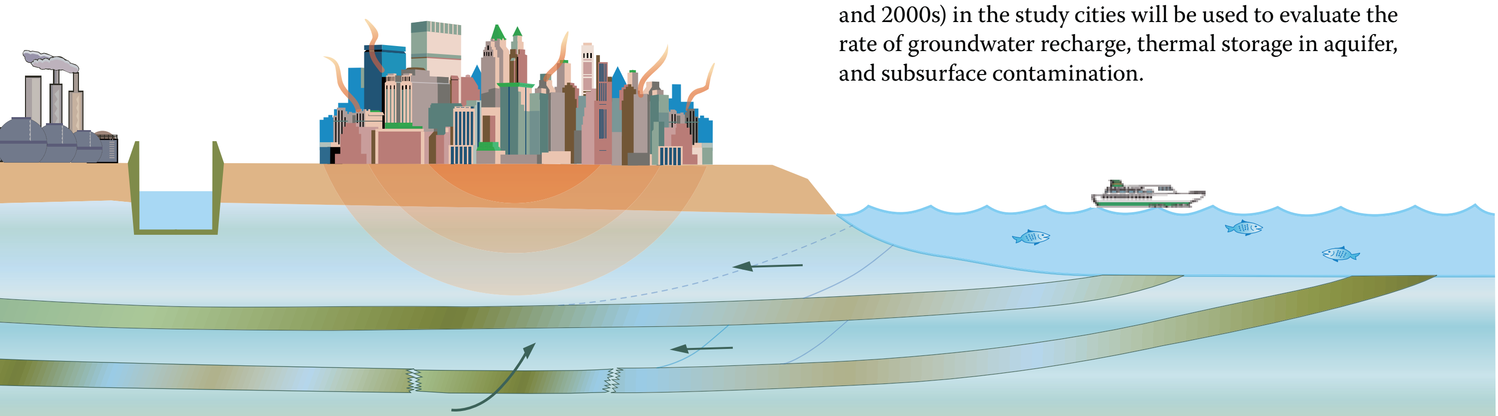
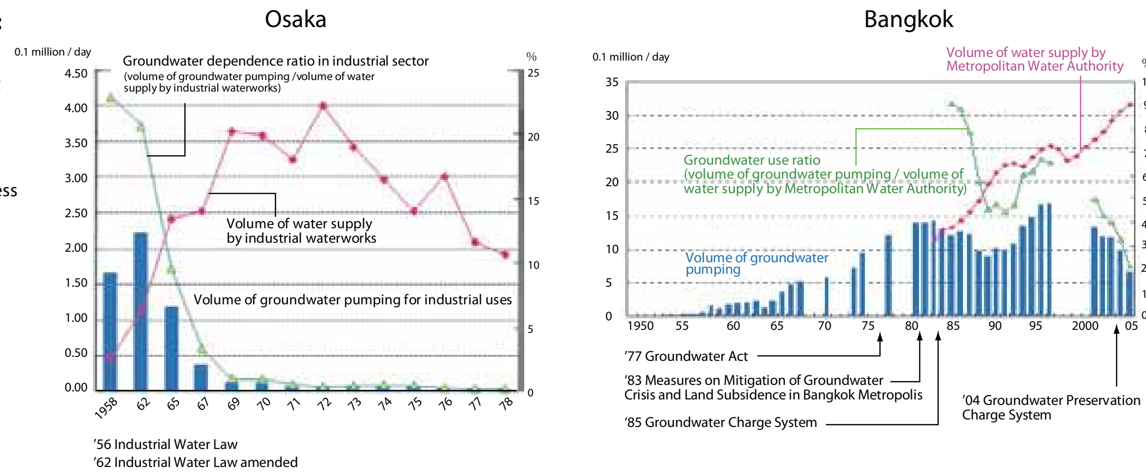


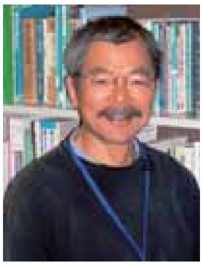
Figure 4
Cross-cutting themes: Legal institutions

This figure demonstrates that appropriate regulation and balanced use of surface- and ground-water can reduce inefficient use. In both Osaka and Bangkok, facilitating access to abundant surface water reduced use of groundwater.



Effects of Environmental Change on the Interactions between Pathogens and Humans

There is an important environmental component to infectious disease. While pathological studies inform effective disease treatment, study of disease ecology—the interactions between pathogen, host and human actions that may create or eliminate 'fertile' disease environments—is increasingly necessary for prediction and prevention of new disease outbreaks. This project intensively examines the ecological and social causes and effects of Koi Herpes Virus disease in Japan and China as a model of pathogen-human interactions. Based on experiments and observations, we will suggest ways to prevent or minimize the emergence and spread of infectious diseases.



Project Leader
KAWABATA Zen' ichiro
RIHN

Zen'ichiro Kawabata is Professor at RIHN. He was previously Professor at Kyoto University and Ehime University, and Assistant Professor at Tohoku University. His research field is microbial ecology and aquatic ecosystem ecology.

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Background

The spread of emerging infectious diseases is becoming a serious global environmental problem. This study investigates the emergence and spread of Koi Herpes Virus (KHV), a pathogen responsible for episodic mass mortality in common carp (*Cyprinus carpio carpio*) since the late 1990s (Figure 1). The common carp is the original domesticated aquaculture species and is an important source of protein today.

The study has four main objectives: (1) to assess whether there is a positive relationships between human-caused environmental changes and the emergence of KHV disease; (2) to describe recent anthropogenic changes to freshwater ecosystems associated with carp behavior; (3) to investigate the ecological conditions that can be associated with emergence and spread of KHV disease; (4) to evaluate the impacts of KHV disease on the local ecosystem services on which people depend, the social and cultural attempts to address KHV disease, and their environmental significance (Figure 2).

The pattern of environmental change in an ecosystem and emergence of a new pathogen affecting both non-human and human species can be seen as a model of pathogen-human interactions. Because both the disease and the selected study sites allow us to conduct experiments to verify patterns of interaction, a further objective of the research is to suggest a general model of disease emergence and spread (Figure 3).

Research Methods and Organization

Fields surveys are conducted at Lake Biwa, Japan, and Lake Erhai, China. Laboratory work is undertaken at RIHN. Our project is organized into five research groups, plus executive and advisory groups, as follows:

The Human Alterations Group investigates the effects of anthropogenic environmental alteration on the emergence and spread of KHV and the behavior of its host *Cyprinus carpio carpio*.

The Pathogen and Host Ecology Group defines the environmental factors involved in KHV and carp biology, so describing the environmental factors involved in KHV infection and communication.

The Ecosystem Impacts Group examines the process of infection and the effects of KHV disease on ecosystem functions such as material cycling.

The Economics and Culture Group describes the KHV disease-associated losses, including in ecosystem services or other economic and cultural aspects, as well as social attempts to redress those losses.

Figure 1 **Carp killed by KHV disease**

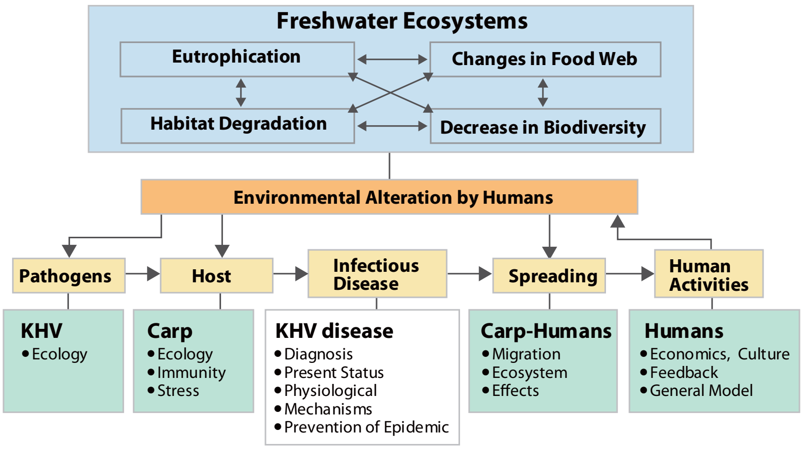
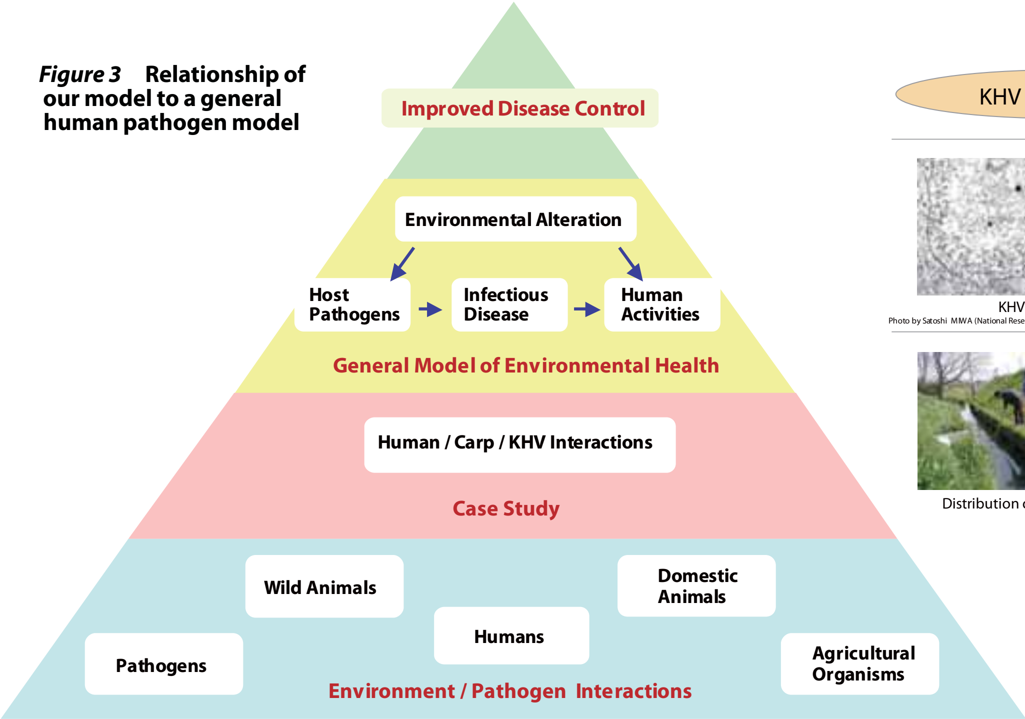


Figure 2 **Case studies: Interactions between KHV disease and humans**

(▢ : research fields with many unrevealed subjects)

Figure 3 **Relationship of our model to a general human pathogen model**



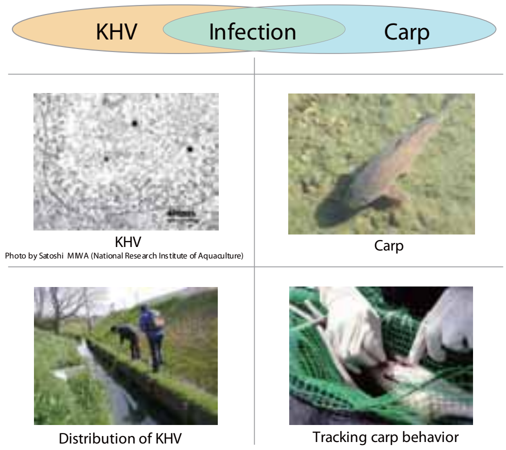


Figure 4
Survey of distribution of KHV and behavioral range of carp to predict the outbreak of infectious diseases.

Carp dishes
Carp is an important food and element of human food culture

The Feedback Group examines the effects of KHV disease-caused losses on subsequent human-driven environmental change.

The Executive Group coordinates the activities of each group and develops the model of pathogen-human interactions.

The Advisory Group, composed of recognized experts in relevant fields, makes suggestions in order to improve the research.

Results to date

1) We surveyed the topology, bottom quality, and water quality of six satellite lakes of Lake Biwa that seemed to be important habitat for common carp. We found heterogeneous environments in these lakes. It was revealed that spatial and temporal changes in water temperature in the human-degraded littoral zone are more homogenous than those in natural zones. This has the potential to affect carp behavior, immunity to KHV and stress of carp. A mathematical model, based on the hypothesis that common carp migrate between the satellite lakes seeking better habitats, predicted that lower connectivity among satellite lakes increases the carp stress level and accelerate the spread of KHV disease.
2) With Chinese collaborators we conducted a pre-survey on spatial and temporal changes in water temperature in Lake Erhai, China.
3) We invented a method to detect KHV in natural waters and so were the first in the world to reveal that KHV remains in lakes and rivers long after outbreak.
4) We collected 528 carp from seven sites in Lake Biwa to obtain materials for stable isotope analysis and to identify their behavioral range.
5) We installed breeding tanks with controlled water temperatures and established a method for quantifying stressor-induced substances in the water to discover the relationship between water temperature and stress in carp.
6) We discovered that only carp larger than 30 cm in length are immune to KHV. This indicates that carp behavior due to age is a key factor in determining the site of outbreak and spread of KHV diseases.
7) We began our study of the effect of common carp extinction on ecosystem functions and human economy and culture.
8) We studied the *legionella* infection process to discover common parameters of *legionella* and KHV diseases.
9) We organized the international symposium “Environmental Change, Pathogens, and Human Linkages” at RIHN in June 2008. We concluded that many infectious diseases may be caused by environmental degradation by humans.

Scheduled Research Activities in 2009

1) Survey the spatial and temporal distribution of water temperature in Lake Erhai, China.
2) Reveal the distribution of infective KHV in Lake Biwa.
3) Develop a micro device to measure the quantity and infectivity of KHV *in situ*.
4) Determine the environmental factors involved in KHV dynamics.
5) Use radio telemetry to document *C. carpio* range and behavior.
6) Clarify the behavior of *C. carpio* infected with KHV to reveal the locations where the infection likely occurs.
7) Conduct controlled experiments to reveal the relationship between environmental factors and stress in carp.
8) Describe the environmental characteristics of the places where KHV and carp interact.
9) Begin assessment of the economic impact of carp die-offs.
10) Create a preliminary model of the interactions between environmental change, KHV and humans.
11) Describe common parameters of KHV and other infectious diseases.
12) Develop set of recommendations to prevent or minimize the emergence and spread of infectious diseases.
13) Promote collaboration with the international program of biodiversity science DIVERSITAS.

Global Warming and the Human-Nature Dimension in Siberia: Social Adaptation to the Changes of the Terrestrial Ecosystem, with an Emphasis on Water Environments

Global warming will likely transform Siberian environments. Early evidence indicates that the hydrological, carbon, and methane cycles are undergoing rapid change, with potentially grave impact on Siberian flora and fauna. Human inhabitants, who have adapted to great changes in social structure and environment in the past, will be forced to adapt again, but to a cascading series of environmental changes whose dimensions are understood in outline. This project uses multiple satellite and surface systems to track changes in the carbon and hydrologic cycles and the cryospher (ice, snow and permafrost), and assesses their likely interactions and significance for human inhabitants of the region
The project is jointly conducted by Japanese and Russian universities and research institutes.

Project Leader
INOUE Gen
RIHN

Professor Inoue's specialties are laser spectroscopy of chemical reactions and monitoring of greenhouse gases, mainly CO_2 and CH_4. He is interested in terrestrial ecosystems as sinks for atmospheric carbon and has developed ground-, aircraft- and satellite-based atmospheric observation systems. He proposed and led the Greenhouse gases Observing SATellite (IBUKI/GoSAT) project for five years, and now serves as its Chief Scientist. He has conducted field-based monitoring of greenhouse gases in Siberia for twenty years.

Core Members

YAMAGUCHI Yasushi	Nagoya University
SASAI Takahiro	Nagoya University
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Background and Project Objectives

Climate models predict that evidence of climate change will have an early effect in Siberia and, as it is located in the high latitudes and in a continent whose climate is determined by radiative cooling, that the effects of climate change will be more significant than in other places. In fact, there is already clear evidence of declining ice-cover, forest degradation associated with wetter environments and increasing flood frequency and intensity.

Rising temperatures can trigger drastic change in ice, snow and permafrost environments, and increase the incidence and intensity of extreme weather events, flood and forest fires, as well as alter the structure of interactions between principal biophysical elements. The immediate effect of these changes is likely to increase the presence of carbon dioxide, methane and water vapor in the atmosphere, all of which contribute to further warming (Figure 2). Warmer environments also present new opportunities for large-scale resource extraction, which in turn increases the risk of environment damage, including natural gas leakage from gas pipelines.

Research takes place in the Lena Basin in East Siberia, an area characterized by a fragile symbiotic relationship between permafrost and forest. Permafrost provides moisture to the forest by preventing soil moisture from draining into deeper soil, while the forest shadows the permafrost from sunlight. A significant change in this relationship could release into the atmosphere an enormous amount of carbon currently stored in trees and soil. Our research in the area is conducted by three interrelated groups.

The Siberia bird's eye group

This group combines "bottom-up" and "top-down" observation of the Siberian carbon cycle. Surface spectral ASTER or MODIS data are combined with a terrestrial carbon-energy-water budget model (BEAMS) developed by our group to examine changes in land cover. This data will be supplemented by monitoring of greenhouse gases in Siberia enabled by Japan's launch of the GOSAT (Greenhouse gases Observing SATellite) in January 2009. GOSAT data should rectify the scarcity of ground-based monitors of greenhouse gases in Siberia. This data will improve our understanding of the CO_2 and CH_4 budget in Siberia and track greenhouse gas emissions due to forest fires and natural gas pipelines. Spectral surface data also allows measurement of flood extent and frequency, area of forest degradation or loss, and change in reindeer

Photo 1 **Flooding of the Lena River, *Yakutsk, overtakes a village***

Photo 2 **Forest degradation caused by a wet environment**

Figure 1 **Past field research area in Siberia.**
Red: natural science
Yellow: socio-ecology

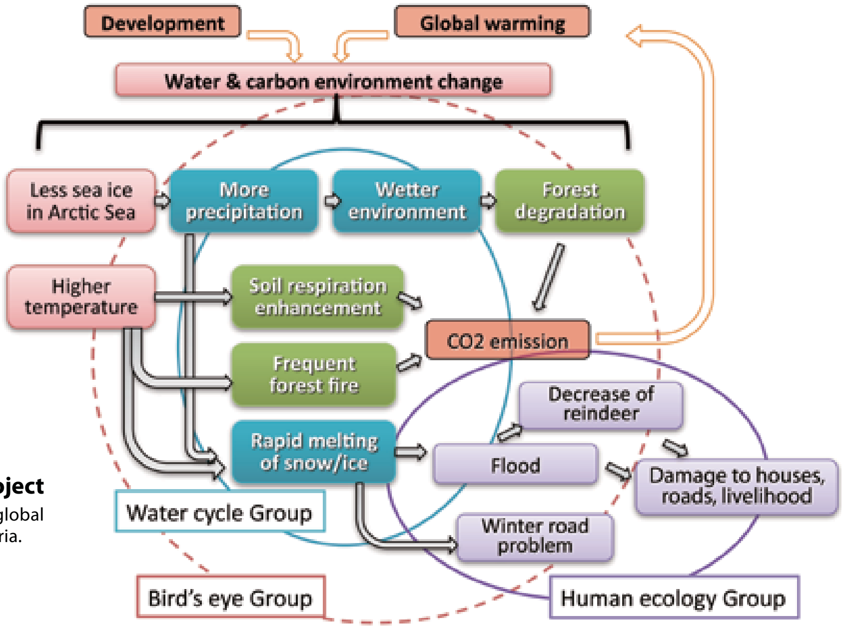

Figure 2 **Flow chart of Project**
Flow chart depicting processes of global warming and development in Siberia.

habitat, phenomena which are also of relevance to the human ecology group.

The water cycle and ecosystem interactions study group

Ice cover in the Arctic Sea is decreasing more rapidly than predicted; atmospheric water vapor will be supplied year round and precipitation will increase in Siberia. How will Siberian forests respond to a wetter environment? There is evidence of sudden forest die-off (Photo 2), perhaps due to increased soil moisture. Isotope analysis of tree rings provides insight into the past conditions of forest-tundra growth. We have constructed a new monitoring tower at Ustimaya, located about 500km to the south of the existing monitoring tower at Yakutsk, to measure water vapor, carbon dioxide and heat budget. Precipitation at the new site is 1.5 times greater than at Yakutsk.

The human ecology group

Siberia's human inhabitants have adapted to the cold environment, but current environmental change affects their life patterns in unprecedented ways. Field studies have revealed that availability of drinking water (stored as ice in winter), availability of bio-fuels (mainly wood), pasture land productivity and patterns of animal reproduction and of hunting are now changing. The number of wild and domestic reindeer has dramatically declined in recent years. Climate warming has negatively affects their range and breeding and grazing grounds; there may also be some linkage between decreasing reindeer populations and recent economic conditions. We are going to investigate these changes by interviewing famers and hunters in villages, and by mounting tracking devices on wild reindeer.

Climate change and social change intersect in complex ways and are often difficult to predict. We believe that the human dimension of climate change in Siberia is a very important factor, as human action to changing environments has the potential to exacerbate, or perhaps mitigate, negative impacts. We begin by analyzing different actors' perceptions of contemporary change, emphasizing perception of abnormal conditions and of what constitutes a "natural disaster." Analysis of difference in social response to environmental change will improve understanding of social-ecological fragility and vulnerability.