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Penultimate Year Report

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SUMMARY OF RESEARCH OBJECTIVES AND CONTENTS

a) Research Objectives

The objective of the project is to elucidate the role of the Amur River in primary productivity in the Sea of Okhotsk and Oyashio region and then evaluate possible human impacts such as land surface disturbances in the Amur River basin on the marine ecosystem of the ocean. In this study, we attempt to answer 1) how dissolved iron is transported from the Amur River basin to the Sea of Okhotsk and Oyashio region, 2) to what extent the supply of dissolved iron regulates the primary production in these open waters, 3) how the land surface disturbances affect the material circulation in the Amur–Okhotsk system, 4) how human activity will impact the system in the future, and 5) how we can conserve this transboundary system. By answering these five questions, we will be able to propose a new global environmental concept, the “giant” fish-breeding forest (GFBF), in which there are physical and humanistic interactions between upstream and downstream and determine a way of conserving the system in a cooperative effort among China, Russia, Mongolia and Japan.

b) Background

The Amur–Okhotsk Project attempts to create a new global environmental concept referred to as the GFBF by expanding the traditional Japanese idea of Uotsuki-Rin (fish-breeding forest), which relates upstream forest with the coastal ecosystem both physically and conceptually. The GFBF hypothesis presents new perspectives in global environmental issues: an ecological linkage between the continent and open sea, the relating of less dependent stakeholders in the system, and finding environmental common ground across complex international boundaries. Multidisciplinary approaches are indispensable in studying and conserving the GFBF because stakeholders need to understand how to achieve a sustainable marine ecosystem in the Sea of Okhotsk and Oyashio region without limiting human activity on land.

We believe the GFBF can be a test bed for global environmental problems in general. Connecting less dependent stakeholders could be a first step in coping with complicated environmental issues. We attempt to visualize socio-economic relationships inside the GFBF system to demonstrate how stakeholders are related to each other unconsciously. Establishment of the concept will help bring together people who have been separated for many years under political tensions.

c) Research Methods

The physical structure of the GFBF was jointly studied by collaborators in the fields of biogeochemistry, geography, hydrology, climatology, glaciology and oceanography. Economic flow, land-use background, and conservation strategies in the system were studied by scientists in the fields of forest management, agronomy, economic geography, international law and politics.

The GFBF and its impacted area encompass nearly 4 million km^2. It includes parts of Mongolia, China and Russia as well as Russian and Japanese exclusive economic zones and international waters. The area has been under extreme political tension since the middle of the 19^{th} century and there has been little transboundary cooperation. This situation has resulted in the Amur River becoming one of the most seriously polluted waters in Russia.

d) Project Organisation

This project is composed of 10 research groups headed by group leaders (GLs). The project leader and 10 group leaders constitute the board of the project. In addition to individual group meetings, at least one project meeting has been held each year to discuss cross disciplinary issues. Daily communications and discussion have been carried out through an internet mailing list.

The themes/tasks of each research group are as follows. **Group 1** (GL: Dr. Kay I Oshima): physical oceanographic conditions in the Sea of Okhotsk and the northern North Pacific; **Group 2** (GL: Dr. Takeshi Nakatsuka): geochemical and biological conditions in the Sea of Okhotsk and the northern North Pacific; **Group 3** (GL: Dr. Seiya Nagao): transport of biogeochemical materials from the Amur River to the Sea of Okhotsk; **Group 4** (GL: Dr. Hideaki Shibata): biogeochemical transport from the terrestrial ecosystem to the Amur River; **Group 5** (GL: Dr. Hiroaki Kakizawa): background of anthropogenic impacts in the Amur River basin; **Group 6** (GL: Dr. Shigeko Haruyama): spatial and historical monitoring of land-use changes in the Amur River basin; **Group 7** (GL: Dr. Sumito Matoba): estimation of atmospheric transport of terrestrial material; **Group 8** (GL: Dr. Takeo Onishi): numerical modelling of basin-scale hydrology and iron transport; **Group 9** (GLs: Drs. Hiroyuki Matsuda and Fumio Mitsudera): numerical modelling of primary production in the Sea of Okhotsk and the northern North Pacific; **Group 10** (GL: Mr. Yasunori Hanamatsu): conservation strategy for the GFBF.

e) Progress up to Now

Three major achievements have been made since the Interim Evaluation (FR) on March 1, 2007.

1. Material linkage from the Amur River basin to the Oyashio region via the Sea of Okhotsk was finally validated by 1) observations of the spatiotemporal distribution of dissolved iron in various parts of the Amur River basin, 2) monthly monitoring of dissolved iron concentrations and discharges at Khabarovsk and Bogorodskoe, 3) observations of the temporal distributions of dissolved iron in the lower reach, mouth, and estuarial area of the Amur River, 4) measurements of dissolved iron in the Sea of Okhotsk and Oyashio region, and 5) measurements of the atmospheric iron input to the Oyashio region (Fig. 1). It was found that approximately 40% of the dissolved iron necessary to support phytoplankton production in the Oyashio region was transported through the GFBF system. The remaining 60% was microbially recycled iron originally provided by both intermediate water and atmospheric input.

2. The Amur–Okhotsk Project identified the importance of the Amur River to the marine ecosystem in the Sea of Okhotsk and Oyashio region at a Japan–Russia meeting during the G8 Summit held at Toya Lake, Hokkaido, in July 2008. The leaders of both countries agreed to begin a joint ecological research program in which the Amur–Okhotsk dissolved iron transport system was stressed. This might be the first example of a Research Institute for Humanity and Nature (RIHN) project contributing to international policy making.

3. The importance of the conservation of the GFBF was referred to in a policy-making paper published by the Economic Research Institute for Northeast Asia and submitted to the Ministry of Foreign Affairs of Japan.

f) Future Issues

The project is still uncertain whether land-use changes have affected the discharge of dissolved iron from the Amur River to the oceans. It is obvious from *in situ* observations that land-use changes such as the reclamation of wetland reduce the dissolved iron concentration locally. However, the impact becomes less obvious when we focus on the whole Amur River basin. This might be explained by a lack of knowledge of the mechanism of the seasonal release of dissolved iron from the land surface to the river. We would like to address this in the fifth year of the project by focusing on the extremely high iron discharge from 1996 to 1998 and by conducting intensive hydrological as well as biogeochemical monitoring in the Kiya River drainage basin.

We are not yet ready to propose how we can conserve the GFBF as an international environmental issue. We will address this by proposing a new framework "North-Eastern Asia GFBF Partnership" (Fig. 2), by uniting existing conservation laws and institutions that were originally created to address the various environmental problems in the system independently.

On the basis of the scientific achievements with respect to the GFBF, we will propose an "Agenda for the conservation of GFBF" through cooperation among Russia, China, Mongolia and Japan.

1. RESEARCH OBJECTIVES AND BACKGROUND

1. Research Objectives

The objective of the project is to elucidate the role of the Amur River in primary productivity in the Sea of Okhotsk and Oyashio region and then evaluate possible human impacts such as land surface disturbances in the Amur River basin on the marine ecosystem of the ocean. In this study, we attempt to answer 1) how the dissolved iron is transported from the Amur River basin to the Sea of Okhotsk and Oyashio region, 2) to what extent the supply of dissolved iron regulates the primary production in these open waters, 3) how the land surface disturbances affect the material circulation in the Amur–Okhotsk system, 4) how human activity will change the system in the future, and 5) how we can conserve this transboundary system. By answering these five questions, we will propose a new global environmental concept, the GFBF, in which materials recycle between upstream and downstream, and determine a way to conserve the system as collaborative efforts among China, Russia, Mongolia and Japan.

2. Background

Those employed in fisheries in coastal and estuarial areas of Japan have protected the forest of the drainage basins bordering their fishery fields. The forest was called uotsuki-rin (the fish-breeding forest) and the existence of such forest was believed to improve the condition for fish growth in the coastal areas by providing various nutrients to the coast. In the late 1970s, professional fishermen noticed that coastal zones were seriously damaged and the areas were no longer productive. Pioneering fishermen believed that such ecological deterioration in coastal and estuarial areas was caused by rapid changes in the land surface of the adjacent drainage basins through excessive land-development starting during the Japanese economic growth in the 1960s. Some leaders of fishery groups advocated reforestation in the adjacent drainage basins to restore a rich ecological environment in coastal and estuarial areas (*e.g.*, Hatakeyama, 1994; Yaginuma, 1999). The movement is called uotsuki-rin undoh (the fish-breeding forest movement).

Practically, it was totally unknown to what extent the material discharged from rivers affects the marine ecosystem, how much and what kinds of materials are exported under various conditions of land surfaces and how far the terrestrial materials affect the off-shore marine ecosystem. Matsunaga *et al*. (1984, 1998) conducted one of the first studies to indicate a relationship between riverine organic-iron complex and phytoplankton in an estuarial area. Since then, an increasing number of studies have shown that the land–ocean linkage of material transport through rivers plays a key role in the growth of fish populations in estuarial and coastal areas (*e.g.*, Yamashita and Tanaka, 2008). The mechanisms behind the linkage are not yet fully understood; thereby, several international and domestic research organizations have begun tackling these issues with a multidisciplinary approach (*e.g.*, Connected Rings of Forest–Human Habitation–Marine by the Field Science Education and Research Centre of Kyoto University; Land–Ocean Interactions in the Coastal Zone by the International Geosphere Biosphere Program / International Human Dimensions Program).

In contrast to the relationship between the land-surface and the adjacent estuarial and coastal areas, it is widely accepted there is no relationship between the land-surface and open waters. This is because some of the riverine materials flocculate in estuarial areas and then accumulated on the continental shelves without moving to the open waters. Our project focuses on this conventional idea.

The northern North Pacific is known to be high in nutrients and low in chlorophyll (HNLC); dissolved macro nutrients (nitrate, phosphate and silicate) in the surface water cannot fully be utilized by phytoplankton because of the low availability of iron. Iron is usually supplied to estuarial and coastal regions from the land surface and it is difficult for iron to be transported to the remote central area of the northern North Pacific. This idea was proposed by Martin *et al*. (1989) and is called the iron limitation hypothesis. The idea is now being confirmed by a mesoscale *in situ* iron enrichment experiment in the North Pacific (Tsuda *et al*., 2003).

The neighbouring Sea of Okhotsk is also characterised by sufficient nutrients supplied by the winter convective mixing of surface and deep waters. The Sea of Okhotsk is, however, not an HNLC region. This is probably because sufficient dissolved iron is transported from the Amur River. The Amur River, including major tributaries like the Shilka, Argun, Zeya, Bureya, Songhua Jiang (Sungari) and Ussuri Rivers, is 4444 km long and has a drainage area of 2,129,700 km^2 (Simonov and Dahmer, 2008). The major part of the drainage area is covered by boreal forest, mixed forest and swamps. The lower part of the drainage area is cultivated land and major cities such as Blagoveshchensk, Harbin, Khabarovsk and Komsomolsk-na-Amure. The relatively less developed Amur River basin enables the river to transport various kinds of terrestrial materials to the Sea of Okhotsk. Of particular importance is dissolved iron, which is considered to originate in an anoxic environment such as swamps.

The Sea of Okhotsk was studied intensively from 1997 to 2002 during the Core Research for Evolutional Science and Technology project led by Prof. Masaaki Wakatsuchi of the Institute of Low Temperature Science, Hokkaido University. It was found that two oceanographic mechanisms transport the water and materials from the mouth of the Amur River to the northern North Pacific. One is the East Sakhalin Current, which is a western boundary current along the east Sakhalin coast. Part of this current flows eastward as far as Bussol Strait to enter the northern North Pacific. The volume transport of this current is estimated to be in the range 3–10 Sv with an increase from summer to winter (Ohshima *et al*., 2002; Mizuta *et al*., 2003). The other mechanism transports water and material from the coastal area near the Amur River to the Sea of Okhotsk and further to the northern North Pacific including the Oyashio region (Nakatsuka *et al*., 2002). At the bottom of the northwestern continental shelf of the Sea of Okhotsk, very cold dense water due to brine rejection forms in winter. This water is characterized by enormously high turbidity due to tidal mixing and is transported into the intermediate depth by the East Sakhalin Current. By these two mechanisms, the water and material of the Amur River are effectively transported to the southern part of the Sea of Okhotsk and further to the northern North Pacific. Although no measurement of iron concentrations were conducted during Wakatsichi’s project, it is highly probable that the riverine iron can be transported by the above mechanism to the northern North Pacific where iron is the key element controlling phytoplankton growth.

If this is the case, the Amur River basin plays a crucial role in determining the biomass production both in the Sea of Okhotsk and the northern North Pacific including the Oyashio region. This relation reminds us of the Japanese concept of uotsuki-rin (the fish-breeding forest). However, the Amur–Okhotsk–Oyashio linkage is much stronger than that in the conventional concept. More importantly, this is the first attempt to relate the continental-scale terrestrial environment with open waters. Therefore, we refer to the idea as kyodai uotsuki-rin kasetsu (the “giant” fish-breeding forest hypothesis) and the verification of the hypothesis constitutes the first part of this project.

The dissolved iron mainly forms as a complex of iron and fulvic acids originating from forests and swamps in the basin (Matsunaga *et al*., 1998). The processes of the formation of the dissolved iron, its transportation to the river, and its delivery to the ocean are still open to question. It is, nevertheless, clear that changes in the land surface and river discharge affect the flux of the dissolved iron significantly, because the land surface and river constitute the source and method of dissolved iron inputs. The change in the dissolved iron flux may affect biomass production in the Sea of Okhotsk and the adjacent Oyashio region in the long run. Verifying the impact of terrestrial anthropogenic disturbances in the Amur River basin on primary production in the Sea of Okhotsk and Oyashio region is the second part of this project.

The Amur River drainage was developed after the end of the 19th century in Russia (Ganzey, 2005). In China, *i.e.* the Songhua Jiang River basin, intensive human activity dates back several hundred years. An accelerated human impact became more obvious from the middle of the 20th century on both sides of the Amur River. The area is disturbed currently by various anthropogenic and natural impacts such as forest fires, deforestation, agricultural and industrial activities, flooding and drought. Land-use changes in the Amur River drainage area, therefore, might have caused or may cause significant changes in the flux of dissolved iron, which might have or may result in biomass production changes in the ocean.

The Sea of Okhotsk and the northern North Pacific are known to be one of the most productive oceanic areas in the world. Approximately 50% of the sea product of Japan is from this area. Therefore, the ecosystem and environment of the Sea of Okhotsk and the adjacent Oyashio region are important not only with respect to the environment but also the economy of Japan.

Moreover, recent climatological analysis showed that sea–air CO_2 exchange in Oyashio and its adjacent areas was a unique centre where the most intensive exchange in pCO_2 occurred (Takahashi *et al*., 2002). This indicates phytoplankton growth in this region is important not only to the sea product but also the global climate.

Therefore, it is very important to clarify a robust relationship between conditions of the Amur River basin and ecosystems in the Sea of Okhotsk and Oyashio region to predict land-use impacts on the future marine primary productivity in the ocean. This information will be helpful not only for people concerned with uotsuki-rin, but also for people consuming sea products. In this context, the Amur River basin and the Sea of Okhotsk and Oyashio region are the most typical and extensive examples in the world.

As mentioned previously, the conservation of uotsuki-rin was begun by fishermen who profited from this system. The idea was then accepted nationwide and there began regional-scale attempts to protect uotsuki-rin by various stakeholders such as fishermen, citizens and municipal officers. The third part of this project therefore presents an idea of how we can conserve the GFBF, which encompasses multiple countries, exclusive economic zones and open waters.

In addition to physical boundaries, the Amur River has been the site of political boundaries between China and Russia since the “Treaty of Aigun” and “Convention of Peking” signed by the two countries in 1858 and 1860, respectively. Since the two agreements were considered to be unequal treaties, the boundary was rather unstable until the two countries finally agreed to define the boundary in 2004. This history has made the Amur River one of the most difficult rivers to monitor for conservation purposes. In practice, there was no formal joint-monitoring program between the two countries until a notorious accident involving a petrochemical company in the Chinese province of Jiling in 2005. This accident significantly polluted the Songhua River, the largest tributary of the Amur River (UNEP, 2006).

The Sea of Okhotsk has been a political hot spot between Russia and Japan. Owing to territorial conflict, it was practically impossible for Japan to monitor environmental problems in the Sea of Okhotsk during the last half of the 20th century. A collaborative effort between Russia and Japan for the environmental conservation of the Sea of Okhotsk is urgently needed owing to increasing activities relating to oil mining and natural gas exploration in the Sea of Okhotsk and its vicinity.

The above background indicates the GFBF is of local as well as worldwide importance and its concept will contribute to the solving of practical problems several countries are facing.

2. Significance as an RIHN Project

The Amur–Okhotsk Project is worth conducting at the RIHN for three reasons.

1. **The GFBF is not a local but a global environmental problem.**
   As mentioned in the previous chapter, the GFBF and its impacted area encompass 4 million km^2 and cover four countries (Mongolia, China, Russia and Japan) including their exclusive economic zones and open waters. It is also important to the global atmospheric CO_2 budget since the Sea of Okhotsk and Oyashio region are where the most active exchange of CO_2 due to phytoplankton growth and deep water convection occurs. We believe this is a worldwide unique system and worth conserving for both practical and ethical reasons.

2. **The GFBF can only be understood using a cross-disciplinary approach.**
   The GFBF is a natural system that transports various nutrients, trace elements like dissolved iron, and pollutants from an upper area (*i.e.* the Amur River basin) to a lower area (the Sea of Okhotsk and Oyashio region). However, fluxes of such materials can fluctuate significantly owing to various human activities including agriculture, forestry and industry. These human activities are then influenced by both local and international sociological, political and economic situations with which the lower stakeholders are closely related. Therefore, it is not true to categorize the GFBF as a problem where the offenders and victims are fixed at the ends of the system. The stakeholders in the system are interchangeable by complex relationships.

3. **The GFBF can be conserved by an international approach.**
   In spite of its importance and uniqueness, there has been no framework for protecting/conserving the GFBF. This is mainly due to the geopolitical situation of the Amur River and Sea of Okhotsk. The long-term political tensions in the area have hidden the environmental deterioration of the Amur River and Sea of Okhotsk from the public. We would like to inform domestic and international communities of the GFBF and its importance by presenting scientific evidence. Our project will seek a method for conserving this vast linkage by studying the physical background and the relationships among stakeholders.

3. Research Methods, Organisation and Plan

The physical structure of the GFBF was studied by joint collaborations between groups in the fields of biogeochemistry, geography, hydrology, climatology, glaciology and oceanography. Economic flows, land-use background analyses, and a conservation strategy for the system were studied by scientists in the fields of forest engineering, agronomy, economic geography, international law and politics.

This project is composed of 10 research groups headed by group leaders. The project leader and 10 group leaders constitute the board of the project. In addition to individual group meetings, at least one project meeting was held each year to discuss cross boundary issues. Daily communications and discussions were carried out through an Internet mailing list.

The themes/tasks of each research group are as follows. There are no substantial changes in methodologies employed by Groups 1 to 9 after the Interim Evaluation in March 2007. Group 10 was newly established and is responsible for designing a conservation strategy for the GFBF based on the results obtained by Groups 1-9.

Group 1 (GL: Dr. Kay I Oshima): Physical oceanographic conditions in the Sea of Okhotsk and the northern North Pacific. This group carried out physical oceanographic observations aiming to quantify the flux of the East Sakhalin Current and water exchange across Bussol Strait, all of which are essential in estimating the iron flux in the Sea of Okhotsk and Oyashio region. Special attention was paid to the role of sea ice in the Sea of Okhotsk, which was supposed to be a driver of thermohaline circulation in the Sea of Okhotsk.

Group 2 (GL: Dr. Takeshi Nakatsuka): Geochemical and biological conditions in the Sea of Okhotsk and the northern North Pacific. This group embarked on research cruises in the Sea of Okhotsk and adjacent areas and focused on the spatial distribution of chemical and biological properties to investigate the source and transportation of dissolved iron. *In situ* observations of phytoplankton in the Sea of Okhotsk and Oyashio region were also conducted.

Group 3 (GL: Dr. Seiya Nagao): Transport of biogeochemical materials from the Amur River to the Sea of Okhotsk. This group conducted three different observations: the monthly monitoring of water quality at Khabarovsk, Bogorodtskoe and Nikoraevsk-na-Amure, observations of water samples collected on research cruises along the lower reaches of the Amur River, and observations of water samples collected on research cruises in the estuarial area of the Amur River. These field samplings and the analyses provided a basic idea of how dissolved iron was transported from the Amur River to the Sea of Okhotsk.

Group 4 (GL: Dr. Hideaki Shibata): Biogeochemical transport from the terrestrial ecosystem to the Amur River. This group continuously monitored water quality on various land surfaces including natural forest, forest damaged by fire, wetlands, paddy fields and upland fields in Russia and China. The Sanjiang plain was of particular interest since this vast plain was largely covered with wetlands but has been most intensively reclaimed during the last 20 years of the 20^{th} century.

Group 5 (GL: Dr. Hiroaki Kakizawa): Background of anthropogenic impacts in the Amur River basin. This group analyzed the background behind forest management, agricultural policy and timber trading both in Russia and China. The group paid special attention to the international driving forces behind these socio-economic situations.

Group 6 (GL: Dr. Shigeko Haruyama): Spatial and historical monitoring of land-use changes in the Amur River basin. This group attempted to visualize spatial changes in land uses in the Amur River basin by means of satellite image interpretation, field work and statistical analyses.

Group 7 (GL: Dr. Sumito Matoba): Estimation of the atmospheric transport of terrestrial material. This group extended a real-time observation network for aerosol deposition around the Sea of Okhotsk. It also conducted ice-core drilling to reconstruct the past atmospheric input of iron to the study area.

Group 8 (GL: Dr. Takeo Onishi): Numerical modelling of basin-scale hydrology and iron transport. This group attempted to develop a numerical hydro-geochemical model with special emphasis on iron dynamics for the Amur River basin.

Group 9 (GLs: Drs. Hiroyuki Matsuda and Fumio Mitsudera): Numerical modelling of iron transport in the Sea of Okhotsk and the northern North Pacific. This group attempted to develop a numerical ocean ecosystem model to simulate the importance of dissolved iron to the phytoplankton in the Sea of Okhotsk and Oyashio region. The model was lately modified by including physical code to describe the North Pacific Intermediate Water (NPIW), which was considered to be the main source of current transporting the dissolved iron to the Oyashio region.

Group 10 (GL: Mr. Yasunori Hanamatsu): Conservation strategy for the GFBF. This group was established just recently and will endeavour to find a framework for conserving the GFBF. The group reviewed all international and domestic laws and institutions that were originally created to address particular aspects of the environment in this region.

4. Policies Regarding Human-Rights and Security Features

We have been careful not to violate domestic laws both in China and Russia where our study area is located. Any scientific activities by foreigners are strictly limited by the laws of these countries, and violation of these laws may cause serious diplomatic as well as social problems. Some laws have been changed/revised frequently and they were not announced extensively. It was very important to take precautions against such changes by communicating with scientific colleagues as well as governmental officers.

Another concern in the field was infection of the tick-borne encephalitis virus, which is considered to be fatal. We received a protective vaccination against this virus and successfully finished the 4 years of field research.

5. Outcomes up to now

a) Outcomes of the project as a whole

1) Validation of the GFBF Hypothesis
   Average annual fluxes of total and dissolved iron were estimated in various parts of the GFBF and they confirmed the continuity of iron transport starting from the land surfaces of the Amur River basin and attaining at the surface water of the Oyashio region (Fig. 1). $1.1 \pm 0.7 \times 10^{11}$ g/yr of dissolved iron is transported to the estuarial area from the Amur River annually. Approximately 95% of the dissolved iron coagulates at Amur–Liman (the estuarial area) and 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 NPIW. The former supports primary production in the Sea of Okhotsk while the latter supports that in the Oyashio region. It was estimated that approximately $1.2–1.5 \times 10^{8}$ g/yr of total iron was provided from the atmosphere and NPIW in the Oyashio region. Among the iron used for the spring bloom in the Oyashio region, 40% was provided by the NPIW

and 60% was recycled through microbial processes. We are not yet certain about the importance of atmospherically derived iron to primary production in the Oyashio region because of its sporadicity and spatial unevenness. It was also found by our observation that the iron controls phytoplankton growth in the Oyashio region because phytoplankton growth ceases under iron limitation in spite of a high nitrate concentration.

2) Human impact on the GFBF

Impacts due to land-use changes on the concentration of dissolved iron were clear in our *in-situ* observations of soil interstitial water in wetlands, paddy fields and upland fields. It was also clear that burnt forest provided a lower concentration of dissolved iron than natural forest did. On the Sanjiang plain, the time series of the iron concentration in the Naori River, a tributary of the Songhua Jiang River, shows the iron concentration has decreased with the increasing area of agricultural fields since 1964. The collected information indicates human activity does reduce the iron concentration in the water body of the related area.

It was, however, difficult to find evidence of a decrease in the iron concentration in the main channel of the Amur River. The time series of the iron concentration at Khabarovsk indicated the iron concentration has “increased” since the mid-1990s. This contradicts our finding that the wetlands on the Sanjiang plain were significantly reclaimed after the 1980s. We speculate this might have been caused by excessive pumping of groundwater on the Sanjiang plain during the 1990s followed by abnormal flooding of the Songhua River in 1997–1998. Groundwater contains a much higher concentration of dissolved iron and the paddy fields on the Sanjiang plain were mostly irrigated by groundwater after 1990. This action accumulated the dissolved iron at the surface and it might have been flushed by the flooding. According to our sociological field study on the Sanjiang plain, the groundwater level is continuously lowering; therefore, the paddy field farming on the plain is supposed to be unsustainable in the near future if it continues to use the groundwater.

3) Conservation of the GFBF

The forests in the Russian Far East are degrading owing to unsustainable forest development, forest fires and poor management systems. The rapid increase in timber exports to China and confusion of forest policy in Russia are other causes of accelerated forest degradation. Chinese farming in the Amur River basin became stable after rapid development in the latter half of the 20th century, but the lack of water resources for irrigation has caused rapid lowering of the groundwater table on the Sanjiang plain.

On the basis of the current situation for the GFBF, we have (1) decided to set the agenda for the conservation of this system, (2) realized that this will be in the form of a package deal combining an ideal or general framework including a international legal system or policy with a realistic or specific framework that reflects the political or economic situation in each country and (3) begun presenting the theoretical and sophisticated idea of the forest as an academic outcome, not just a political tool.

4) Unexpected result

The Amur–Okhotsk Project proposed the importance of the Amur River on the marine ecosystem in the Sea of Okhotsk and Oyashio region at a Japan–Russia meeting during the G8 Summit held at Toya Lake, Hokkaido, in July 2008. The leaders of both countries agreed to begin a joint ecological research program that focuses on the Amur–Okhotsk dissolved iron transport system. This may be the first example of the results from an RIHN project being used in international policy making.

The importance of the conservation of the GFBF was noted in a policy making paper published by the Economic Research Institute for Northeast Asia and submitted to the Ministry of Foreign Affairs of Japan.

b) Results of each work group

Groups 1–2: These groups succeeded in validating the physical aspect of the GFBF by showing the continuity of iron transport from Sakhalin Bay to the Oyashio region. This is the first attempt to connect an estuarial area with open waters from the view of material transportation. They also estimated the total iron from the NPIW contributes approximately 40% of the iron used for plankton bloom in the Oyashio region. The remaining 60% is probably recycled through microbial processes in the same region, although the original sources of the iron are still unknown. A significant amount of iron is found to be supplied from the atmosphere, but we are not yet certain how important the air-borne iron is for biomass production in the Oyashio region.

Another major achievement by these groups is the finding of a relationship between the extent of the sea ice in the Sea of Okhotsk and the temperature and dissolved oxygen concentration in the NPIW. They found decreasing trends for the sea ice extent associated with decreasing dissolved oxygen concentration and increasing temperature. This indicates the sea ice induced thermohaline circulation has been weakened recently and implies the dissolved iron transport by the NPIW mentioned above has also been reduced. The decreasing trend in the sea ice is considered to be the result of the global warming trend; therefore, this would be another impact of human activity on the dissolved iron concentration and thus phytoplankton production in the Oyashio region.

Groups 3–4: These groups expanded observations of dissolved iron discharge in the Amur River basin. The observation site includes 1) natural and burnt forest in China and Russia, 2) wetlands, paddy fields and upland fields in China, 3) flooded lakes, wetlands, and forests in Russia, and 4) agricultural wells in China. On the basis of these investigations, they clarified that the major source of iron from the terrestrial basin to the Amur River would be lowland wetlands, which are largely distributed at lower elevations in the middle to lower reaches of the Amur River basin. The concentration of dissolved organic carbon (DOC) in stream water was positively correlated with that of dissolved iron, suggesting DOC played an important role in iron dynamics in terrestrial ground as a carrier of iron. They also found that land-use change from wetland to farmland would cause a significant decrease in dissolved iron mobility owing to the drastic change of the anaerobic condition due to drainage. On the basis of comparative research in upstream tributaries in northeastern China and Russia, wild fire in mountainous regions would also negatively impact on the dissolved iron supply to the Amur River.

The average annual dissolved iron flux was estimated as $1.1 \pm 0.7 \times 10^{11}$ g/yr at Khabarovsk. This value is approximately one-tenth the global riverine flux of dissolved iron. There are seasonal variations in dissolved iron flux, with the maximum flux occurring for the three summer months. The summer flux accounts for 50 ± 13% of the total annual dissolved iron flux. Approximately 95% of dissolved iron is found coagulated in Amur–Liman and Sakhalin Bay, but the remaining dissolved iron and fulvic-like materials are transported on the surface of the ocean to the east of South Sakhalin Island.

Groups 5–6: Land use and historical changes in the Amur River basin were visualized by various temporal as well as spatial mappings. We succeeded in compiling land-use maps for both the 1930s and 2000 for the whole Amur River basin. Changes for the most recent 19 years were analyzed using Pathfinder AVHRR Land datasets and satellite remote sensing techniques. The results show there were significant changes on the Sanjiang plain where approximately 10,000 km^2 of wetland was reclaimed as paddy fields from 1980 to 2000. Aerial changes of Russian forest were not very significant but the quality of the forest is considered to be deteriorating mainly owing to frequent forest fires and poor management.

Such land-use changes were caused by various factors. According to analyses of the underlying causes for degradation of forest resources in Khabarovsk Krai and the current state of forest policy, forest fire and poor management systems were identified as the major causes of forest degradation. The rapid increase in timber exports to China and poor forest policy is considered to accelerate forest degradation. On the Sanjiang plain, there was a rapid development of paddy fields in accordance with governmental policy. Farm management has improved, but a lack of water has become a serious issue and the excessive pumping of ground water has caused the rapid lowering of the ground water table on the Sanjiang plain.

Group 7: The variation of the annual flux of air-borne Fe to the northern North Pacific for the period 1997–2003 was estimated as 1.3 g m^{-2} yr^{-1} from analysis of the Fe concentration of an ice core drilled on an Alaskan mountain. The spring flux accounts for 65–95% of the annual value. The annually averaged and seasonal fluxes of air-borne Fe in the Sea of Okhotsk were estimated as 0.5–5.5 g m^{-2} yr^{-1} by chemical analysis of aerosols collected at Kushiro, Toikanbetsu and Oktyabr'sky in Kamchatka.

Groups 8–9: A hydrological model incorporating a dissolved iron production mechanism was developed. The accuracy of the calculated discharge is sufficient at a time resolution of one month. On the other hand, the predictability of the dissolved iron flux is not suitably reliable level which for use in future projections under different land-use scenarios.

A three-dimensional ecosystem–physical system coupled model including the iron effect for the Sea of Okhotsk was developed. This model showed the contribution of riverine iron to the total iron used for primary production is small in the Sea of Okhotsk. It was found most of the riverine iron is transported to the Oyashio region by the NPIW. We attempted to construct an ocean general circulation model on which we plan to overlay an iron model. This is still in progress and we will continue to develop the model in the 2009 fiscal year.

Group 10: This group formed in October 2008 under the leadership of Mr. Hanamatsu, who specializes in international law. We decided that (1) our final goal was to set the agenda for the conservation of the GFBF on the basis of obtained knowledge, (2) this would be a combination of an ideal or general framework including an international legal system or policy with a realistic or specific framework that reflects the political or economic situation in each country, and (3) we need to present the theoretical and sophisticated idea of the conservation of the GFBF as an academic outcome, not just a political tool.

c) Problems and possible solutions

1. Exporting samples from Russia

It was difficult to export samples that we collected in the Amur River basin until the end of 2007. We have since solved the problem by 1) exporting samples through Vladivostok customs with the help of the Russian Academy of Sciences, Far Eastern Branch, and 2) analyzing samples at Russian institutes by exporting analysis apparatus (a total organic carbon analyzer) from Japan to Russia and contracting a new institute (V. N. Sukachev Institute of Forest, Siberian Branch, Russia Academy of Science) for analysis of organic matters by fluorescence spectroscopy and atomic absorption spectroscopy.

2. Field Research by Foreign Scientists in Russia and China

It has been becoming more difficult for Japanese scientists to conduct field campaigns in both Russia and China. China prohibited foreign scientists from carrying out any hydrological observations without permission from the State Council of the People's Republic of China (PRC Hydrological Law, established on May 1, 2007). In Russia, it became impossible for Japanese scientists to install any mooring system in the Sea of Okhotsk in 2007, which caused serious problems for physical oceanographic observations. These political problems are difficult for scientists to solve; therefore, we hope for ongoing negotiations between the Japanese and Chinese/Russian governments to promote international collaboration in solving our transboundary environmental problems.

d) Past grants and funds related to the project

The Amur–Okhotsk Project is mainly supported by the RIHN but the following grants and funds contributed to the progress of the project significantly.

1) Funds from the Pan–Okhotsk Research Center, Institute of Low Temperature Science, Hokkaido University
2) Funds from the 21st Century COE Program, Graduate School of Environmental Science, Hokkaido University
3) Grants-in-Aid for Basic Research B2 from the Japan Society for the Promotion of Science (JSPS), "Accumulation and transportation of refractory organic carbon in terrestrial environments" (PI: S. Nagao) 2003–2005
4) Grants-in-Aid for Basic Research B2 from the JSPS, "Characterization of riverine POC transported by heavy rain events and its effect on coastal ecosystem" (PI: S. Nagao) 2006–2008
5) Grants-in-Aid for Basic Research B from the JSPS, "Evaluation of human impacts on river environment in the Amur River basin" (PI: K. Yamagata)
6) Grant-in-Aid for Scientific Research in Priority Areas from the Ministry of Education, Science, Sports and Culture (MESSCT), "Western Pacific Air-Sea Interaction Study (W-PASS)" (PI: J. Nishioka) 2007–
7) Grant-in-Aid for Basic Research B, "Reconstruction of deposition history of terrestrial materials on the North Pacific by means of ice core analyses" (PI: T. Shiraiwa) 2007–2009
8) Grant-in-Aid for Basic Research B, "Reconstruction of climate and air-borne materials deposited in the North Pacific by ice core analyses" (PI: T. Shiraiwa) 2004–2005
9) Grant-in-Aid for Scientific Research in Priority Areas from the MESSCT "Western Pacific Air-Sea Interaction Study (W-PASS)" (PI: M. Uematsu) 2006–
10) Grant-in-Aid for Young Scientists B from the JSPS (PI: S. Matoba) 2006–2007

11) Grant-in-Aid for Basic Research A, "Distribution and origin of iron supporting primary production in marginal seas such as the Bering, Okhotsk and Japan Seas" (PI: K. Kuma) 2006–2009

6. Responses to the Comments

Here we respond to the main comments made by the Project Evaluation Committee (PEC) during the Interim Evaluation on March 1, 2007.

1) Necessity of the integration research groups

Ten individual research groups were integrated under the concept of the GFBF. The physical science groups (Groups 1, 2, 3, 4, 6, 7, 8 and 9) were integrated by tracing the dissolved iron from various land-surfaces in the Amur River basin to the Oyashio region. We then integrated the terrestrial groups (Groups 4, 5, 6, 8, and 10) by pursuing the impact of land-use changes on dissolved iron production and the underlying causes of historical land-use changes from the view points of forest management, agricultural policy and economic relationships in the system. Group 10 was newly established in 2008 to seek practical as well as theoretical ways to conserve the GFBF on the basis of the results obtained by Groups 1–9.

2) How the project brings together various stakeholders of the GFBF

Our investigation of the economic interrelation in the system indicates the stakeholders are poorly connected. There is interaction in the export/import of timber, agricultural products and industrial products. The stakeholders in the system are, however, more influenced by policy or economic control from their central government than by neighbouring stakeholders. Therefore, we must conclude it may be difficult to find methods of conservation by uniting stakeholders. This is a crucial difference from the case for the traditional fish-breeding forest in which independent stakeholders have cooperated rather successfully.

We, therefore, decided to coordinate existing laws and policies in an integrated manner so as to manage this system consistently and effectively. This will be the task of Group 10 and it will be concluded during the fifth year of the project.

3) Necessity of connecting with international scientific programs

To increase scientific knowledge within the project, we endorsed our project to the following international scientific programs. By relating our project to the international programs, we are ready to distribute the results of the project more widely and effectively.

A) **SOLAS**: Surface Ocean–Lower Atmospheric Study
B) **GLP**: Global Land Project
C) **IMBER**: Integrated Marine Biogeochemistry and Ecosystem Research

4) Role of sea ice on the GFBF system

We excluded this point intentionally in the Interim Evaluation two years ago. The role of the sea ice in the Sea of Okhotsk on the system is essential and significant because the sea ice formation drives thermohaline circulation in the Sea of Okhotsk. Group 1 leader, Prof. Kay I Ohshima, and his colleagues indicated that the recent decrease in the sea ice could be the reason why an increase in temperature and decrease in dissolved oxygen were observed in the NPIW. The sea ice changes are, however, considered not to be an issue of the system but a global one.

Therefore, we did not take this process into consideration in spite of our full understanding the role and importance of the sea ice.

5) **Impact of pollution in the Amur River on project execution**
The December 2005 explosion of a petrochemical factory in the Chinese province of Jilin polluted the Songhua Jiang and Amur Rivers significantly. The spilled benzene and nitrobenzene were immediately removed by activated carbon to some degree and this effort was continued the following year by Chinese and Russian authorities. In 2008, the authorities considered the Amur River to be no longer affected by the accident.
The accident motivated both China and Russia to collaborate to prevent transboundary pollution of the Amur River. They began joint-monitoring of the water quality of the Amur River. This does not necessarily mean that foreign scientists can join this program, but the accident contributed to further conservation of the Amur River by increasing people's consciousness of the shared environment.

7. FUTURE ACTIVITIES

a) Research objectives until the next evaluation meeting

The final year of the project will be devoted to the following five outstanding tasks.

1) **Complete understanding of the physical part of the GFBF system**
   a) direct and indirect linkages between the temporal variability in the Amur River iron flux and primary productivity in the Pacific Ocean will be analysed "spatially" by satellite remote sensing and "historically" using a dataset of the seasonal nutrient variability in the Oyashio region;
   b) the relative importance of riverine and atmospheric iron to primary productivity in the Sea of Okhotsk and the northern North Pacific will be estimated both horizontally and vertically by iron isotopic analyses of ocean suspended, sinking and sedimentary particles;
   c) seasonal and yearly variations in the dissolved iron concentration will be evaluated by focusing on the relationship among the water level and characteristics and concentrations of dissolved organics and dissolved iron;
   d) land-use change impacts on dissolved iron productivity will be assessed by running numerical experiments under different land-use scenarios.
   e) the long-term trend of dissolved iron dynamics will be analysed along with increasing agricultural activities on the Sanjiang plain;
   f) the impact of land-cover conservation on dissolved iron productivity will be evaluated by numerical modelling;
   g) an ocean general circulation model including iron circulation will be constructed to simulate the impact of iron on primary production.

2) **Qualitative understanding of the socio-economical part of the GFBF system**
   a) implementation of forest policy reform and its effect on forest management including forest fire will be completed;
   b) change of timber trade structure of Russian Far East and its effect on forest management and industry will be completed;
   c) relationship between irrigation system and ground water pumping will be clarified for Sanjiang plain.

3) **Agenda Setting for the Conservation of the GFBF**
   a) a new framework "North-Eastern Asia GFBF Partnership" will be constructed to motivate stakeholders to conserve the GFBF (Fig. 2);
   b) a package proposal "Agenda for the conservation of GFBF" will be presented.

4) **A closing international symposium of the project** will be held in Kyoto in January 2010 and set "Agenda for the conservation of the GFBF" as a collaborative result of the project.

5) **The result of the project will be published and announced by various ways** including books, a project report, academic papers and oral and poster presentations in academic as well as public medium.

b) Plans until the beginning of the new fiscal year

The 5 tasks listed in the previous section will be addressed immediately.

8. ACHIEVEMENTS UP TO NOW

a) Books

【English】

Ganzey, S.S. (2005) *Transboundary Geo-systems in the South of the Russian Far East and in Northeast China*, Pacific Institute of Geography and RIHN, 235pp.

【Japanese】

Onishi T. (2008) Rich iron from wetlands, in "*Prescription of the Earth – toward deep understanding of environmental problems* ", Research Institute for Humanity and Nature (eds.), Showado, 188-191.

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Tachibana, Y. and Honda, M. (eds.) (2007) *Interaction Between Climate and Ocean in the Sea of Okhotsk*. Meteorological Study Note, 214, 178pp.

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Yamane, M. (2006) Challenges of forest resource use in Russian Far East with a special focus on Russo-Sino timber trade, in "*Indigenous People and Commercial Usage of the Forest Resources in Northeast Asia, Sasaki, S. ed.*", The National Museum of Ethnology

【Other languages】

None

b) Academic Papers

【English】

Ohshima, K. I., and Simizu, D. (2008) Particle tracking experiments on a model of the Okhotsk Sea: toward oil spill simulation. *Journal of Oceanography*, 64, 103-114.

Onishi, T., Shibata, H., Yoh, M. And Nagao, S. (2008) Mechanism for the production of dissolved iron in the Amur River basin – a modeling study of the Naoli River of the Sanjiang Plain, M. Taniguchi, Y. Fukushima, W.C. Burnett, M. Haigh & Y. Umezawa (eds.) *From Headwaters to the Ocean: Hydrological Change and Watershed Management*, Taylor & Francis, 355-360

Tachibana, Y., Oshima, K. and Ogi, M. (2008) Seasonal and interannual variations of Amur River discharge and their relationships to large-scale atmospheric patterns and moisture fluxes, *Journal of Geophysical Research*, 113, D16102.

Kakizawa, H. (2007) Local attitude toward participatory management in the Russian Far East, *Journal of Forest Economics*, 52(1)

Nishioka, J., Ono, T., Saito, H., et al., Nakatsuka, T., Takeda, S., Yoshimura, T., Suzuki, K., Kuma, K., Nakabayashi, S., Tsumune, D., Mitsudera, H., Johnson, W. K., and Tsuda, A. (2007) Iron input into the western subarctic Pacific, importance of iron export from the Sea of Okhotsk, *Journal of Geophysical Research*, 112, C10012, doi:10.1029/2006JC004055

【Japanese】

Nakatsuka, T., Nishioka, J. and Shiraiwa, T. (2008) Linkage between inland and open ocean ecosystems by material transport through river, shelf and intermediate water layer-Background of 2006/2007 research expedition in the Sea of Okhotsk-. Monthly "*Kaiyo*", Special, 50, 68-76.

Nishioka, J., Nakatsuka, T., Ono, K. and others (2008) Biogeochemical importance of mixing process in Kuril straits –Impacts on iron/nutrient ratios in Western

Subarctic Pacific-, Monthly “*Kaiyo*”, Special, 50, 107-114.

Ohshima, Kay I., Nakanowatari, T. and Wakatsuchi, M. (2008) Weakening of overturning in the Sea of Okhotsk and the northern North Pacific by global warming. Monthly “*Chikyu*”, 30 (3), 127-133.

Nagao, S., Ito, S., Terashima, M., Yoh, M., Yan, B., Zhang, B. Onishi, T., (2007）: Fluorescent properties of dissolved humic substances in the Sanjiang Plain river waters, *Journal of Water and Environment*, 30, 11, 629-635

Masuda, Y., Haruyama, S., Kondoh, A. and Murooka, M. (2006) Changes in land-cover in the Amur River basin by NDVI analysis, *Special Issue of Agricultural Planning Society*, 25, 245-250.

【Other languages】

None

c) Reports/ Proceedings/ Newsletters

【English】

Murooka, M., Haruyama, S. and Masuda, Y.(2008) Land cover detected by satellite data in the agricultural development area of the Sanjiang Plain, China, *Journal of Rural Planning*, 26.197-202.

Shiraiwa, T. ed. (2008) Report on Amur-Okhotsk Project No.5, RIHN, 218pp.

Matoba, S., S. V. Ushakov, K. Shimbori, H. Sasaki, T. Yamasaki, A. A. Ovshannikov, A. G. Manevich, T. M. Zhideleeva, S. Kutuzov, Y. D. Muravyev, and T. Shiraiwa (2007) The glaciological expedition to Mount Ichinsky, Kamchatka, Russia, *Bulletin of Glaciological Research*, 24, 79-85.

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Haruyama, S., Masuda, Y. and Murooka, M.(2006) Land cover change of the three river plain using remote sensing data analysis, *Proceedings of the International Conference, Problems of sustainable use of the transboundary territories*, Vladivostok, Russia.144-146.

【Japanese】

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【Other languages】

None

d) Articles in Newspapers/ Magazines

【English】

Shiraiwa, T. (2006) The Amur-Okhotsk Project: Trilateral cooperation to protect a shared environment, *Gaiko Forum (Japanese Perspectives on Foreign Affairs)*, 6 (3), 36-42.

【Japanese】

Yamane, M. (2008) Recent development of Sino-Russo border timber trade and timber processing, with a central focus on Ussuri river basin, *Mokuzai Joho*, 208, 1-4.
Yamane, M. (2007) Recent development of forest resource use in Far East Russia, with a special focus on the relation to China, *Journal of the Japan Paper Association*, Pulp & Paper, 57 (3), 16-22.
Shiraiwa, T. (2006) World Natural Heritage, SHIRETOKO, viewed from Pan-Okhotsk Scale, *Geography*, 51 (4), 27-36.
Yoh, M. (2006) Wetland ecosystem and global environment, Oze-Tsushin, 2, 1-2.
Kakizawa, H. (2005) Russian forest policy in confusion, *Mokuzai Joho*, 168.

【Other languages】

Shiraiwa, T. (2007) Amur-Okhotsk Project, Russia, 5, 79-81 (In Russian)

e) Video/ Picture Works

【English】

None

【Japanese】

None

【Other languages】

None

f) Field Research

【Research in Japan】

2005-2008: 5 times in Hokkaido and Honshu island

【Research outside Japan】

2008: 8 times in Russia, 1 time in China, 1 time in USA
2007: 8 times in Russia, 8 times in China
2006: 11 times in Russia, 8 times in China
2005: 11 times in Russia, 5 times in China

g) Symposia/ Conferences/ Workshops

International Symposium on Amur-Okhotsk Project (2005) Kyoto
Japan-China Symposium on Amur-Okhotsk Project (2005) Sapporo
International Symposium on Amur-Okhotsk Project (2004) Kyoto

h) Individual Presentations

【Oral Presentations】

Onishi, T. and others (2008) Mechanism for production of dissolved iron in the Amur River basin – a modelling study of the Naoli River of the Sanjiang Plain, HydroChange 2008, October 1-3, Kyoto, Japan.
Nakatsuka, T., Nishioka, J., Shiraiwa, T. and project members (2008) Biogeochemical linkage between Amur River basin and western subarctic Pacific by iron transport through Okhotsk Sea Intermediate Water: A new paradigm to explain changes in ocean primary productivity, PICES Okhotsk Workshop, August 27.
Nakatsuka, T., Nishioka, J. and Shiraiwa, T. (2008) Linkage between inland and open ocean ecosystems by iron transport through river and intermediate water flows –Huge but vulnerable system in the Amur River watershed and the Sea of Okhotsk-, IGBP Congress, Capetown, South Africa, May 8.
Nakatsuka, T. and project members (2008) Linkage between inland and open ocean ecosystems via river and ocean current -working hypothesis of Amur-Okhotsk Project-, The Oceanographic Society of Japan, March 27, Tokyo.
Shiraiwa, T. (2007) The Amur-Okhotsk Project, The 2nd International Far Eastern Economic Forum, Khabarovsk, Russia, September 18.

【Poster Presentations】

Matoba, S. and others (2008) Chemical composition of an ice-core obtained from Mount Ichinsky, Kamchatka, Russia, Japanese Society of Snow and Ice, Tokyo.
Nishioka, J., Nakatsuka, T., Saito, H., Ono, T. and Shiraiwa, T. (2008) The importance of sea-ice formation in the Sea of Okhotsk for supplying iron to the western subarctic pacific, IMBER/IMBIZO workshop.
Park Hong (2008) Formation and operation of paddy fields agriculture at the Sanjiang Plain in China: a pre-research of farm households bookkeeping analysis, Int. Symp. Green Bio in Korea, Korea, May.
Yasunari, T. and others (2008) Importance of spring cyclonic activities in east Asia on Asian dust storm and the stratosphere-to-troposphere transport, First Int. Conf. From Deserts to Monsoon, Crete, Greece, June.
Murooka, M., Yaruyama, S. and Masuda, Y. (2007) Land cover change on the Sanjiang plain, China, 007KSRP-RPA International Symp., Soel.

i) Social Activities

Shiraiwa, T. (2008) "Giant" Fish-Breeding Forest and its Conservation, Amagasaki Citizens' College, December.
Shiraiwa, T. (2008) Global warming and its impact on northern fisheries, Tottori Pref. Citizens' Forum, November.
Onishi, T. (2008) Environmental problem from the view point of cycle, Hokuryo High School, November.
Onishi, T. (2008) Course on Environmental System, Doshisha University, October.
Nakatsuka, T. and others (2008) Potential impacts of material supplies from western region of the Sea of Okhotsk into the area around Shiretoko Peninsula –iron organic matter and pollutants-, Scientific Meeting in Shiretoko World Heritage Committee, March.

j) Media Interviews/ Book Reviews

【Books】

None

【Magazines, journals】

None

【Newspaper articles】

Mainichi Newspaper, "Wetlands and iron", February 3, 2007
Mainichi Newspaper, ""Giant" Fish-Breeding Forest, the Amur River", July 8, 2006
Yomiuri Newspaper, "Amur river transports iron: fruitful Sea of Okhotsk", March 11, 2006

【TV programmes】

NHK News Today Asia, "Amur-Okhotsk Project", December 27, 2006
TV Asahi, "Pollution of the Amur River and its impact on Japan", March 15, 2006.
TBS "Our Precious Spaceship Earth", February 19, 2006

【Radio programmes】

None

k) Miscellaneous achievements

1) The Amur-Okhotsk Project succeeded in proposing the importance of Amur River on the marine ecosystem in the Sea of Okhotsk and Oyashio region in the occasion of the **Japan-Russia summit meeting during the G8 SUMMIT Meeting** held in Toya Lake, Hokkaido in July 2008. Both leaders agreed to start a joint ecological research program, <u>in which the Amur-Okhotsk dissolved iron transport system was stressed</u>.
2) Agenda setting for Ministry of Foreign Affairs by submitting a report entitled

"Russia and Asian Pacific –Perspectives and Problems on Russian Involvement-" (edited by Economic Research Institute for North East Asia in March 2008). The Amur-Okhotsk Project was responsible for the agenda setting related to environmental problems.

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Hatakeyama, S. (1994) *Moriwa Umino Koibito (The Forest is the Sweetheart of the Sea)*, Hokuto Syuppan, 192p.

Martin, J. H., Gordon, R.M., Fitzwater, S. and Broenkow, W.W. (1989) VERTEX: phytoplankton/iron studies in the Gulf of Alaska. *Deep-Sea Research*, 36, 649-680.

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Simonov, E.A. and Dahmer, T.D. (2008) *Amur-Heilong River Basin Reader*, WWF, Ecosystems Ltd., 426p.

Takahashi, T., Sutherland, S.C., Sweeney, C., Poisson, A., Metzl, N., Tilbrook, B., Bates, N., Wanninkhof, R., Feely, R., Sabine, C., Olafsson, J. And Nojiri, Y. (2002) Global sea-air CO2 flux based on climatological surface ocean pCO2, and seasonal biological and temperature effects, *Deep Sea Research Part II*, 49 (9-10), 1601-1622.

Tsuda, A. and 25 others (2003) A mesoscale iron enrichment in the western subarctic

Pacific induces a large centric diatom bloom, *Science*, 300 (5621), 958-961.
UNEP (2006) *The Songhua River Spill China, December 2005, -Field Misson Report-*, UNEP, 26p.
Yaginuma, T. (1999) *Moriwa Subete Uotsukirin (All Forest works as Fish-Breeding Forest)*, Hokuto Syuppan, 246p.
Yamashita, Y. and Tanaka, M. eds. (2008) Linkage of forests, rivers and coasts and biological production in estuarine and coastal waters, *Kouseisya-Kouseikaku*, 147p.

10. Members　プロジェクトメンバーの氏名を、所属・役職・研究分担事項とともに述べてください。

Name	Affiliation	Position	Specialised Fields	Category of Majors (S: Science, H: Humanity, M: Multidiscipline)	Group (s) in the Project	Roles in the Project	Core Member/Leader (Put ○ for core member, put ◎ for the leader)
SHIRAIWA, Takayuki	Research Institute for Humanity and Nature	Associate Professor	Physical geography	M	Project leader	organization of the project	◎
FUKAMACHI, Yasushi	Institute of Low Temperature Science, Hokkaido Univ.	Assistant Professor	Physical Oceanography	S	Group 1	physical oceanographic analysis on the North Pacific Intermediate Water	
YASUDA, Ichiro	Graduate School of Frontier Science, Univ. of Tokyo	Professor	Physical Oceanography	S	Group 1	tidal mixing of water in the Bussol Strait	
WAKATSUCHI, Masaaki	Institute of Low Temperature Science, Hokkaido Univ.	Professors emeritus	Physical Oceanography	S	Group 1	physical oceanographic analysis on the North Pacific Intermediate Water	
NAKATSUKA, Takeshi	Graduate School of Environmental Studies, Nagoya Univ.	Professor	geochemistry	S	Group 2	transport of materials by dense shelf water and North Pacific Intermediate Water	○
KUMA, Kenshi	Graduate School of Fisheries Science, Hokkaido Univ.	Professor	geochemistry	S	Group 2	analysis of iron of open waters	○
NISHIOKA, Jun	Institute of Low Temperature Science, Hokkaido Univ.	Associate Professor	geochemistry	S	Group 2	transport of iron in the Sea of Okhotsk and Oyashio region	

SUZUKI, Koji	Graduate School of Environmental Earth Sciences, Hokkaido Univ.	Associate Professor	Ocean biogeochemistry	S	Group 2	Phytoplankton dynamics in the Sea of Okhotsk and Oyashio region	
SEKI, Satoshi	Institute of Low Temperature Science, Hokkaido Univ.	Research Fellowship	Geochemistry	S	Group 2	Analysis on bottom sediment in the Sea of Okhotsk	
SOURIN, Rumi	Faculty of Science, Shizuoka Univ.	Assistant Professor	Ocean biology	S	Group 2	Microbial process in the open waters	
TUDA, Atsushi	Graduate School of Frontier Science, Univ. of Tokyo	Associate Professor	Ocean biology	S	Group 2	Zooplankton dynamics in the Sea of Okhotsk and Oyashio region	
MATSUNAGA, Katsuhiko	Yokkaichi Univ.	Professor	Geochemistry	S	Group 2	Fuluvic acids and iron complex in the sea water	
YOSHIMURA, Takeshi	Environmental Science Research Laboratory, Central research Institute of Electric Power Industry	Chief Researcher	Geochemistry	S	Group 2	Transport of iron in the Sea of Okhotsk and Oyashio region	
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NAGAO, Seiya	Graduate School of Environmental Earth Sciences, Hokkaido Univ.	Associate Professor	Geochemistry	S	Group 3	Biogeochemical analyses on Amur- river water	○
KODAMA, Hiroki	Analytical Research Center for Experimental Sciences, Saga University	Associate Professor	Geochemistry	S	Group 3	Analysis on organic matter in the river water	
TERASHIMA, Motoki	Japan Atomic Energy Research Institute	Special Promotional Topics Staff	Geochemistry	S	Group 3	Experimental study on dynamics of organic matter and iron	
SHIBATA, Hideaki	Field Science Center for Northern Biosphere, Hokkaido Univ.	Associate Professor	Biogeochemistry	S	Group 4	Biogeochemical characteristics of river waters from different land surfaces	○
YOH, Muneoki	Environmental Conservation, Tokyo Univ. of Agriculture & Technology	Associate Professor	Biogeochemistry	S	Group 4	Biogeochemical characteristics of river waters from different land surfaces	○
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KAKU, Eigyoku	Environmental Conservation, Tokyo Univ. of Agriculture & Technology	Graduate	Biogeochemistry	S	Group 4	BIOGEOCHEMICAL CHARACTERISTICS OF RIVER WATERS FROM DIFFERENT LAND SURFACES	
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HIMIYAMA, Yukio	Hokkaido Univ. of Education	Professor	Human geography	H	Group 6	Land-use changes and its background analysis	
UEMATSU, Mitsuo	Ocean Research Institute, Univ. of Tokyo	Professor	Geochemistry	S	Group 7	Deposition of various materials from atmosphere	○
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KUBOTA, Jumpei	Research Institute for Humanity and Nature	Associate Professor	Hydrology	M	Group 8	HYDROLOGICAL ANALYSES	
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SAITO, Seiichi	Graduate School of Fisheries Science, Hokkaido Univ.	Professor	Ocean biology	S	Group 9	SATELLITE OBSERVATION ON PRIMARY PRODUCTION	
SUGIMOTO, Takashige	School of Marine Science and Technology, Tokai Univ.	Professor	Ocean biology	S	Group 9	ASSESSMENT OF TERRESTRIAL IMPACT ON ESTUARY ECOSYSTEM	
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SHESTERKIN, Vladimir P.	Institute of Water and Ecological Problems, FEBRAS	Senior researcher	Geochemistry	S	Russian Collaborations	Geochemical analysis on waters from Amur River	

KIM, Vladimir.	Institute of Water and Ecological Problems, FEBRAS	Hydrologist	Geochemistry	S	Russian Collaborations	Geochemical analysis on waters from Amur River	
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GANZEI, Sergry S.	Pacific Institute of Geography, EBRAS	Deputy Director	Human geography	H	Russian Collaborations	Land-use changes in the Amur River basin and its transboudary problems	
EMORSHIN, Victor V.	Pacific Institute of Geography, EBRAS	GIS-Center.Head	Geographical information system	M	Russian Collaborations	GIS compilation of land-uses in the Amur River basin	
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GAVRILOV, Alexandr V.	ROSHYDROMET	Head of administration	Hydrometeorology	S	Russian Collaborations	Hydro-geochemical monitoring in the Amur River	
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XU, Xiaoniu	Anhui Agricultural University	Professor	Geochemistry	S	Chinese Collaborations	GEOCHEMICAL ANALYSIS ON WATERS FROM CHINESE FOREST	

11. Figures and Supplementary Materials

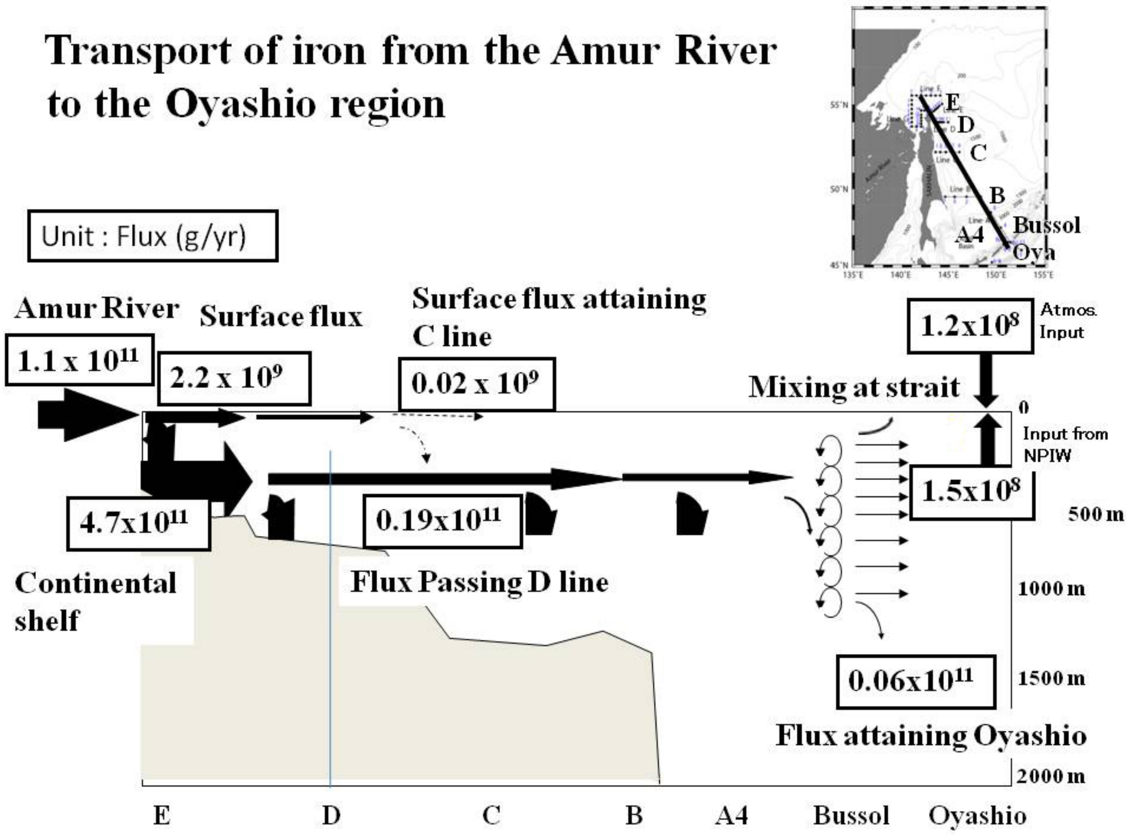

FIGURE 1 TRANSPORT OF IRON FROM THE AMUR RIVER TO THE OYASHIO REGION AS A PHYSICAL PART OF THE GFBF.

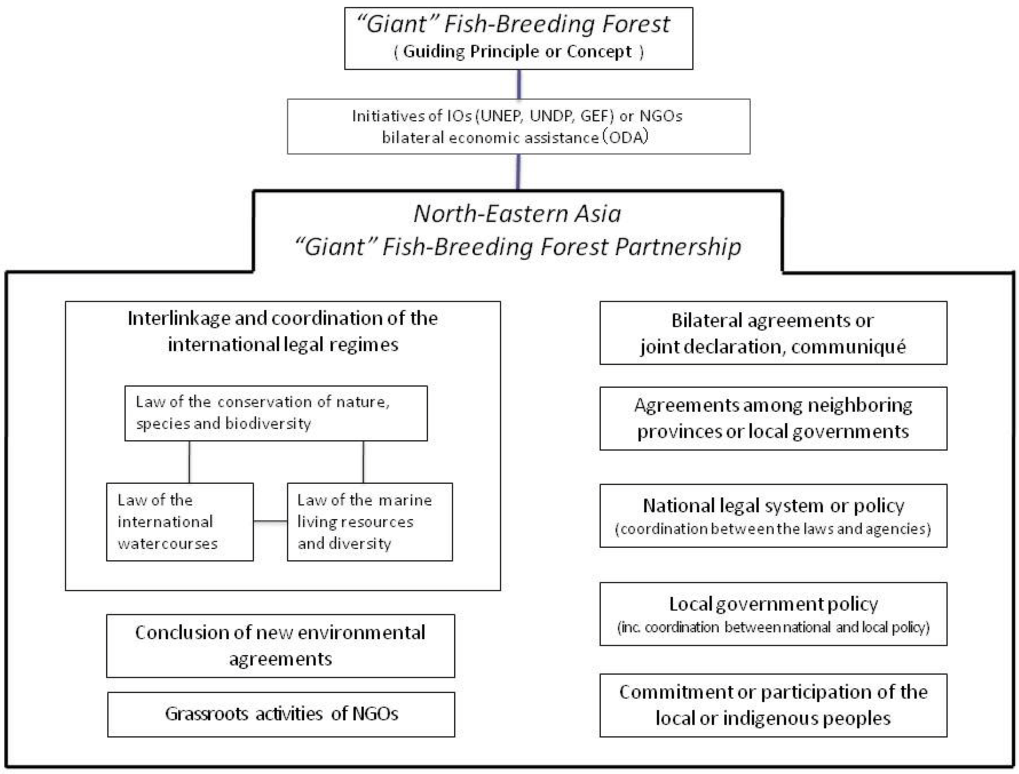

FIGURE 2 STRUCTURE OF NORTH-EASTERN ASIA GFBF PARTNERSHIP