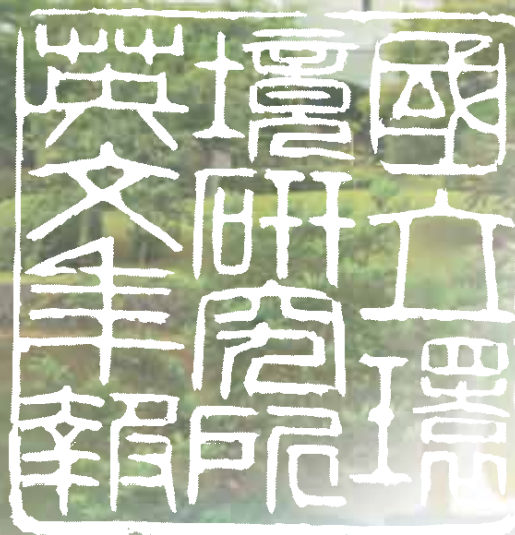


# NIES Annual Report

# 2021

AE - 27 - 2021



# NIES Annual Report

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# Foreword



It is our pleasure to present the Annual Report of the National Institute for Environmental Studies (NIES). Since its establishment in 1974, NIES is the sole research institute in Japan conducting a broad range of interdisciplinary, integrated environmental research closely related to society, social change, and the people of Japan. This Annual Report is the official record of activities at NIES in Fiscal Year 2020 (FY2020: April 2020 to March 2021) which marked the final year of our Fourth Five-Year Plan (FY2016-FY2020).

During our Fourth Five-Year Plan, NIES established three new research bases to respond to public needs in line with the social and governmental changes. The Fukushima Branch established in 2016 serves as a collaboration hub to conduct environmental emergency research on recovery, renovation and emergency management on the aftermath of the Great East Japan Earthquake hitting Fukushima in 2011. The Lake Biwa Office Branch established in 2017 conducts research on lake environment and its ecosystem, playing a role to return research results to the local community. The Center for Climate Change Adaptation (CCCA) established in 2018 in response to Climate Change Adaptation Act facilitates planning and implementation of adaptation actions by local governments and various business entities.

The Tsukuba Headquarters together with the three new research bases worked across research fields to pursue specific goals. The specific fields chosen varied from low carbon society to sustainable material cycles, harmonization with nature, health and environmental safety, and environment-economy-society integration. We also worked with external institutes and agents to conduct research projects such as monitoring global distribution of greenhouse gases and nation-wide birth cohort study. Our research provides infrastructures for environmental research by archiving and providing research tools and data/samples through monitoring data, greenhouse gas emissions inventory, environmental and biological specimen banking, reference laboratory functions, and various environmental data bases. All of these are supported by our basic and elemental research conducted, some of which requiring incessant efforts, some in sprouting phase, and some to be developed as a core of a research program.

NIES continues to collaborate with wide research networks, domestic and international, having research agreements with over 50 foreign institutes and universities, and 12 research projects conducted under the Science and Technology Cooperation Agreements between the governments. NIES participated and took turns to host the Tripartite Presidents Meeting with the National Institute of Environmental Research (Korea) and the Chinese Research Academy of Environmental Sciences (China) to promote research collaborations among the three countries; and the NIES International Forum to discuss environmental issues with Asian research communities. Our researchers also contribute to global initiatives including the Intergovernmental Panel on Climate Change (IPCC), Global Climate and Health Alliance (GCHA), and Future Earth.

With our Fourth Five-Year Plan achievements in mind, we have started our Fifth Five-Year Plan this April. NIES will be pursuing our research with new goals and a new organizational structure for the public to respond and implement measures based on the latest scientific knowledge. Despite continued restrictions caused by the COVID-19 pandemic since FY2020, we will maintain research productivities with our do-

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mestic and international collaborators through in-person as well as virtual contacts.

This Annual Report summarizes our achievements in FY2020. I sincerely hope that these achievements and findings will facilitate a greater understanding of NIES' activities, promote worldwide collaboration with our researchers, and contribute to environmental issues around the world.

A handwritten signature in black ink, reading "Masahide Kimoto". The signature is written in a cursive style with a large initial 'M' and a long, sweeping tail on the 'o'.

Masahide KIMOTO  
President  
November 2021

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During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established in 1971 as part of the Japanese government to develop measures to counteract serious problems associated with environmental pollution, such as Minamata disease, which was caused by poisoning from organic mercury in factory wastewater, and chronic bronchitis and asthma caused by sulfur oxides from factories in large industrial complexes. Understanding that research on environmental sciences was necessary and could address public needs, the Environment Agency established the National Institute for Environmental Studies (NIES) in Tsukuba Science City, about 50 km north of Tokyo, in 1974. It is now Japan's primary institute for comprehensive research in environmental science.

During the two decades following the establishment of NIES, rapid technological progress, structural changes in industry, and lifestyle changes, created additional issues for environmental science to confront. Moreover, global environmental problems such as climate change; depletion of the stratospheric ozone layer; acid deposition; destruction of tropical rain forests; desertification; and decreasing biodiversity, attracted greater concern worldwide. NIES subsequently underwent a major reorganization in 1990, including the establishment of the Center for Global Environmental Research, to enable it to conduct more intensive research on conservation of the natural environment and on global environmental changes and their effects.

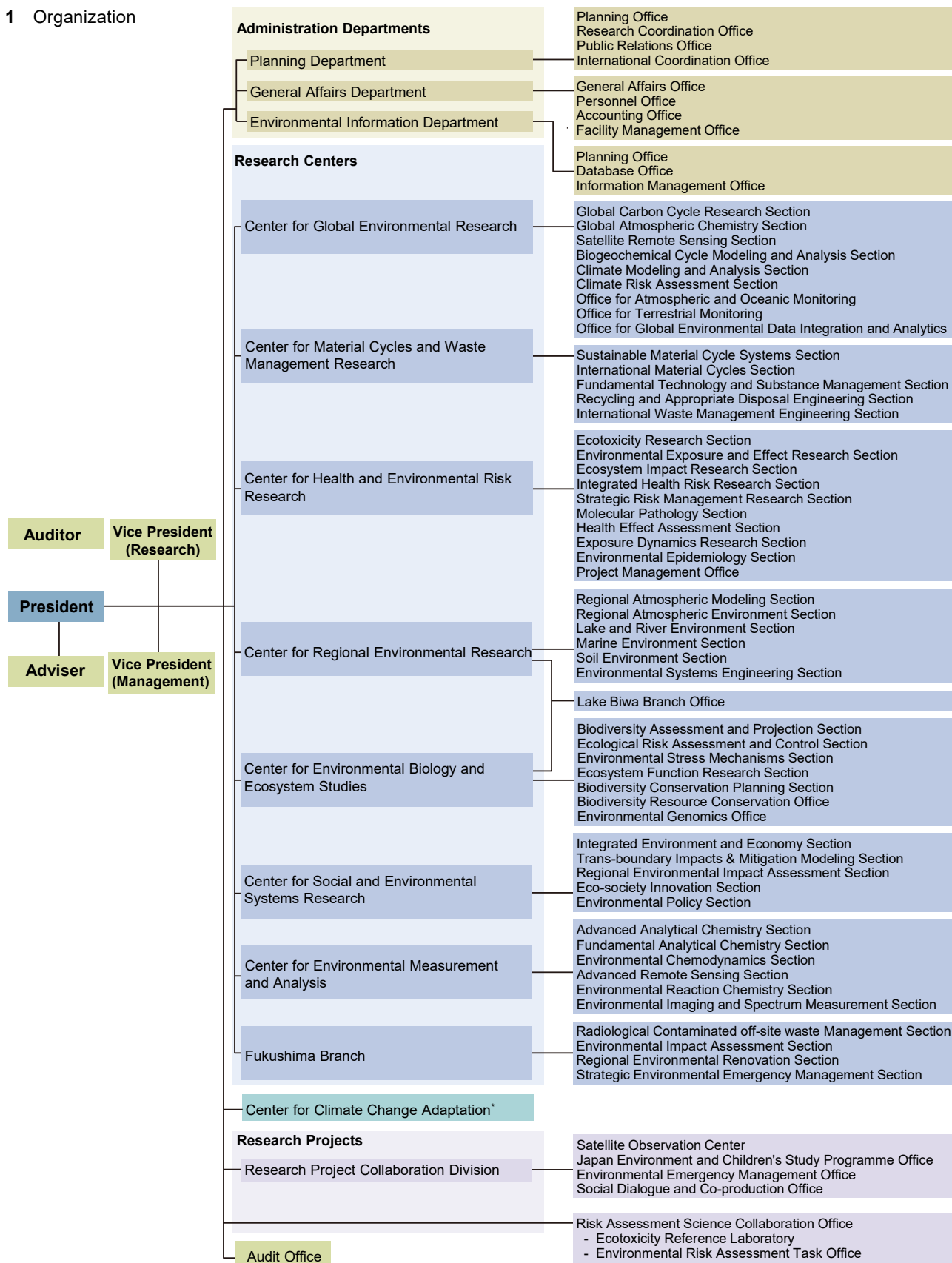
January 2001 saw the transition of the Environment Agency into the Ministry of the Environment as part of structural changes within the Japanese government, and the establishment of a Waste Management Research Division at NIES. That year also marked the establishment of NIES as an Incorporated Administrative Agency, giving it a degree of independence from the national government. The change in the administrative status of the institute allows more prompt and flexible responses to societal demands. Concurrently, NIES prepared a five-year plan (2001–2005) in line with the objectives of the Ministry of the Environment.

Following the second five-year plan (2006-2010), the third five-year plan (2011–2015) was adopted in 2011. During the third five-year plan, research was carried out under eight fundamental fields of environmental research. Research activities to respond to and recover from the Great East Japan Earthquake have also been ongoing since the direct aftermath of the disaster. In March 2013, the five-year plan was revised following a directive of the Minister of the Environment and NIES relaunched as a National Research and Development Agency from April 2015.

April 2016 marked the beginning of the fourth medium-and-long-term plan (2016-2020). NIES established five issue-oriented research programs for this plan's term, and pursued them in an integrated manner that transcends individual fields. NIES has established Fukushima Branch, where it is running Environmental Emergency Research Programs. Also in April 2017, Lake Biwa Branch Office was established



Fig. 1 Organization



\*Center for Climate Change Adaptation is co-managed by Center for Global Environmental Research; Center for Regional Environmental Research; Center for Environmental Biology and Ecosystem Studies; and Center for Social and Environmental Systems Research.

located in Lake Biwa Environmental Research Institute where developed research for water environmental protection is jointly conducted. In December 2018, we established the Center for Climate Change Adaptation (CCCA) in line with the enactment and enforcement of the Climate Change Adaptation Act to research and promote adaptation to climate change. Furthermore, to produce scientific findings on environmental protection, NIES has been carrying out research projects that include consolidating the institute's research foundation through basic research, data acquisition and analysis, preservation and provision of environmental samples, and other efforts.

NIES plays a central role in research networks too, for example GOSAT/GOSAT-2 satellite observations and the Japan Environment and Children's Study (a large-scale environmental epidemiology survey). Also an important work among our tasks is actively disseminating environmental information in easy-to-understand formats, including the outcomes of our research efforts and projects.

As of March 31, 2021, there are 300 NIES permanent staff and 698 contract staff (Table 1; Figs. 2 to 5). The total budget for FY2020 was 20,192 million yen (Table 2).

**Table 1**  
Numbers of permanent staff

Administration Department	56
Research Centers	239
Executives and Advisers	5
<b>Total</b>	<b>300</b>

(As of March 31, 2021)

**Table 2**  
Budget for the fourth five-year plan

(Unit: million yen)

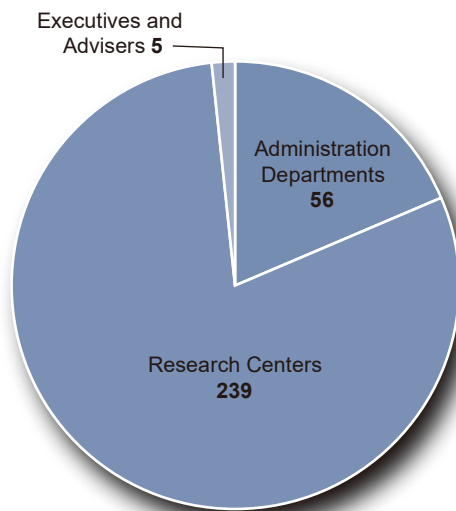
Category		2016–2020 Budget (5 years)	Fiscal Year 2020 Budget
Revenue	Grants for Operating Costs	62,665	16,307
	Subsidies for Facilities	1,710	328
	Commissioned Work	17,786	3,557
	<b>Total</b>	<b>82,162</b>	<b>20,192</b>
Expenditure	Project Costs	44,399	12,486
	Facility Improvements	1,710	328
	Expenses for Commissioned Work	17,786	3,557
	Personnel Expenses	16,112	3,353
	General Administrative Expenses	2,154	469
<b>Total</b>	<b>82,162</b>	<b>20,192</b>	

Note: The budget for each annual work plan will be requested and decided for each fiscal year, based on the medium-and-long-term plan.

Administration Department	:	56	
Research Centers	:	239	(6)
Executives and Advisers	:	5	
Total		300	(6)

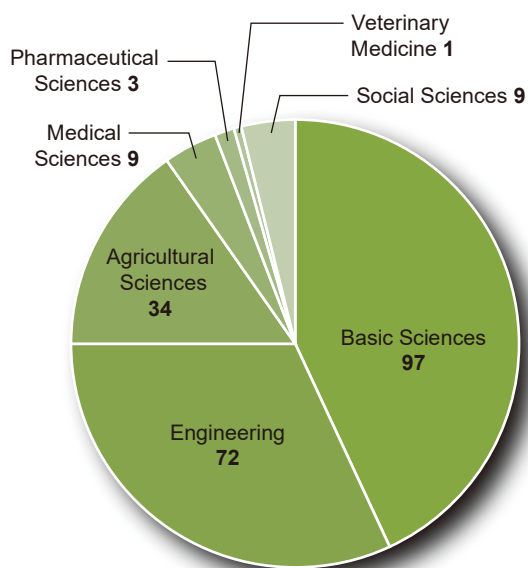
**Notes:**

1. Data is as of March 31, 2021.
2. Figures in parentheses indicate number of foreign nationals.



**Fig. 2** Permanent staff breakdown

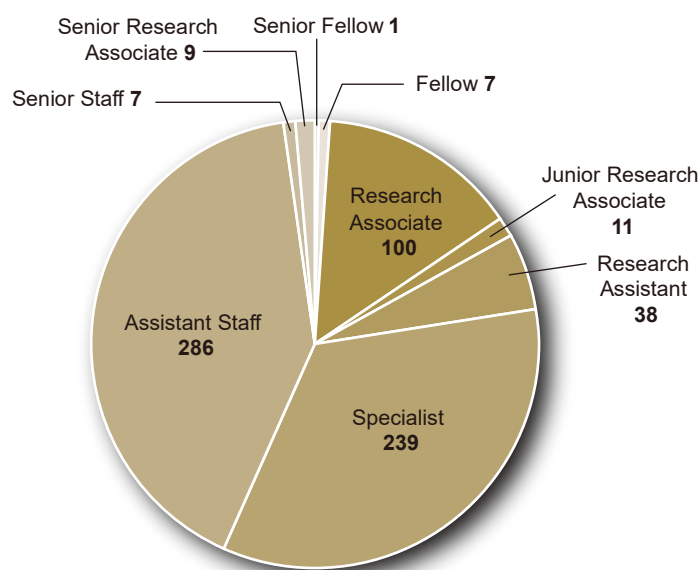
Basic Sciences	:	97	43.95%
Engineering	:	72	30.94%
Agricultural Sciences	:	34	14.80%
Medical Sciences	:	9	4.04%
Pharmaceutical Sciences	:	3	1.34%
Veterinary Medicine	:	1	0.45%
Social Sciences	:	9	4.48%
Total		225	



**Notes:** Data is as of March 31, 2021.

**Fig. 3** Fields of expertise (Researchers holding doctorates (95.6%))

Senior Fellow	:	1	
Fellow	:	7	
Research Associate	:	100	(40)
Junior Research Associate	:	11	(3)
Research Assistant	:	38	(14)
Specialist	:	239	(9)
Assistant Staff	:	286	
Senior Staff	:	7	
Senior Research Associate	:	9	
Total		698	(66)

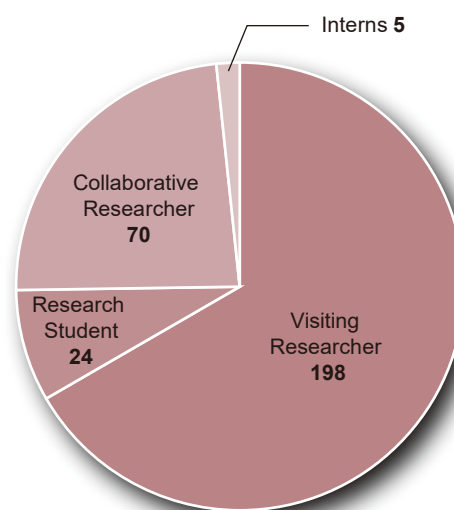


**Notes:**

1. Data is as of March 31, 2021.
2. Figures in parentheses indicate number of foreign nationals.

**Fig. 4** Contract Staff Breakdown

Visiting Researcher	198	(12)
Research Student	24	(8)
Collaborative Researcher	70	(14)
Interns	5	(3)
Total	297	(37)



**Notes:**

1. Data is the total number accepted in FY2020.
2. Figures in parentheses indicate number of foreign nationals.

**Fig. 5** Visiting and Collaborative Researchers, Research Students, and Interns



# Issue - Oriented Research Programs

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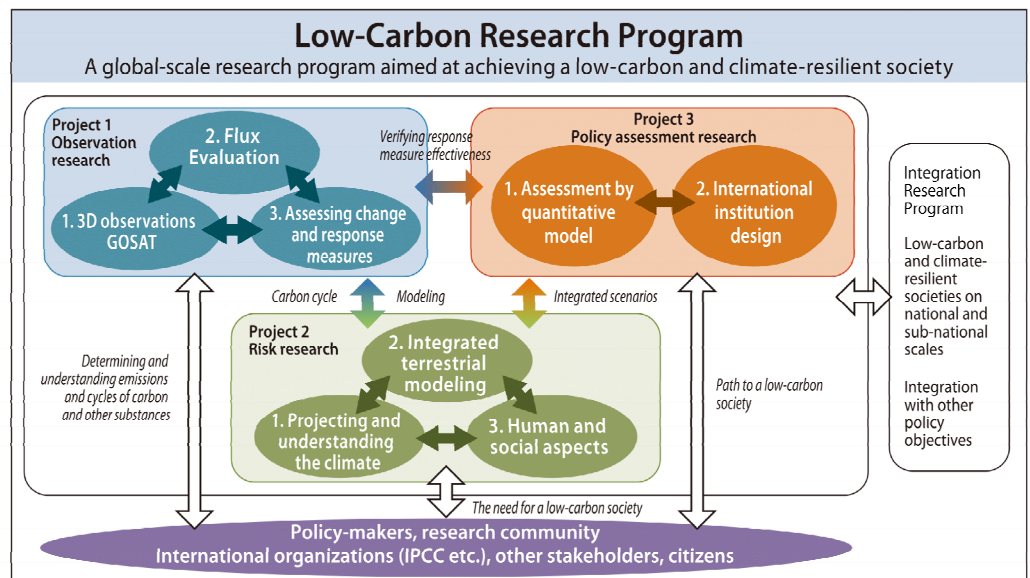


### Low-Carbon Research Program

The concept behind this program is to build a scientific foundation that society can use to tackle the goal of keeping the global mean surface temperature increase well below 2 °C, and preferably below 1.5 °C, relative to pre-industrial levels. In the program we have conducted observations, mainly in the Asia-Pacific region, to assess the balances of the greenhouse gases (GHGs) that cause global warming, as well as climate change impacts and control measures. To accomplish this, we have used surface and aerial observations, and data from observation satellites launched in 2009 and 2018, to develop a highly reliable three-dimensional global-scale GHG monitoring system. Furthermore, we have combined climate change projection models, impact assessment models, and integrated socioeconomic assessment models and used them to discuss the need for, and feasibility of, building a sustainable, low-carbon society along the path indicated by this comprehensive research program.

The program consists of three research projects: (1) Study of a multi-scale system for observing and evaluating GHG variation and mitigation; (2) Global-scale climate risk research based on integrated assessment of climate projections, impacts, and response options; and (3) Policy assessment research toward a global low-carbon society (Fig. 1). Each project and its research highlights are described below.

**Fig. 1** Structure of the Low-Carbon Research Program. The three projects interact with each other and with society.





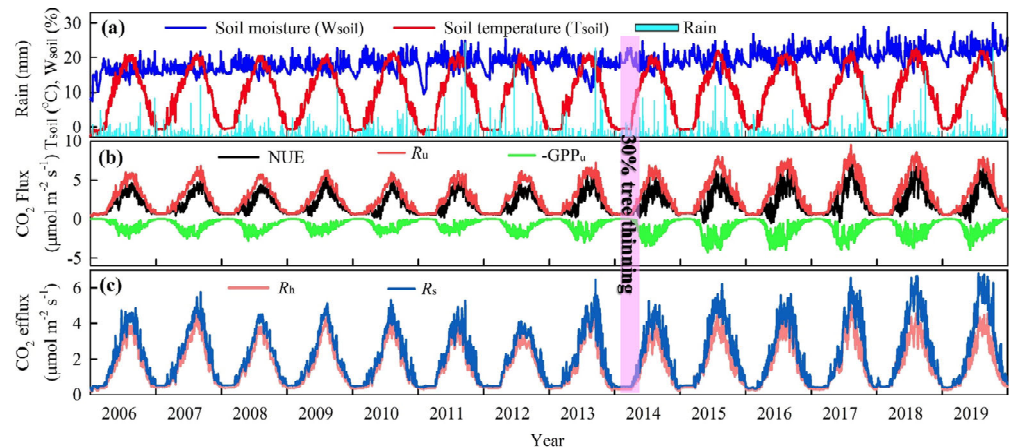
### **Project 1. Study of a multi-scale system for observing and evaluating GHG variation and mitigation**

This project aimed to develop a multi-scale observation and analysis system for estimating spatial and temporal variations in the atmospheric concentrations of GHGs and their surface fluxes, including anthropogenic and natural sources and sinks. The system is essential for analyzing a variety of climate change mitigation and adaptation policies and evaluating their effectiveness. The project comprises three sub-themes: (1) Evaluation of GHG budgets at different spatial scales, from global to local; (2) Estimation of oceanic and terrestrial GHG budgets and their upscaling; and (3) Assessment of mitigation and impacts of climate change at different spatial scales.

Sub-theme 1 has constructed an observation network for atmospheric GHGs that is based on international collaboration by three kinds of platform, namely ground-based station or site, shipboard laboratory, and aircraft. Global CO<sub>2</sub> flux spatiotemporal variations were estimated by using an inverse system named NICAM-TM 4D-Var, with conventional ground-based observations including those made by using the sub-theme 1 observation network. The estimated global land flux clearly showed El Nino-related anomalies, such as those for 1997–1998 and 2015–2016. The long-term mean changes in the surface CO<sub>2</sub> flux showed increasing trends of sinks (or decreasing trends of sources) in North America, eastern Eurasia, and Equatorial Asia.

Sub-theme 2 has evaluated terrestrial and oceanic CO<sub>2</sub> budgets on the basis of observations. Figure 2 shows the temporal variations in parameters related to terrestrial carbon sinks, namely precipitation and soil moisture, land temperature, and CO<sub>2</sub> flux due to photosynthesis and respiration, from 2006 to 2017 at the northern foot of Mt. Fuji. An increase in the amount of photosynthesis in the forest floor (green line in the figure) in the region could be detected after thinning in 2014. The results of this study are expected to help us to establish appropriate forest management methods based on the perspective of the carbon cycle. The sub-theme has also evaluated the distributions of partial pressure of carbon dioxide (pCO<sub>2</sub>) and air-sea CO<sub>2</sub> flux in the global ocean (60°S–70°N) for the past two decades by using an international pCO<sub>2</sub> database. During this period, a strengthening in CO<sub>2</sub> uptake by the ocean occurred, especially in the North Pacific, the North Atlantic, and the Southern Ocean (south of 30°S), whereas the exchange was relatively stable in the Indian Ocean and the South Atlantic. These findings imply that the impact of ocean acidification on ecosystems may differ among different regions. To clarify these findings more pCO<sub>2</sub> measurements are needed, especially in regions where observations are still scarce, such as in the eastern South Pacific and the Indian Ocean.

**Fig. 2** Changes in (a) soil temperature, soil moisture, and precipitation; (b) CO<sub>2</sub> flux, respiration, and photosynthesis at the forest floor; and (c) microbial respiration and soil respiration from 2006 to 2017 in larch forest at the northern foot of Mt. Fuji. NUE, net understory CO<sub>2</sub> exchange;  $R_u$ , understory respiration; GPP<sub>u</sub>, understory gross primary production;  $R_h$ , soil heterotrophic respiration;  $R_s$ , soil respiration



In sub-theme 3, emissions of CH<sub>4</sub> and N<sub>2</sub>O from terrestrial ecosystems were estimated by using a process-based model (VISIT), which implements biogeochemical schemes. Global total CH<sub>4</sub> emissions from natural wetlands and paddy fields in 2000–2020 were estimated as 150.5 and 40.0 Tg CH<sub>4</sub> year<sup>-1</sup>, respectively. Similarly, global total N<sub>2</sub>O emissions from natural ecosystems and croplands were respectively estimated as 11.5 and 5.8 Tg N<sub>2</sub>O year<sup>-1</sup>. Considering the high global warming potential of these gases, their emissions largely offset the net CO<sub>2</sub> uptake by terrestrial ecosystems. Also, sensitivity simulations implied that these emissions can be reduced by appropriate practices such as optimization of water management and fertilizer input. In conjunction with the top-down estimates from sub-themes 1 and 2, these bottom-up results have contributed to syntheses performed by the Global Carbon Project and will hopefully contribute to IPCC reports and then climate management and projection.

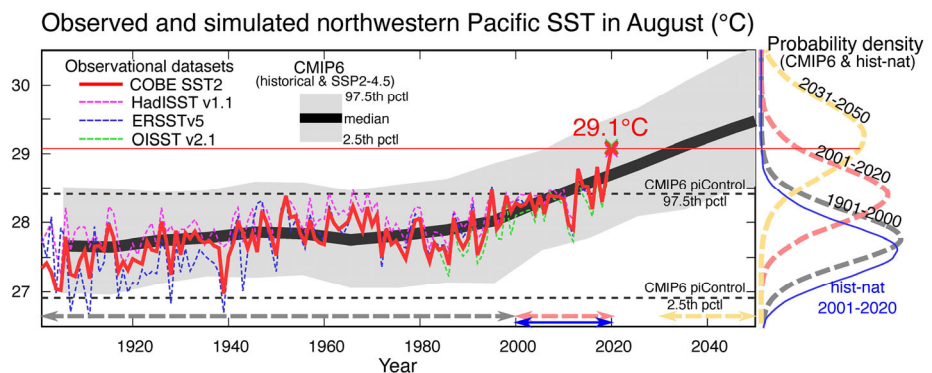
### **Project 2. Global-scale climate risk research based on integrated assessment of climate projections, impacts, and response options**

In this project, we have been developing a comprehensive modeling approach in which models for climate projections, impact assessments, and assessments of response options at a global scale are used in an integrative manner. With this approach, we aim to describe synthetic scenarios of climate change risk. The project consists of three sub-themes: (1) Projection and interpretation of climate change; (2) Synthetic assessment of low-carbon scenarios based on an integrated terrestrial model; and (3) Assessment of climate impacts, adaptation, and mitigation from the human and social perspectives.

Sub-theme 1 contributes to the development of climate change risk scenarios by projecting the future climate and helping us to understand past climate changes. This fiscal year, by using 31 climate models of Coupled Model Intercomparison Project (CMIP) 6, we quantified human-caused changes in the occurrence likelihood of exceeding the record-high northwestern Pacific sea-surface temperature (SST) observed in August 2020. Figure 3 shows the time series of

SST anomalies in the northwestern Pacific (120°E–180°E and 20°N–35°N) derived from observational datasets. It indicates that August 2020 set the record, regardless of the data used. The CMIP6 model ensemble reproduced well the potential variability from the 20th century to 2020, as its 2.5th to 97.5th percentile range well covered the observations that exceed the range in the pre-industrial control simulations (piControl). By using this ensemble, we estimated that the occurrence frequency of exceeding the record-high level (29.1 °C) was once per 600 years in 1901–2000 but increased to once per 15 years in 2001–2020. The frequency in 2001–2020 could be less than once per 1000 years without anthropogenic forcing, as in the “hist-nat” (natural-only historical simulations) experiment of DAMIP (Detection and Attribution Model Intercomparison), consisting of six CMIP6 models. Our results also indicate that the record-high level is expected to be a new normal climate condition of the northwestern Pacific region by 2031–2050, when global warming will likely exceed 1.5 °C. Therefore, even if we could achieve the 2 °C goal of the Paris Agreement, measures for adaptation and mitigation to global warming must be implemented promptly in Japan.

**Fig. 3** Time series of observed and simulated northwestern Pacific sea-surface temperature (SST) in August. The simulated probability density functions in 1901–2000, 2001–2020, and 2030–2050 with anthropogenic forcing (thick dashed lines) and in 2001–2020 without anthropogenic forcing (hist-nat; blue thin line) are also shown.



(Hayashi, M., Shiogama, H., Emori, S., Ogura, T., Hirota, N (2021) The northwestern Pacific warming record in August 2020 occurred under anthropogenic forcing. *Geophysical Research Letters* 48, e2020GL090956.)

In Sub-theme 2, we have developed models that can project the future of land climate, ecosystems, water resources, crop yield, and land use, as well as an integrated model created by coupling these land models (Model for Interdisciplinary Research On Climate INTEGrated land surface model, MIROC-INTEG-LAND). We found that future changes in the climate and a decrease in water resources may decrease food crop yields, leading to an increase in cropland area and an increase in water demand for irrigation. These changes would be dependent on socioeconomic scenarios. We also found that the efficiency of net ecosystem production, which represents CO<sub>2</sub> absorption by natural ecosystems, can change. This was especially likely under a future overshoot scenario, whereby the surface air temperature would exceed the stabilization target once and then return to the target.

In sub-theme 3 we have improved a model for finding an optimal global emission pathway to achieve given climate targets, and we have used the model to conduct climate policy analyses. This year, we studied

cost-effective implementation of the Paris Agreement by using flexible GHG metrics. These metrics, which are conversion factors used to evaluate emissions of non-CO<sub>2</sub> GHGs on a common scale with CO<sub>2</sub>, serve crucial functions in the implementation of the Paris Agreement. Although different metrics have been proposed, their economic cost-effectiveness has not been investigated under a range of pathways, including those substantially overshooting the temperature targets. In the study, we have shown that cost-effective metrics for CH<sub>4</sub> that minimize the overall mitigation costs are time dependent and are primarily determined by the pathway and are strongly influenced by temperature overshoot. Parties to the Paris Agreement have already adopted the conventional GWP100 (100-year global warming potential), which has been shown to be a good approximation of cost-effective metrics for the coming decades. In the longer term, however, we suggest that parties consider adapting the choice of common metrics to the future pathway as it unfolds, as part of the recurring global stocktake, if global cost-effectiveness is a key consideration.

### **Project 3. Policy assessment research toward a global low-carbon society**

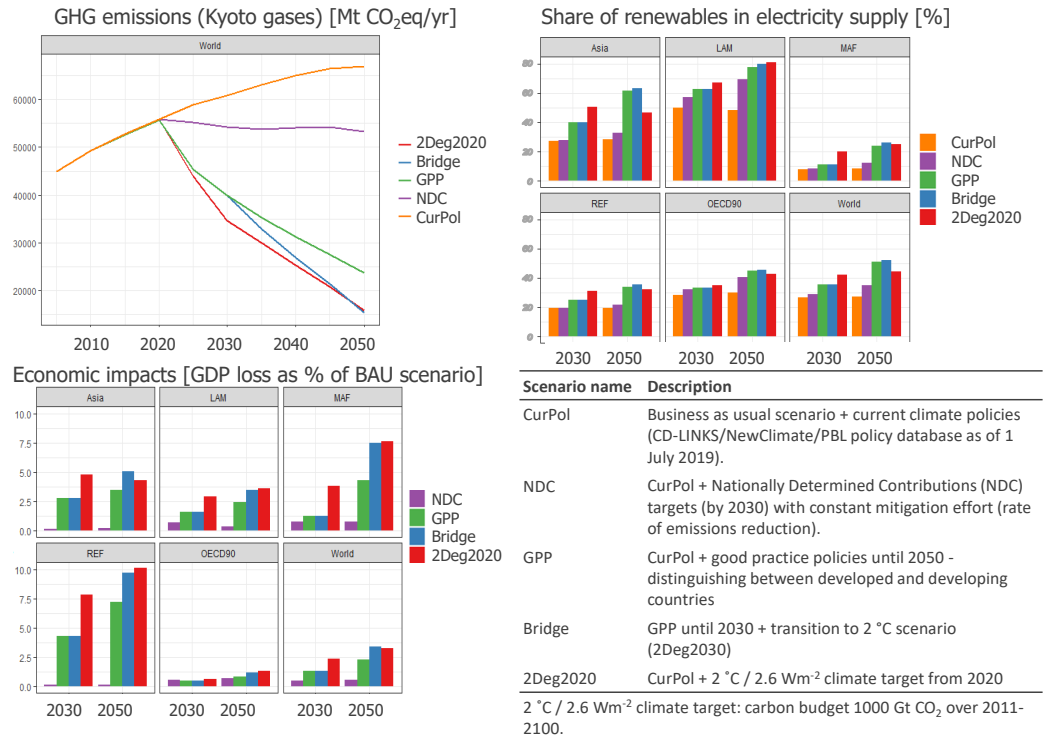
The aim of Project 3 is to provide scientific knowledge from the perspectives of modeling and analysis, scenario development, and negotiation processes, to achieve a global low-carbon society. National- and local-scale analyses toward a low-carbon society are being implemented in the Integration Research Program. Project 3 of the Low-Carbon Research Program consists of two sub-themes: (1) Assessment by using quantitative models, and (2) International institution design. The following are the main results obtained in FY 2020 in each sub-theme.

In sub-theme 1, we assessed the global emission pathways of long-lived GHGs with the goal of achieving the global 2 °C target, analyzed the co-benefit mitigation effects of SLCFs (short-lived climate forcers) and air pollutants, and evaluated mitigation costs and their economic impacts, by using the AIM/Enduse [Global] model and the AIM/CGE [Global] model. Figure 4 shows the global GHG emission pathways and the region-wise economic impacts and renewables shares in 2030 and 2050 among different scenarios, obtained by using the AIM/CGE [Global] model. There are substantial emission gaps between the Nationally Determined Contributions (NDCs) reported in major countries and the GHG emission reduction required to achieve the global 2 °C target. To close the gaps between the NDC scenario and the 2 °C target scenario, the Good Practice Policy (GPP) scenario was analyzed; we considered such factors as different levels of carbon pricing and energy efficiency improvement in multi-regions and multi-sectors and different emissions reduction rates by non-CO<sub>2</sub> mitigation measures compared to 2015. We found that the GPP scenario could narrow the emission gap in 2030 between NDC and the 2 °C target to around 70%, but that that would still not be enough to achieve the 2 °C target pathway. We therefore applied a bridge scenario to transit smoothly from the GPP scenario to the 2 °C target scenario. Under the bridge scenario, it would be necessary to further

# 1. Low-Carbon Research Program

enhance mitigation measures after 2030; thus, the impacts on GDP loss would become larger than under the GPP scenario, especially in Asian regions.

**Fig. 4** Global GHG emission projections, region-wise economic impacts, and renewables shares for achieving the 2 °C target.



As part of sub-theme 2, we traced discourses related to climate security in Japan to determine why so little discourse exists in Japan and whether or not such discourses could suggest new areas to consider, with the aim of responding more comprehensively to the climate change problem. As the level of understanding of climate change has increased, the term “climate security” has been increasingly used in the rapidly growing literature on this subject. Although Japan has officially acknowledged the importance of tackling climate change, discussion of climate security has been almost nonexistent among Japanese government officials, politicians, and academics. Because of the different interpretations and uses of the term “climate security” in the existing literature, we first categorized existing approaches to climate security into four types (Table 1) and used this categorization to examine Japan’s discourses from these perspectives. Two of the approaches, namely “long-term irreversible planetary changes” and “short-term abrupt risks to individuals,” had been considered in Japan previously but without specific reference to the term “climate security.” The other two, however, had not been used, and they need to be included in discussions of climate change in Japan. The topics not discussed in Japan include indirect economic losses of Japanese industries via loss or disruption of supply chains, loss of Japan’s exclusive economic zone owing to sea-level rise, and the potential inflow of refugees from extreme weather patterns outside Japan.

**Table 1** Summary of the four categories of climate security discourse

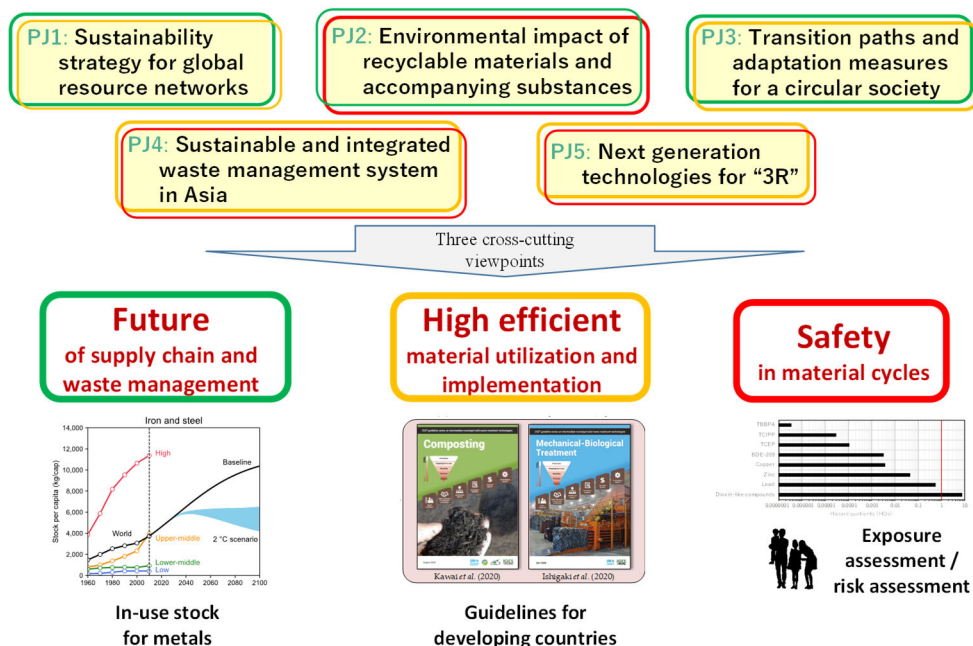
Category	Threat	Objects of protection	Means to improve level of security
Long-term irreversible planetary changes	Changing global climate, warming world	The planet, human beings, and the ecosystem	GHG emission reduction at a global level (mitigation policy)
Short-term abrupt risks to individuals	Extreme weather events and other impacts of climate change at the regional and individual levels	People's daily lives, including stable supply of basic human needs	Adaptation measures, building resilience
Causes of conflict and violence	Migration and other causes of conflict among groups	Own group	Reduction of social instability
Impacts on military and defense organizations	Long-term changes such as sea-level rise, and short-term changes such as extreme weather events	National territory, military facilities, and defense forces	Adaptation in the areas of defense and other military operations

### Sustainable Material Cycles Research Program

To help materialize the future vision for an international resource-use strategy, this program will elucidate supply chain structures and the factors that shape those supply chains. Measures to achieve a sustainable material-cycle-based society will be proposed on the basis of an assessment of the effects of resource and environmental conservation throughout the life cycles of products and services. The program will also develop and evaluate measures for advancing sustainable, integrated waste management systems in Japan and the broader Asian region. The fundamental technologies and social systems needed for waste prevention/minimization, reuse, and recycling in harmony with a low-carbon-footprint society and other initiatives will also be proposed.

We have been working to implement the following five research projects, with a view to three cross-cutting key points, namely “future of supply chain and waste management,” “high efficiency of material utilization and implementation,” and “safety in material cycles.” Figure 1 highlights some of our accomplishments across the entire Sustainable Material Cycles Research Program and their connections with these three viewpoints.

**Fig. 1** Positioning of our highlights in the entire Sustainable Material Cycles Research Program and their relationships with the five projects and three cross-cutting viewpoints. Each of the three viewpoints—“Future,” “High efficiency,” and “Safety”—is related to several projects, as shown by the colors of their frames.



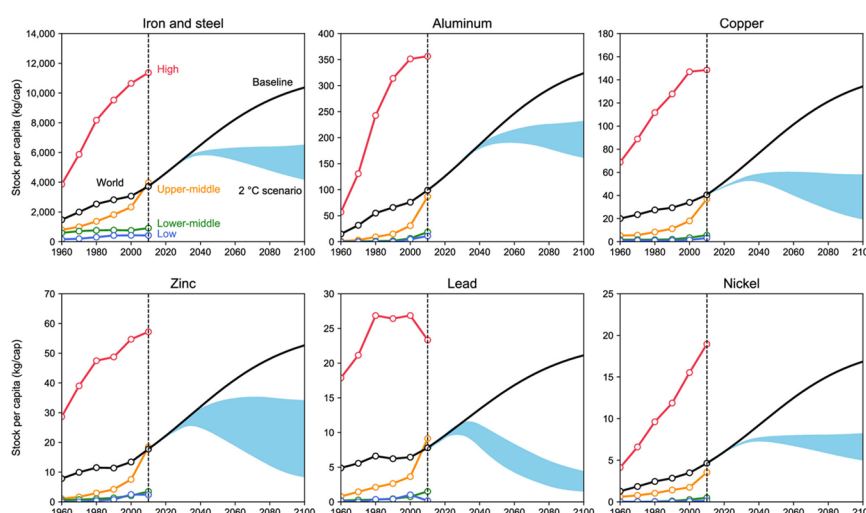
#### 1. Designing a sustainability strategy for global resource networks from a consumption-based perspective (Research Project 1)

A sustainable metal supply requires well-coordinated strategy and policy packages based on a sound scientific understanding of anticipated long-term demand, supply, and associated environmental implications. Such information is, however, highly fragmented among various case studies. Accordingly, we explored the projected long-term status of six major metals—iron, aluminum, copper, zinc, lead, and

nickel—with around 200 data points for global demand through 2030, 2050, and 2100 (Fig. 2). This extensive review showed that global demand for these major metals could increase continuously over the 21st century by approximately two- to six-fold, depending on the metal (Watari et al. 2021).

Then, we explored global scenarios for metal flows, stocks, and use intensity in the global economy to 2100, harmonized with climate goals. We found that, despite advances in low-carbon-metal production, a transformative system change to meet society's needs by using less metal is required to remain within the 2 °C pathway. Globally, demand for goods and services over the 21st century needs to be met with approximately 7 t/capita of metal stocks, roughly half the current level in high-income countries. This systemic change will require a peak in global metal production by 2030 and deep decoupling of economic growth from both metal flows and stocks. The level at which per capita metal stocks should converge in light of the climate goals identified in this study provides one reasonable benchmark for the extent to which resource efficiency needs to be promoted.

**Fig. 2** Per capita in-use stocks of six major metals, 1960–2100 (Watari et al. 2020). In the panels, the ranges in the 2 °C scenario are due to differences in assumptions regarding end-of-life recycling rates and product lifetimes. The upper limit of the range (circular economy scenario) assumes that end-of-life recycling rates and product lifetimes increase to the theoretical maximum by 2100 according to the saturation curve. The lower limit of the range (business as usual scenario) represents the assumption that all model parameters are constant throughout the scenario period.



### References:

Watari T., Nansai K., Giurco D., Nakajima K., McLellan B., Helbig C. (2020) Global metal use targets in line with climate goals. *Environmental Science & Technology*, 54(19), 12476–12483

Watari T., Nansai K., Nakajima K. (2021) Major metals demand, supply, and environmental impacts to 2100: A critical review. *Resource Conservation and Recycling*, 164 (105107)

## 2. Assessment of resource efficiency and environmental impact in the cycles of recyclable materials and accompanying substances (Research Project 2)

To identify chemicals with high priority for risk management in the area of waste electrical and electronic equipment (WEEE) dismantling, we estimated the daily chemical intakes of workers engaged in WEEE dismantling, and we assessed their

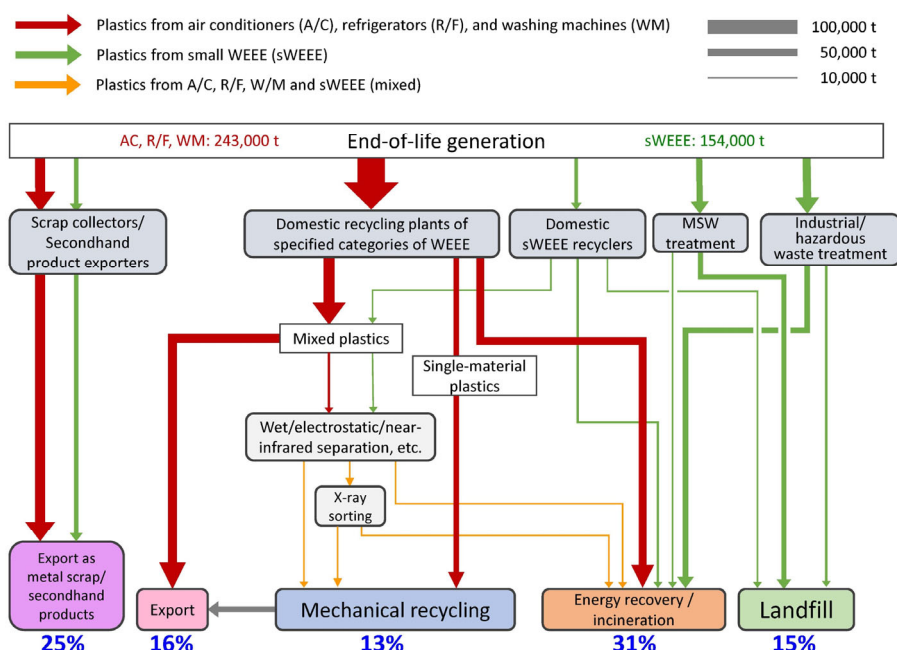


## 2. Sustainable Material Cycles Research Program

health risks from chemical exposure via indoor dust ingestion or inhalation and intake of free-range chicken eggs which persistent organic pollutants were accumulated. Our findings suggest that dust emitted to surrounding environment should be controlled, and that measures against indoor dust exposure (Wannomai et al. 2021) should be implemented to reduce the adverse health effects of lead and dioxin-like compounds via dust exposure and egg intake, respectively, in WEEE-dismantling areas.

Flows of plastics originating from WEEE in recycling processes in Japan, together with the flows of brominated flame retardants (BFRs) from these plastics, were estimated for fiscal year (FY) 2017. Although mixed plastics export from Japan is considered to have decreased after China's waste plastic import ban, recycled pellets from WEEE plastics are still exported to China and other Asian countries. Nevertheless, large proportions of BFRs were eliminated from the recycled plastics during the sorting processes. Estimated flows of WEEE plastics in Japan in FY 2017 are shown in Figure 3.

**Fig. 3** Estimated flows of WEEE plastics in Japan in FY 2017



### Reference:

Wannomai T., Matsukami H., Uchida N., Takahashi F., Tuyen L.H., Viet P.H., Takahashi S., Kunisue T., Suzuki G. (2021) Inhalation bioaccessibility and health risk assessment of flame retardants in indoor dust from Vietnamese e-waste-dismantling workshops. *Science of The Total Environment*, 760, 143862

### 3. Proposal of transition paths and adaptation measures for a circular society (Research Project 3)

First, we conducted a scenario analysis by using a municipal waste management

model that we had developed in previous years. The model estimates municipal waste flows in Japan on the basis of a bottom-up approach, in which municipal solid waste management data for each municipality are used and aggregated to the national level. By using the current (2015) and projected (up to 2030) populations, we simulated how the different policies of 1741 municipalities affect national-level policy outcomes, such as the amount of recycling, the reduction of final disposal, and the reduction of GHG emissions, taking into account regional characteristics. Policies mainly considered were food waste recycling, plastics waste recycling, and consolidation of waste incinerators. In addition, we estimated the outcomes of food waste recycling at large shopping centers by introducing methane fermentation technology.

Second, we conducted a questionnaire survey of community leaders in the city of Tsukuba because population aging is considered to have negative impact on the maintenance of waste collection points managed by communities (e.g. neighborhood associations). The results revealed that more inappropriate disposal was reported in areas where waste collection points were not managed by neighborhood associations, elderly people were unable to perform their assigned waste-collection-point cleaning duties, and the elderly tended to be more isolated in large-scale residential areas than in rural areas. These results suggest the need to introduce alternative methods of maintaining waste collection services in our aging society, taking local situations into account.

Third, to enhance the quality of resource circulation and reduce natural resource consumption, we applied the Social Return on Investment method to evaluate the social impact of resource circulation programs (e.g., product upcycling and its social values). We also analyzed statistical data about product lifespan. No marked difference in average lifespan was observed between different reasons for discarding the products (i.e., mechanical failure and replacement with new products). This suggested that the difference revealed between expected product lifespan and actual product lifespan in our previous studies was caused by both physical degradation and functional obsolescence.

### References:

Inaba R., Tasaki T., Kawai K., Nakanishi S., Yokoo Y., Takagi S. (2021) National and subnational outcomes of waste management policies for 1,718 municipalities in Japan: Development of a bottom-up waste flow model and its application to a declining population through 2030. *J. of Material Cycles and Waste Management*, <https://doi.org/10.1007/s10163-021-01303-7>.

Tasaki T., Nishimura S., Inaba R., Kawai K., Yamaguchi N. (2021) Estimation of National Outcomes from Consolidating Municipal Waste Incinerators: Development of Consolidating Algorithm and its Application. *J. of Japan Society of Civil Engineers, Sec. G (Environmental Research)* <In print, in Japanese>

### 4. Establishment of a robust, sustainable, and integrated waste management system for Asia (Research Project 4)

On the basis of numerous field surveys and data collection on waste management in developing Asian countries, we developed a self-diagnosis tool to evaluate local conditions for installing waste management technologies such as incineration, anaerobic digestion, and composting. The tool will apply to municipalities in developing Asian countries and will indicate the feasibility of installing waste management technologies as alternatives to direct landfilling.

We also investigated the viscoelastic properties of waste as an indicator of adhesiveness, which is a problem in the appropriate treatment of wet wastes in tropical Asia. The relationships between the moisture content of the waste and physical indices such as elastic modulus, rigidity modulus, and tensile force were identified. We found that the mechanical loss tangent (loss modulus/storage modulus) was an effective indicator of the adhesiveness of each component of waste. The characteristics of organic wastes were taken into account in our optimization of the operation of biodrying, one of the main technologies used in the mechanical and biological treatment (MBT) of waste. The catabolic heat generated by the initial decomposition of organics does not contribute directly to evaporation, but the change caused in the water-holding capacity of organics by decomposition may be the main mechanism that leads to moisture vaporization and evaporation.

We developed guidelines on composting and MBT that were published by UNEP (the United Nations Environment Programme) (Ishigaki and Liu 2020; Kawai et al. 2020). These guidelines should help decision-makers and policy-makers in developing Asian countries to evaluate the feasibility of introducing these methods and implementing them sustainably to improve local waste management systems (Fig. 4).

**Fig. 4** Our guidelines on composting and mechanical and biological treatment of waste



### References:

Kawai K., Liu C., Gamaralalage P.J.D. (2020) CCET guideline series on intermediate municipal solid waste treatment technologies: Composting. United Nations Environment Programme and Institute for Global Environmental Strategies.

<https://www.unep.org/ietc/resources/publication/ccet-guideline-series-intermediate-municipal-solid-waste-treatment>

Ishigaki T., Liu C. (2020) CCET guideline series on intermediate municipal solid waste treatment technologies: Mechanical-biological treatment (MBT). United Nations Environment Programme and Institute for Global Environmental Strategies.

<https://www.unep.org/ietc/resources/toolkits-manuals-and-guides/ccet-guideline-series-intermediate-municipal-solid-waste>

### 5. Development of next-generation technologies for “3R” (Research Project 5)

As part of the development of waste-to-energy technologies, we have been investigating a biofilm reactor that overcomes the inhibition by long-chain fatty acids (LCFAs) in anaerobic co-digestion of waste grease and food waste. The reactor is designed for on-site biogas generation inside large commercial facilities. This year, we investigated the effects of microbial concentration and operating temperature (mesophilic and thermophilic) on the tolerance of the anaerobic bioreactor to LCFAs. We observed a significant correlation between the half maximum inhibitory concentration (IC<sub>50</sub>) of LCFAs and the microbial concentration. By contrast, temperature did not affect the IC<sub>50</sub> at the same concentration of microorganisms. These results support the high tolerance of the biofilm reactor, which operates with high microbial concentrations, to LCFAs. Also, we newly investigated the effectiveness of installing the on-site biogas system using food waste and waste grease into large commercial facilities in Japan. Model estimation suggested that the system will potentially decrease CO<sub>2</sub> emissions by 1.7 billion tonnes and save 22 thousand tonnes of resources in Japan. (Kobayashi et al, 2021)

As part of the development of waste-to-material technologies, we have been investigating the behavior of useful and harmful metals in waste thermal treatment facilities. We have been focusing on the difficult-to-crush metal particles remaining on the sieve after ball-mill crushing of incineration bottom ash (BA) or grate sifting ash (GA) discharged from these facilities. We conducted a detailed analysis of particle size and elemental composition to establish a flowchart of the procedure to determine the elemental compositions of BA and GA. This included the development of a formula for the amount of sample required to obtain representative values. By sampling BA and GA generated at one incinerator in Japan once a month and analyzing the elemental composition according to the flowchart, we were able to determine the annual fluctuations in metal composition, focusing on precious metals. Finally, we quantified the resource value of the BA and GA. (Back and Sakanakura 2021)

As part of the development of appropriate treatment technologies for nanowaste,

we confirmed that carbon nanotubes were completely decomposed by incineration and did not remain in incineration residues and flue gases during incineration experiments. We also confirmed by chemical analysis of landfill leachates that titanium dioxide nanoparticles were not discharged from landfill sites. To develop a method of measuring microplastics, we investigated collection and identification methods for airborne microplastics in waste treatment facilities. The microplastics could be collected by using a high-volume air sampler and identified by using microscopic Raman spectroscopy.

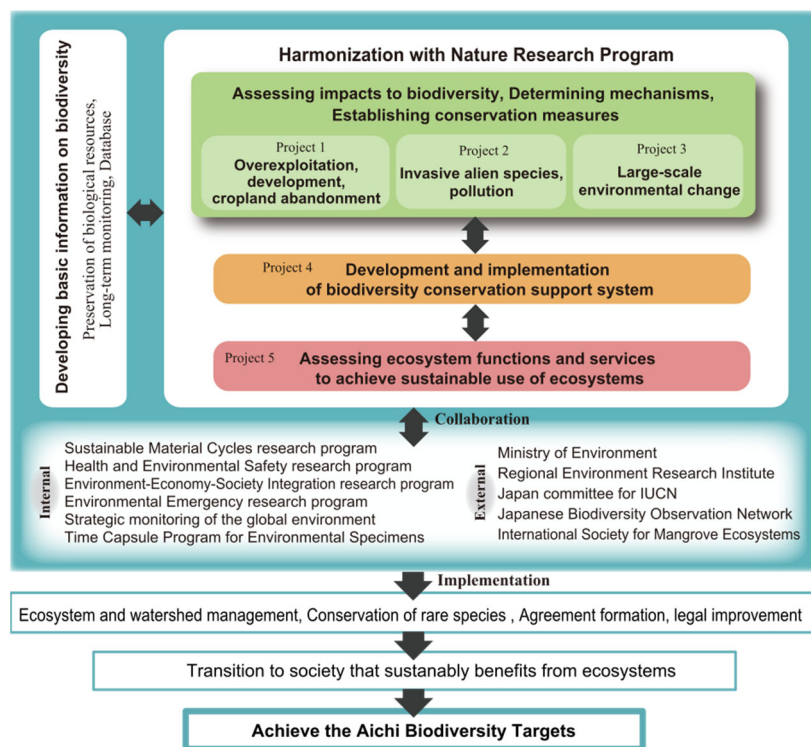
### **References:**

- Kobayashi T., Yokoo Y., Kuramochi H., Tasaki T., Inaba R., Kawai K. (2021) Potential effectiveness of on-site anaerobic co-digestion of oily sludge and kitchen waste at large commercial facilities in Japan for reducing CO<sub>2</sub> emissions and waste recycling. *Journal of Water and Waste*, 63(4), 298–305
- Back S., Sakanakura H. (2021) Distribution of recoverable metal resources and toxic elements in municipal solid waste incineration bottom ash depending on particle size and density. *Waste Management*, 126, 652–663

**Harmonization with Nature Research Program**

The Harmonization with Nature Research Program is structured to address the four biodiversity crises described in the National Biodiversity Strategy and Action Plan of Japan in order to achieve the Aichi Biodiversity Targets of the 2010 Convention on Biological Diversity (Fig. 1). Project I responds to the first crisis, namely that resulting from development and other problems caused by human activities (e.g., habitat destruction or overfishing), and the second crisis, namely that caused by reduced stewardship of nature (abandonment of cultivation and reduction in the abundance of *satoyama* landscapes). Project II responds to the third crisis, caused by organisms and materials introduced by humans (e.g., invasive species or pollution). Project III responds to the fourth crisis, caused by large-scale environmental changes (e.g., climate change). Project IV was established to set up biodiversity conservation measures in an integrated manner. On the basis of the conservation of biodiversity through these efforts, Project V works on the evaluation and sustainable use of ecosystem functions and services, including the conservation of land–sea continua.

**Fig. 1** Overall structure of the Harmonization with Nature research program



The research is being conducted at the global, national (Japan), and local scales. Figure 2 shows our specific research sites in Japan, as described in this report.

### 3. Harmonization with Nature Research Program

**Fig. 2** Locations of the study sites referred to in this report

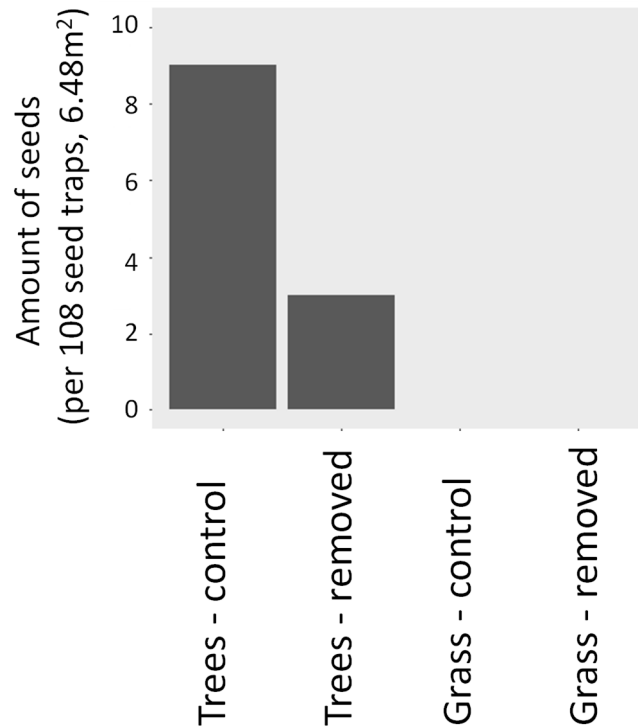


#### **1. Biodiversity assessment of impacts of large-scale human activities (Project I)**

In a sub-project targeting the overuse issue at the global scale, we quantified the spatial overlaps between the distributions of 6164 globally threatened terrestrial vertebrate species and five major forest disturbance drivers at the global scale, namely commodity-driven deforestation, shifting agriculture, forestry, wildfire, and urbanization. We showed that each driver had distinct relative importance among species groups, such as forest-habitat-specific and taxonomic groups, as well as geographic regions. In particular, the proportion of shifting agriculture—small-scale temporary land use—drastically increased in threatened species' ranges, by 35.3 percentage points above the global baseline. These facts highlight the need for measures to ensure local communities' livelihoods to regulate land use in a sustainable manner and halt further losses of biodiversity.

In a sub-project targeting the underuse issue at the national scale, we conducted a seed-dispersal survey showing that abandoned paddy fields with adult trees tended to have a larger amount of seed dispersed by animal- than abandoned fields without trees (Fig. 3). The reason for this was thought to be the perching tree effect (when birds and other animals stay in trees and excrete feces containing seeds, the number of seeds deposited under the trees increases).

**Fig. 3** Amounts of *Cornus controversa* seeds captured by seed traps on long-abandoned paddy fields without (control) and with plant-removal treatment. “Trees” and “Grass” indicate the predominant plant types.



Moreover, we analyzed agricultural census data and found that landowners tend to abandon their paddy fields when incomes from agriculture are low. This was consistent with the findings of previous studies in European countries. On the other hand, paddy fields tended to be sustained in agricultural areas with productivity disadvantages, suggesting that the direct payment system (i.e. governmental income support for farmers) may be effective in reducing abandonment in areas where the direct benefits from farming are low.

Synthesis of these results and results from previous years suggested that decentralization of human population distribution and the establishment of efficient protected areas for *satoyama* organisms are desirable for biodiversity conservation under a declining population. To achieve these goals, we stress the importance of balancing the maintenance of biodiversity with production functions, for example, by turning abandoned land into secondary forests for biomass utilization and utilizing payment systems for the environmental value of agricultural land.



#### **2. Development of intensive control methods for invasive alien species management (Project II)**

Severe febrile thrombocytopenia syndrome (SFTS), which is caused by a tick-borne virus and has a mortality rate of about 30%, has been spreading in Japan since 2012. Recently, some people in urban areas have been infected. The ticks that carry the virus parasitize mammals inhabiting mountain forests, but the recent encroachment of wild animals into human habitats is thought to have led to the appearance of the ticks in urban areas.

Therefore, there is a risk that tick populations will further increase in residential areas adjacent to parks and green spaces, increasing the risk of transmission of infectious diseases such as SFTS. In fact, in our survey of the municipality of Tsushima Island, tick larvae were collected in excessive densities from the grass around fishing ports and residential areas. Urgent countermeasures are therefore necessary.

In FY 2020, we tested the acute toxicity of various pesticides to ticks in the laboratory in order to select effective acaricides. The methods used were as follows.

**Test chemicals:** A total of 13 chemicals were selected from among various insecticides with reported insecticidal and acaricidal activity. We chose 12 fast-acting chemicals (five pyrethroids, A to E; four organophosphates, F to I; one neonicotinoid, J; one phenylpyrazole, K; and one oxadiazole, L) and one inhibitor of molting (IGR = insect growth regulator, M). Concentrations of 0.0001, 0.001, 0.01, 0.1, and 1 µg/0.2 µL acetone solutions of each agent were prepared for the study.

**Test organism:** Approximately 50 larvae of a *Haemaphysalis longicornis* rearing strain (Kyushu University strain, rearing conditions: about 23 °C; 100% relative humidity; light: dark = 14:10) were released on mice, and the satiated larvae that had dropped from the host after about 4 to 6 days were collected each day and stored in rearing jars. After about 2 to 4 weeks, the freshly molted nymphs were stored in rearing jars for pre-sucking toxicity testing, which was performed on different nymphs every 4 days. In addition, about 50 nymphs were released on to 2 mice, and those nymphs the satiated nymphs that had dropped from the host in about 4 to 8 days were collected and stored in rearing jars every week for post-sucking toxicity testing. Twelve fast-acting Insect-acaricides were used in the pre-sucking toxicity tests, and the IGR agent was used in the post-sucking toxicity tests (Fig. 4).

**Insecticide treatment:** A micro-syringe was used to apply 0.2 µL of acetone solution to the dorsal surface of the nymphs. After the acetone had been volatilized, for the pre-sucking test, five treated nymphs were placed in each glass tube, and lethality was confirmed after 24 and 48 h. In the post-sucking test, the

number of live adult ticks present in the test tube after treatment of five nymphs with the IGR was checked after about 30 days. (Molting from nymph to adult generally occurs in 18 to 24 days.) All tests were done in triplicate.

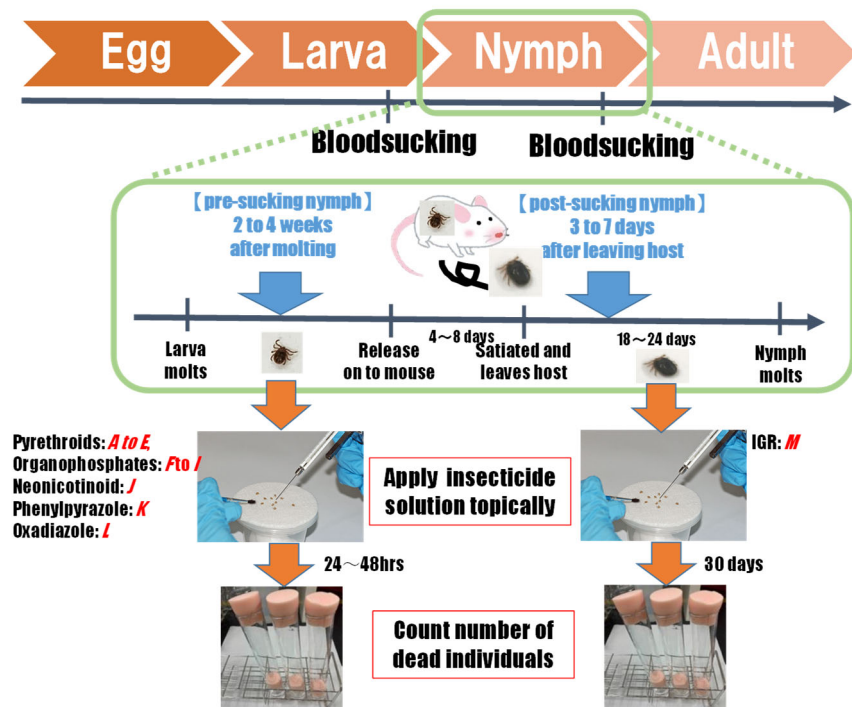
Evaluation of pesticide efficacy: From the percentage of dead individuals obtained, LD<sub>50</sub> values were calculated by using the probit method (Robertson et al. 2017).

In the acute percutaneous toxicity test in pre-sucking nymphs, the LD<sub>50</sub> value was calculated from the percentage of dead ticks after 48 h. The lowest value among the 12 fast-acting agents was obtained with pyrethroid-like insecticide E (48-h LD<sub>50</sub> = 0.002 µg). The LD<sub>50</sub> for nymphs after blood-sucking was calculated to be about 0.001 µg for IGR insecticide.

Starving ticks in the pre-bloodsucking stage, which are highly likely to bite, wait for humans or other mammals in grassy areas on the border between green areas and roads. Fast-acting pyrethroid E was judged to be effective in quickly eliminating these individuals. In contrast, the effect of pyrethroid E on ticks after bloodsucking decreased, suggesting that alternating spraying of the pyrethroid with the use of an IGR, which was highly effective in this stage, would be effective.

Our next step will be to develop chemical control tests using these two insecticides in the field.

**Fig. 4** Acute transcutaneous toxicity test of ticks.



Reference

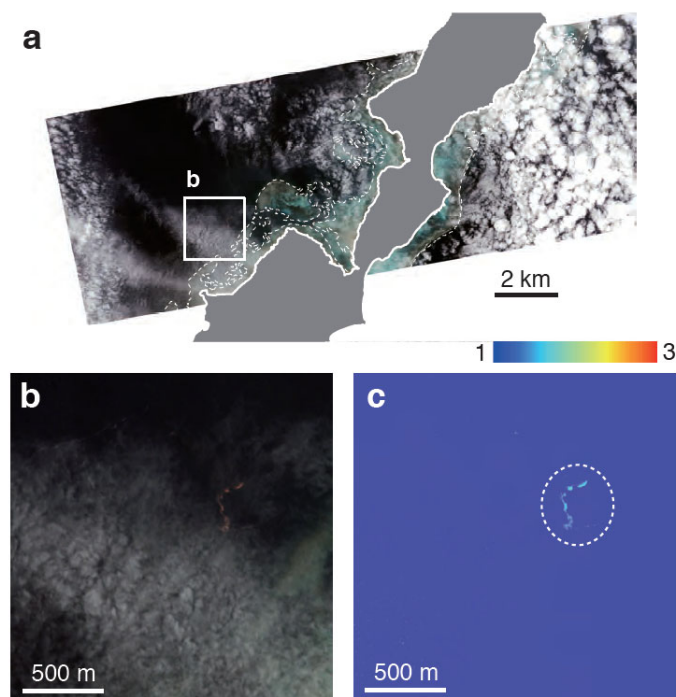
Robertson JL, Russell RM, Preisler HK. (2007) Bioassays with arthropods. 2nd ed. Boca Raton, FL: CRC Press

#### 3. Ecological responses to large-scale environmental changes (Project III)

##### 3.1. Coral-spawn slicks: Reflectance spectra and detection by using optical satellite data

We examined the feasibility of using optical satellite remote sensing to detect and monitor coral-spawning events. The reflectance spectra showed that coral-spawn slicks could be discriminated from other sea-surface features. Analysis of Planet Dove imagery enabled successful detection of coral-spawn slicks at Ishigaki Island, Okinawa, Japan ( $24^{\circ}31'40''\text{N}$ ,  $124^{\circ}17'31''\text{E}$ ) by using reflectance values in the green and red wavelength regions (Fig. 5). This detection was attributable to both the high spatial resolution (3.7 m) and high temporal resolution (1 day), given that coral spawning occurs within a short period (up to several days), typically once a year, and that the coral-spawn slicks are narrow at about 10 m. High-frequency satellite observations, including those from satellite constellations, should provide a powerful tool for understanding coral-reef processes and features for which detection requires high spatial and temporal resolutions (Yamano et al. 2020, *Remote Sensing of Environment* 251:112058).

**Fig. 5** True-color image of the northern part of Ishigaki Island (a), showing the area with coral-spawn slicks (b) and the red-green-band ratio values (c) for Planet Dove imagery. The dashed-line ellipsoid in (c) indicates the main slicks. The image was acquired at 10:18 on 18 May 2019 (Japan Standard Time).

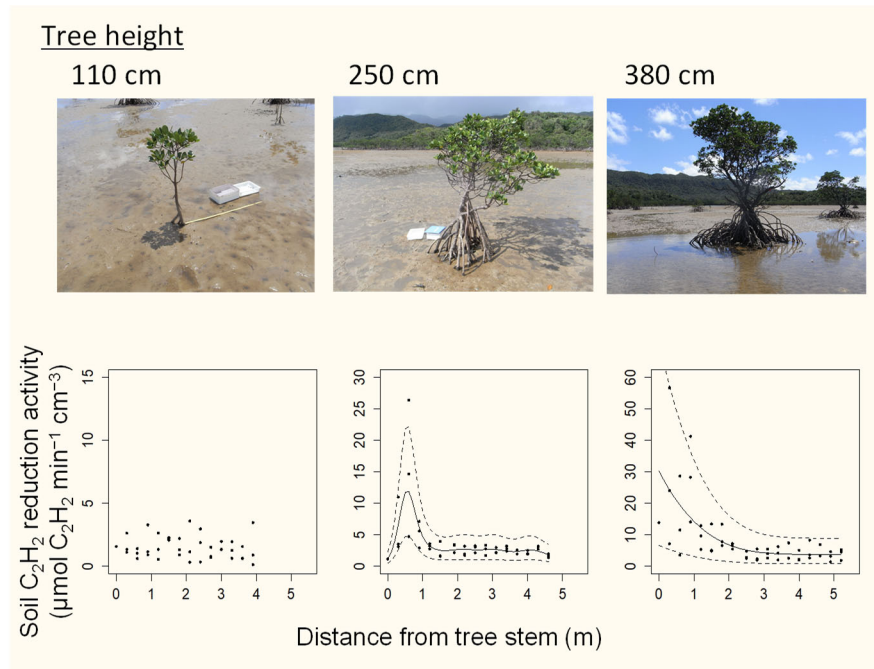


##### 3.2. Mangrove–diazotroph relationships: diazotrophic communities have high nitrogenase activity in the mangrove rhizosphere

The soils of tidal flats, on which mangroves grow, are often depleted in nitrogen because the nitrogen-containing litter is washed offshore during ebb tides. Under such site conditions, it remains unclear how mangrove plants acquire the nitrogen required to support their vigorous growth. In this study, we discovered that the rhizospheres of mangrove trees dominated by *Rhizophora stylosa* are characterized by high levels of nitrogen fixation. As trees grow and develop

greater root biomass, the diazotrophic communities perform more nitrogen fixation, which is pertinent to plant growth (Fig. 6). The mutualistic relationship between mangrove roots and diazotrophs seems to benefit the mangroves by enabling them to colonize, and become established on, open tidal flats. This study of *R. stylosa* was conducted in the northern part of Iriomote Island, one of the southernmost islands of Japan (Inoue et al. 2020, *Annals of Botany* 125:131–144).

**Fig. 6** Observed data points for soil acetylene ( $C_2H_2$ ) reduction activity at the tree scale, along with fitted profiles from a generalized additive model. When a model that included distance as an explanatory variable was selected by using the Akaike information criterion, the fitted profiles are shown as solid lines, with the 95% prediction interval denoted by dashed lines.



#### **4. Evaluation of biodiversity and development of a system for supporting conservation design (Project IV)**

For each land-use type, we analyzed the spatial arrangement that would enable both the expansion of renewable energy use for climate change mitigation and biodiversity conservation. This analysis was conducted in collaboration with the Climate Change Adaptation Program and Economic Partnership Group of our institute.

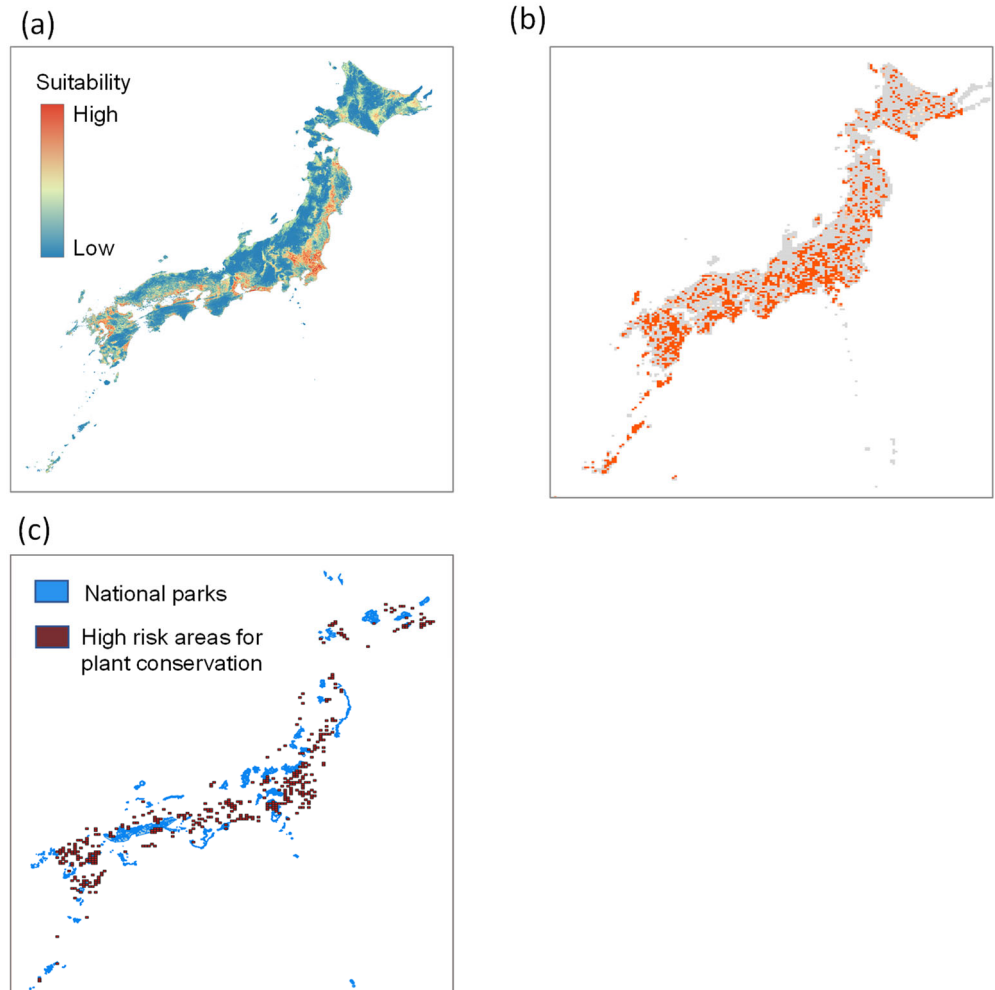
First, on the basis of the distribution of photovoltaic panels throughout Japan, a statistical model was constructed to estimate the distribution of suitable areas for construction of panels (Fig. 7a). Information such as the location and power-generation capacity of photovoltaic panels was provided by Professor Kitamoto of the National Institute of Informatics and was developed as polygons in the Climate Change Adaptation program. As a result of the distribution estimation, the area of panels constructed tended to be small in areas with high snowfall in winter, and the area of panels constructed tended to be large on wasteland, bare land, and golf courses.

By using our estimations of the areas suitable for panel construction and information on the distribution of endangered vascular plants, we analyzed the protected area layout that would allow both conservation of endangered species and panel construction. SecSel, a protected-area selection software developed in this project, was used for the analysis. We assumed that panels could not be constructed at sites selected as protected areas, and the estimated area suitable for construction at such sites was treated as a cost of lost opportunity. This allowed us to select protected areas efficiently to conserve endangered plants while leaving as much suitable area for panel construction as possible. However, even in areas that are suitable for panel construction, areas with particularly high conservation importance will be selected as protected areas (Fig. 7b).

We conducted a gap analysis between the results of this protected area selection and existing national parks. We found that the sites estimated to be both of high conservation importance and good for solar panel construction are often outside national parks (Fig. 7c). It is important to consider effective measures to avoid constructing panels at these important sites outside the parks.

**Fig. 7**

(a) Estimated distribution of areas suitable for photovoltaic panels; (b) results of prioritization for conservation of endangered vascular plants, avoiding areas suitable for photovoltaic panels; some areas were prioritized highly for conservation even though they were highly suitable for photovoltaic panels; (c) gap analysis of existing national parks and high-risk areas for endangered plants



## 5. Evaluation of ecosystem functions and services and their sustainable use (Project V)

### 5.1 Interactions among multiple ecosystem services in the Lake Kasumigaura watershed

To enable a more accurate assessment of fish diversity by using environmental DNA (eDNA), we developed a novel statistical method to appropriately correct false negatives in the eDNA metabarcoding. By using this statistical model, we found that the richness of native freshwater fish species in the Lake Kasumigaura watershed was negatively related to the proportion of croplands and was lower at sites with concrete banks without riparian vegetation than at other sites. This suggests that there are trade-offs among fish diversity, agricultural production, and disaster prevention in the watershed. With quantitative polymerase chain reaction using species-specific primers and probes, we developed the method further to both to detect the presence, and reflect the patterns of abundance, of *Acheilognathus tabira erythropterus*, one of the most endangered fish species in

the Lake Kasumigaura watershed. We experimentally confirmed the species specificity of the primers and probes, and we then collected eDNA samples from 35 sites in a sub-watershed (detailed names are not provided because of conservation reasons) in summer in 2020. We detected the presence of *A. tabira erythropterus* at only one site. Although our survey was only a snapshot, our result suggests the critical status of this species. Application of our method to citizen science could help to assess the detailed spatial distribution of this species.

We corroborated with Ibaraki Kasumigaura Environmental Science Center to value the multiple ecosystem services of Lake Kasumigaura by using three different economic valuation methods. The replacement cost method based on market price estimated that Lake Kasumigaura generates at least 121.7 billion JPY/year. The estimate per unit area (5.5 million JPY/ha/year) was approximately four times the reported average values of all other lakes and rivers across the world. Questionnaire-based economic valuation methods (choice experiment and best–worst scaling method) revealed that individuals’ willingness-to-pay for good water quality and biodiversity conservation is higher than that for other ecosystem services. These results can inform appropriate and adaptive management actions to maintain the water quality and biodiversity of Lake Kasumigaura. This is also the first study led by local government in Japan to comprehensively value multiple ecosystem services of an individual lake.

#### **5.2 Sustainability of ecosystems on the Ogasawara Islands**

We cryopreserved genetic resources obtained from endangered species in the Ogasawara Islands, including the Bonin flying fox (*Pteropus pselaphon*), the Japanese wood pigeon (*Columba janthina nitens*), and an endemic species of freshwater shrimp (*Paratya boninensis*). We analyzed the data obtained in our field survey of freshwater ecosystems on the Ogasawara Islands, focusing on the effects of the serious drought that occurred from the end of 2016 to the first half of 2017. Although total species diversity was quickly restored, species composition in the ecosystems has been restored to only two-thirds of that before the drought. The degree of restoration differed among biological groups. The species diversity and composition of insects showed wide temporal variety. The species diversity of Decapoda was restored quickly, but that of Mollusca was not restored for 2 years after the drought. We also obtained the mitochondrial COI (cytochrome c oxidase I) sequences of animal species collected from freshwater on Chichijima (*jima* = “island”) and have constructed a DNA database. To contribute to Open Science, this database is open to the public (<https://www.nies.go.jp/ogasawara/#/>). We developed a new model for the evolution of ecosystems on oceanic islands. By using the model, we simulated the invasion and eradication of alien species on Nakoudojima in the Ogasawara Islands. After the invasion, denuded land appeared on one-third of the simulated islands. This result agreed with the case on Nakoudojima Island, indicating that

the model was very capable of reproducing the situation on real oceanic islands. After the eradication of invasive species, only about 60% of the simulated islands were restored to their original state (fully covered by forest) in about 50 years. We then focused on those simulated islands that could not be restored to their original states. We analyzed the ratios of forest, grassland, and denuded land just before the eradication of invasive species. The ratios coincided with those on the real Nakoudojima. This result indicated that it may not be possible to restore the vegetation of Nakoudojima. In fact, the vegetation on the island has still not been restored, even though about 15 years have passed since the eradication of invasive species.

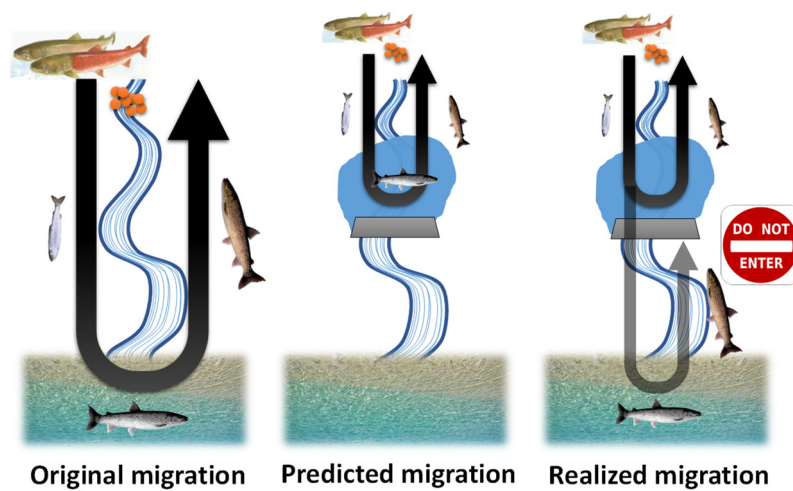
#### **5.3 Ecosystem functions, services, and connectivity in basin ecosystems between rivers and sea**

In northern Hokkaido, research focusing on the synergy between biodiversity conservation and the provision of ecosystem services was conducted in the upper basin of the Koetoi River. The Hokushin Dam, which was constructed to supply drinking water, has blocked migration of the critically endangered Sakhalin taimen (*Parahucho perryi*), the largest salmonid species in Japan, since the 1980s. Fortunately, the reservoir and its watershed have preserved habitats for an artificially landlocked population of the species, primarily because of the presence of well-preserved forests and streams and the large water body supporting the abundance of prey species. These habitats serve as one of the few remaining strongholds of Sakhalin taimen. However, we have brought this synergistic relationship into question, because our research has indicated that the above-dam population is not completely landlocked and that some individuals (presumably those characterized by a strong anadromous life-history trait) continuously emigrate from the reservoir to sea, without contributing to reproduction above the dam because they are unable to return to the reservoir (Fig. 8). The loss of genetic variability in the semi-landlocked taimen population may jeopardize its long-term persistence.



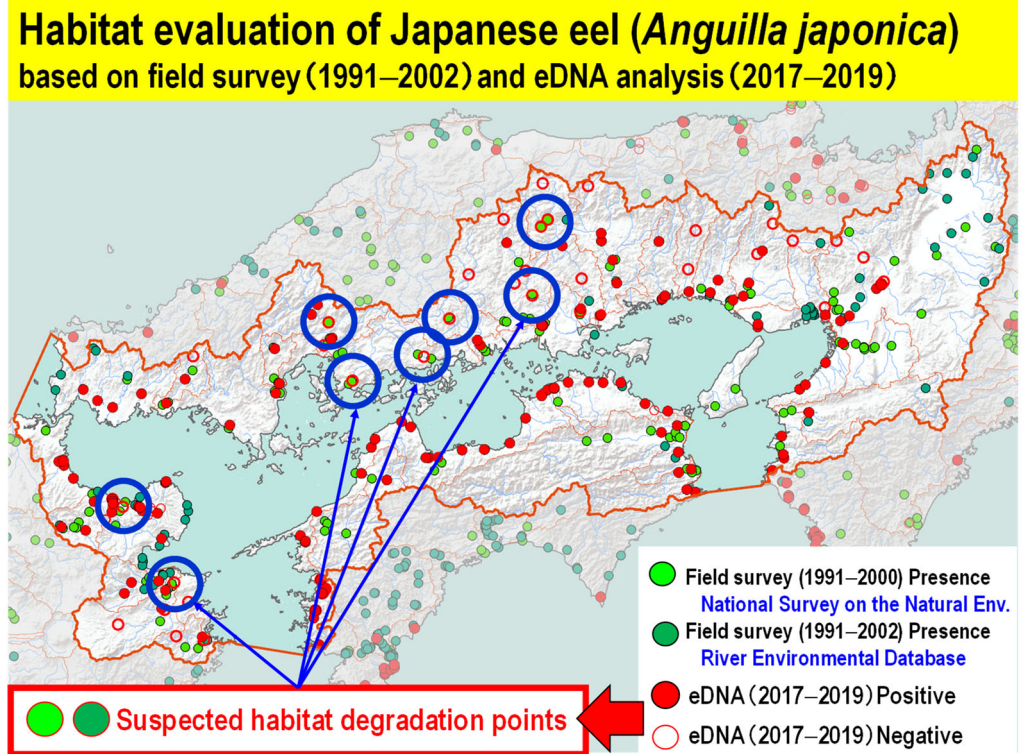
### 3. Harmonization with Nature Research Program

**Fig. 8** Migration patterns of Sakhalin taimen before and after construction of the Hokushin Dam



Research was also conducted to recover the linkages between forests, *satoyama* (the border zones between mountain foothills and arable flat land), rivers and sea by restoring the habitat of freshwater migratory fish. The main target is the Anguillidae, including the Japanese eel (*Anguilla japonica*). The endangered Japanese eel is a symbolic indicator species that links marine ecosystems to watershed ecosystems via rivers. Unfortunately, the abundance of the resources used by the Japanese eel has decreased dramatically in Japan since the 1970s. The main reasons for this drastic decrease in the watershed are habitat degradation in the riparian zone and migration obstruction by river structures. As a result of this research, we compiled a habitat evaluation map of Japanese eel in the Seto Inland Sea area (Fig. 9). The light green and dark green sites are the habitats of Japanese eel in the National Survey on the Natural Environment (1991–2000) and the River Environmental Database (1991–2002), respectively. Furthermore, in this map, the results of a 2017–2019 analysis (presence/absence) by using environmental DNA (eDNA) are overlaid on the abovementioned field survey results. The red dots are the points where the results of the environmental DNA analysis were positive (= present). In other words, it is highly possible that Japanese eels inhabited these points during the 2017–2019 survey period. In contrast, the empty red circles are points that were negative (= very likely to be absent) in the eDNA analysis. From these results, we evaluated the green (light green and dark green) points with red outlines as suspected habitat degradation sites. The causes of degradation of individual habitats are complex and the factors cannot be generalized at this time. However, it is likely that there are many factors, such as movement inhibition by river crossing structures, water pollution, depletion of food resources and disappearance of micro habitat (riparian zone, cover, etc.). In the future, we will need to monitor these habitat deterioration points continuously to clarify the factors involved and study habitat restoration measures.

**Fig. 9** Habitat evaluation map of Japanese eel (*Anguilla japonica*) in the Seto Inland Sea area. Light green and dark green points with red outlines are suspected habitat degradation points.

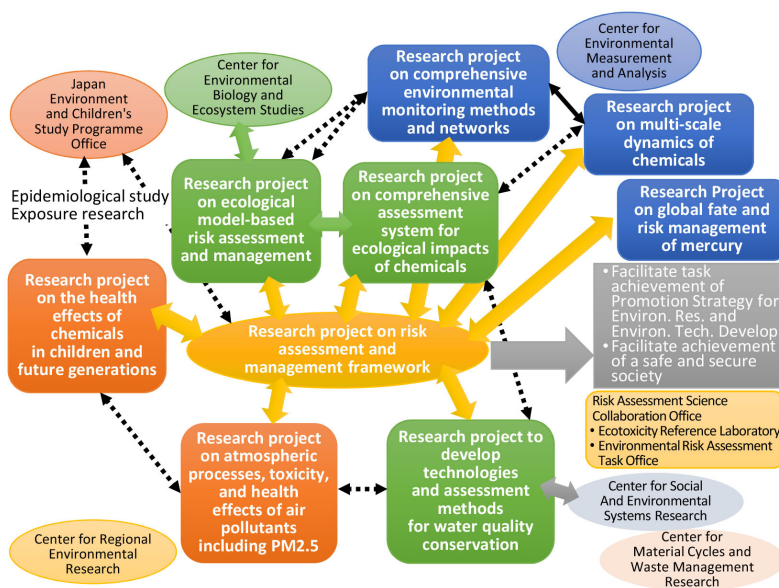


In the Ota River estuary on the coast of Hiroshima Bay, research was conducted on the effects of river structure installation for flood control on biodiversity and ecosystem services in downstream areas. Before the installation of a spillway, the Ota River estuary consisted of several rivers that flowed through the city. To reduce the damage caused by repeated flooding, a straight spillway was built along the edge of the city. At this time, several of the meandering city rivers were spared from riparian alterations such as straightening and reclamation. Therefore, a highly natural brackish water area with a tidal rhythm was maintained in this basin. The field survey found many species endemic to brackish water in these rivers. However, the spillway is usually separated by movable gates both from the upstream and from the brackish city rivers at the junction of the rivers, the downstream area exists as a lagoon—a tidal zone filled with seawater. Almost all of the coastline on the mainland side of Hiroshima Bay has been reclaimed, but on the tidal flat along the inside of the spillway there has been regeneration of a habitat that had been lost because of coastal development. Our field surveys have also detected an increase in the number of species and biomass of marine organisms. As a result, the estuary of the Ota River, including the city's branch rivers and the spillway area, maintains a rich biodiversity, with brackish water organisms and marine organisms. We therefore consider that construction of the flood control spillway was a wise decision from the perspective of compensatory mitigation.

### Health and Environmental Safety Research Program

To ensure the establishment of a Safe and Secure Society, as described in the Fourth Basic Environment Plan of the Ministry of the Environment, we need to address current environmental concerns about chemical contamination and ensure that major environmental pollution events, such as the outbreak of Minamata disease in Japan, do not happen again. This is the basis for the establishment of all other sustainable goals in the Low-carbon, Sound material-cycle, and Natural symbiosis fields. The aim of this research program is to provide scientific support to establish a safe and secure society through new findings on hazards, analytical technologies, fate processes and models, and abatement technologies, as well as advanced risk assessment methodologies and management frameworks for environmental chemicals. To achieve this aim, the program is using a multifaceted, systematic approach to gain new insights into health and environmental hazards and develop methods for assessing the health and environmental risks posed by environmental chemicals and abatement technologies for those risks. The program is examining the effects of chemicals on higher-order biological functions and multi- or transgenerational impacts. It is developing new systems for assessing the ecological impacts of chemical bioaccumulation, as well as advanced high-throughput chemical analyses, to give us a more comprehensive understanding of the dynamics of environmental chemicals. In addition, the program is examining the atmospheric processes and adverse health effects associated with exposure to PM<sub>2.5</sub> and other air pollutants. It is developing advanced methods for conserving regional aquatic environments and for the global fate and risk management of mercury. The projects are described below (Fig. 1).

**Fig. 1**  
The Health and Environmental Safety Research Program consists of nine research projects. The projects' outcomes are integrated to establish a general scientific basis for a safe and secure society.

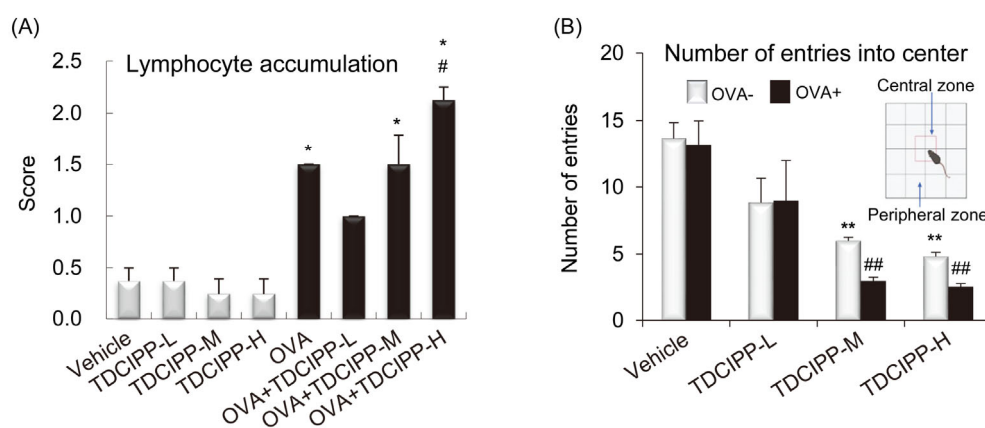


### 1. Research project on the health effects of chemicals in children and future generations (Project 1)

This project is examining the risks posed by chemicals to higher-order biological functions and the inter- and transgenerational impacts of chemicals by using animal models and cultured cells. Our main research outcomes this year were as follows.

We examined whether dietary exposure to tris(1,3-dichloro-2-propyl)phosphate (TDCIPP) aggravates allergic asthma in mice. Administration of TDCIPP-H (high dose,  $2 \mu\text{g kg}^{-1} \text{day}^{-1}$  (a dose comparable to the human tolerable daily intake) and ovalbumin (OVA) tended to worsen allergic pulmonary inflammation compared with that in mice given OVA alone (Fig. 2A) and promoted  $\text{CD4}^+$  cell activation in the mediastinal lymph nodes. In addition, we found that TDCIPP exposure significantly induced anxiety-like behaviors (Fig. 2B) through the alteration of neurogenesis and neuroinflammation.

**Fig. 2** Degrees of lymphocyte accumulation in the lungs (A) and results of an open field test for anxious behavior (B). Data are shown as means  $\pm$  SE;  $n = 3$  or 4 animals/group for (A),  $n = 6$  animals/group for (B); \* $P < 0.05$ , \*\* $P < 0.01$  vs. vehicle group; # $P < 0.05$ , ## $P < 0.01$  vs. OVA group. TDCIPP-L,  $0.02 \mu\text{g kg}^{-1} \text{day}^{-1}$ ; TDCIPP-M,  $0.2 \mu\text{g kg}^{-1} \text{day}^{-1}$ ; TDCIPP-H,  $2 \mu\text{g kg}^{-1} \text{day}^{-1}$ .



We evaluated developmental neurotoxicity by using animal models and observed changes caused in social communication by brominated dioxins and autism-like behavior resulting from exposure to secondary organic aerosol. We showed that ADHD-related chemicals had a higher Tanimoto coefficient than, and were in a different category from, conventional dopaminergic toxins. We also used a simultaneous microdialysis method to examine the chemicals that cross the blood-brain barrier. In addition, we developed avian embryo multi-specimen culture methods and evaluated the neurodevelopmental toxicity of various insecticides by using mouse embryonic stem cells.

We investigated the mechanism of the paternally transmitted effects of gestational arsenic exposure in children (F1 generation) on grandchildren (F2 generation) by using mice. We used a reduced representation bisulfite sequencing method focusing on retrotransposons to analyze the DNA methylation of F1 sperm. We found that hypomethylated DNA sites overrepresented in active retrotransposon subfamilies such as IAPE in long terminal repeats (LTRs) and L1MdA and L1MdT in long

interspersed elements (LINEs). Furthermore, hypomethylated DNA accumulated in the promoter regions of these retrotransposons. As reduced DNA methylation activates retrotransposons, the results suggested the possibility that arsenic exposure augments the activation of harmful retrotransposons in the F1 sperm or the resulting F2 embryos, or both.

### **2. Research project on comprehensive environmental monitoring methods and networks (Project 2)**

The purpose of this project is to develop advanced comprehensive analytical methods and networks to monitor environmental chemicals that affect human health and the environment. This year we conducted the following studies.

Bioassays are useful tools for collecting data as part of chemical risk assessments and environmental quality monitoring. In this study, we examined whether a battery of bioassays could be used to detect the toxicities of chemicals listed in the Japanese Air Pollution Control Act and Water Pollution Control Law. Our bioassay battery was able to detect the toxicity of almost all of the prepared chemicals, with the following detection rates: cytotoxicity, 70%; Nrf2 activity, 44%; p53 activity, 16%; pregnane X receptor (PXR) agonist activity, 15%; progesterone receptor (PR) antagonist activity, 15%; androgen receptor (AR) antagonist activity, 10%; aryl hydrocarbon receptor (AhR) agonist activity, 3.3%; and estrogen receptor alpha (ER $\alpha$ ) agonist activity, 1.6%. These results indicate that our bioassay battery can be used to detect the toxicity of not only the chemicals listed in the control act but also their analogs.

In developing a comprehensive target analysis method, we used liquid chromatography with tandem mass spectrometry (LC-MS/MS) to create a simultaneous analysis system for 70 substances (for which standard substances could be secured) from among those substances showing human estrogen receptor (hER) binding activity. We also developed a molecularly imprinted polymer (MIP) for purifying thyroid hormone receptor (TR)-binding active substances for comprehensive analysis. In addition, as a method of morphological analysis of organometallic compounds, we performed a parallel liquid chromatography–inductively coupled plasma tandem spectrometry (LC-ICP-MS/MS) and LC-electrospray ionization (ESI)-MS/MS analysis of lipophilic organic arsenic.

As an alternative method for selective and sensitive detection of organochlorine compounds, which are substances of concern, the gas chromatography coupled with atmospheric pressure chemical ionization quadrupole time-of-flight mass spectrometry (GC-APCI/TOFMS) method was investigated. Its results showed good agreement with ions detected in previous studies by the LC-ESI-MS and LC-APCI-MS methods, indicating the possibility of selective identification and semi-quantification of SCCP, MCCP, and PBDD/DF and halogenated flame retardants such as PBDE, HBCD, HFR, OPFR.



using these two models and evaluated the gap in the estimated recovery potential of the diversity index (i.e., the intervention effect) between them. We found that the model developed on the basis of AIC values yielded a biased estimate of the intervention effects of chemicals. The gap obtained by using the estimate based on the statistical causal inference was more pronounced in a chemical with a marginally negative effect (nickel) than in one with a substantial negative effect (total organic carbon). These results suggest that, especially when multiple chemicals are being managed simultaneously, the use of statistical analyses without causal inference makes it difficult to optimize the effort allocation of the management measures (i.e., concentration reduction) to each chemical to achieve maximum recovery of ecosystems.

We developed an aquatic ecosystem model to determine the effects of chemicals on the behavior of ecosystems. We showed that animal species diversity and biomass decreased monotonically as the chemical concentration increased. The species diversity of aquatic plants showed the same trend. However, the biomass of the plants showed complex behavior due to interspecific interactions. The relationship between total plant biomass and the chemical concentration changed with the trophic conditions in the model ecosystem. These results indicate that we should consider the effects of interspecific interactions among many species and the trophic conditions in ecosystems to estimate the effects of chemicals on ecosystems.

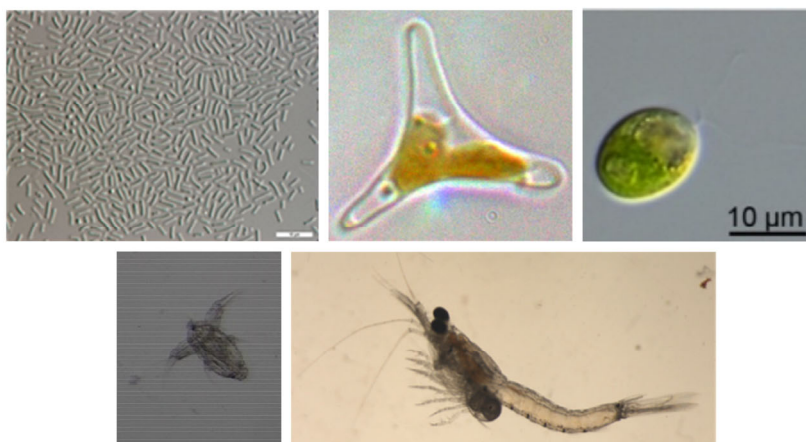
An understanding of the mechanisms by which species diversity is maintained in biological communities is essential for predicting changes in biodiversity under environmental disturbance. We developed a community model to explain the mechanisms of species diversity maintenance in a local community and then investigated the effect of habitat disturbance by using an extensive simulation. We improved the conventional community model, which assumes community size to be a constant (zero-sum assumption), to a more realistic model that allowed a change in community size (non-zero-sum assumption). We found that the number of new species between censuses decreased under habitat fragmentation, suggesting that habitat fragmentation would reduce local species diversity by limiting the recruitment of new species. These results give us insights into the factors we need to control for effective species conservation.

### **4. Research project on comprehensive assessment system for ecological impacts of chemicals (Project 4)**

We used various testing organisms, such as plants (including algae), invertebrates (including crustaceans), and fishes, to develop and validate testing methods. As a consequence of developing short-term chronic toxicity tests by using these marine and estuarine organisms, we developed an algal growth inhibition test by using a marine green alga (*Dunariella primolecta*: NIES-2256) and a marine diatom (*Phaeodactylum tricornutum*: NIES-4392) in addition to one that we developed by using a marine cyanobacterium (*Cyanobium* sp.: NIES-981). We also developed a

method using gametophytes of sea lettuce (*Ulva aragoënsis*). Moreover, we developed a short-term chronic toxicity test by using the domestic copepod species *Acartia sinjiensis* and *Tigriopus japonicus*, with metamorphosis as an endpoint, and we conducted interlaboratory validation testing of the test methods by using a mysid (*Americamysis bahia*), a marine amphipod (*Ptilohyale barbicornis*), and the embryos of Pacific oyster (*Crassostrea gigas*) with reference chemicals. Embryo and larval tests were developed for marine fish red seabream and Javanese medaka and validated by interlaboratory ring testing. Finally, draft protocols for short-term chronic toxicity tests were completed for algae, seaweeds, invertebrates, and fishes (Fig. 4).

**Fig. 4**  
Marine and estuarine organisms used to develop short-term chronic toxicity test methods. Top left: *Cyanobium* sp.; top center: *Phaeodactylum tricorutum*; top right: *Dunaliella primolecta*; bottom left: *Acartia sinjiensis*; bottom right: *Americamysis bahia*



We also conducted sediment toxicity tests in the freshwater amphipod *Hyaella azteca* for selected polycyclic aromatic hydrocarbons, the anti-fungal agent triclocarban, and the organophosphorus insecticide chlorpyrifos to consider the partitioning and equilibrium among three phases: freely dissolved, sorbed to particulates, and sorbed to dissolved organic matter. Toxicity values and the environmental concentrations measured in sediments were compiled from the literature for comparison with the experimental results. We also investigated parameters such as organic carbon content to better adjust for the risk assessment of hydrophobic organic chemicals in sediment considering the different exposure pathways. Moreover, we cooperated with a project aimed at developing an adverse outcome pathway by using juvenile hormone of daphnia, as well as with a related OECD integrated approach to testing and assessment (IATA) case study.

From January 2013 to June 2020, we conducted trawl surveys off coastal Fukushima, Japan, of the community structure of megabenthos (fishes, crustaceans, mollusks, and echinoderms) and analyzed its spatiotemporal changes in the wake of the March 2011 earthquake, tsunami, and nuclear disaster. The surveys covered three latitudinal transects along the coast—off Soma (north), off Fukushima Daiichi Nuclear Power Plant (central), and off Iwaki (south)—and three depths (10, 20, and 30 m) at each transect. The whole population density (i.e., total number of individuals of megabenthos/km<sup>2</sup>) decreased over time, although the total wet weight (kg/km<sup>2</sup>) of megabenthos fluctuated, without any clear trend, among years.



Although the stocks of large elasmobranchs and a few mid-sized fishes (i.e., puffers) seemed quite high, decreasing trends were observed in the populations of several kinds of flatfishes, crustaceans, and echinoderms. In a chain of studies to elucidate possible reproductive failure in crustaceans, we explored the spatiotemporal distributions of their larvae at three different depths (20, 50, and 80 m) along nine transects (i.e., 27 sites in total) off coastal Fukushima from July to September–October 2020, by using a plankton net (especially for collecting fish larvae) with a diameter of 1.3 m. Interestingly, no (or few) larvae of the penaeid shrimps *Trachysalambria curvirostris* and *Metapenaeopsis dalei* were collected at any sampling site during the survey period. Because relatively high population densities (i.e., total number of individuals/km<sup>2</sup>) of adult *T. curvirostris* and *M. dalei* were observed off coastal Fukushima in 2020, it is possible that certain environmental factors might have inhibited either sexual maturation; copulation and spawning of adults; or embryo development and hatching and the subsequent survival of larvae of both penaeid shrimp species.

To connect two approaches—laboratory experiments and field surveys—we investigated the mixture toxicity of field-collected water or sediment samples and assessed its impacts. In the mixture toxicity evaluation, we examined mixture effects such as the additive, synergistic, and antagonistic effects of multiple chemicals, including plastic additives (di-alkyl esters of phthalic acid) and cationic detergent groups with partly common chemical structures, by using short-term chronic toxicity tests in three freshwater aquatic organisms, namely zebrafish (*Danio rerio*), *Ceriodaphnia dubia*, and the green alga (*Raphidocelis subcapitata*). An additional 31 river water samples were collected, and screening toxicity tests were conducted with *C. dubia* and *R. capitata*. We found toxic effects in either of these two species from nearly one-third of the samples. Further detailed toxicity tests using the three organisms, including zebrafish embryos, were conducted on 12 selected samples. These were followed by inductively coupled plasma mass spectrometry (ICP-MS) analysis of metals, comprehensive measurement by using gas chromatography automated identification and quantification system (GC-AIQS), and measurement of pharmaceuticals with liquid chromatography with tandem mass spectrometry (LC-MS/MS). We also fractionated three strongly toxic samples to identify the unknown major toxicant of concern in a case study of effect-directed analysis.

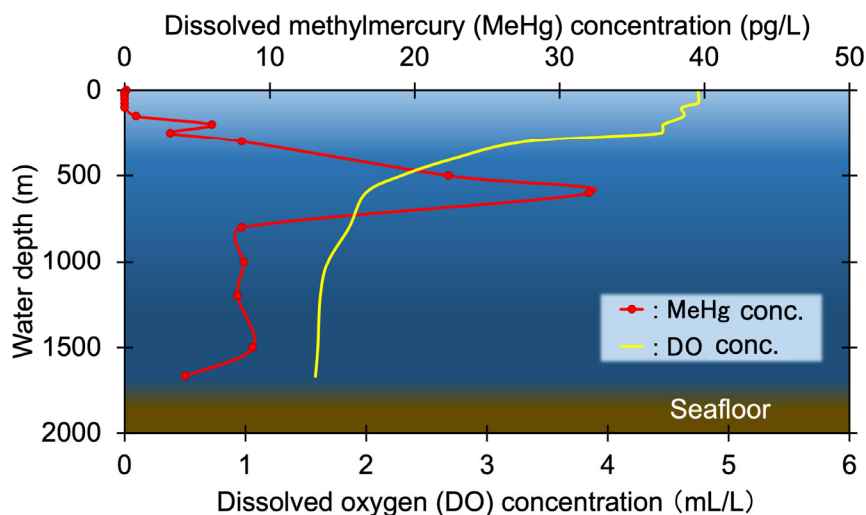
### **5. Research project on multi-scale dynamics of chemicals (Project 5)**

In this project, we examined the dynamics of chemicals at various spatiotemporal scales by using state-of-the-art analytical techniques and constructing mathematical models to better understand and predict the concentrations and dynamics of environmental chemicals.

We determined the vertical distribution of the concentrations of seawater-dissolved methylmercury (MeHg) in the East China Sea to evaluate the sources of this

compound. The MeHg distribution results indicated in-situ production of MeHg in the mesopelagic zone (Fig. 5). This pattern generally corresponds well with the documented distribution of seawater MeHg concentrations in the Pacific, where relatively large amounts of MeHg are present in the mesopelagic zone.

**Fig. 5**  
Vertical profiles of dissolved methylmercury and oxygen concentrations in the East China Sea



To perform a long-term simulation, including future prediction, by using our global models for mercury (FATE-Hg) and persistent organic pollutants (FATE-POPs), we obtained data for climate, reactants, and terrestrial and marine carbon cycles from public data from CMIP6. We revised the input files by using data from multiple Earth system models (MIROC-ES2L, MRI-ESM2-0, and UKESM1-0-LL) under multiple climate change scenarios (ssp1-2.6, ssp2-4.5, ssp3-7.0, and ssp5-8.5).

We predicted the concentrations of 10 substances in river waters throughout Japan by using a multimedia fate model, G-CIEMS, and emissions data obtained from the Pollutant Release and Transfer Register (PRTR) system. By comparing the ranges of the predicted concentrations with those of observations obtained by the Ministry of the Environment, we were able to suggest that the emissions data for ethylenediaminetetraacetic acid, terephthalic acid, and perfluorooctanesulfonic acid (PFOS) lacked one or more emission sources.

As part of a study of the indoor-scale dynamics of chemicals, we experimentally measured the transfer of two organophosphate additives from polyethylene terephthalate (PET) and polyvinyl chloride (PVC) sheets to house dust attached to the sheets' surfaces. We also measured the aerial emission of these compounds from the sheets. The emission flux and the rate of transfer to dust were similarly higher from the PET sheets than from the PVC ones. This suggested that airborne transport was a means of transfer to the dust.

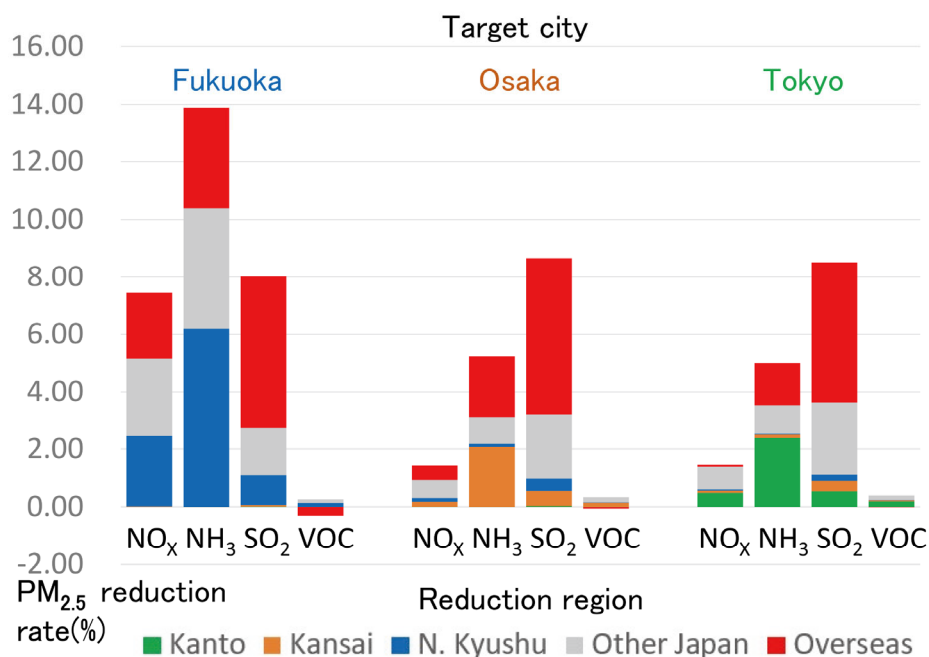
## 6. Research project on atmospheric processes, toxicity, and health effects of air pollutants including PM2.5 (Project 6)

## 4. Health and Environmental Safety Research Program

Rapid economic growth in East Asia has resulted in a marked increase in energy consumption, leading to increased emission of air pollutants. High concentrations of PM<sub>2.5</sub> have been reported in Japan, and their adverse health effects are now of major public concern. To control air pollution, to collect evidence of its adverse health effects, and to construct alert systems for air pollution, we are developing an integrated air-quality modeling system and are conducting in vitro toxicity studies and epidemiological studies. In the fifth year of this project, we obtained the following results.

Numerical analysis was conducted to estimate the effect of reducing emissions inside and outside the Kanto, Kansai, and northern Kyushu regions. The calculation area was divided into five regions: Kanto, Kansai, northern Kyushu, other Japanese regions, and overseas regions, and calculations were made to reduce either NO<sub>x</sub>, NH<sub>3</sub>, SO<sub>2</sub>, or volatile organic compound (VOC) emissions by 20% for each region. We investigated the reduction rates of PM<sub>2.5</sub> in cities in Kanto (Tokyo), Kansai (Osaka), and northern Kyushu (Fukuoka) by comparing the PM<sub>2.5</sub> concentrations from each reduction calculation result with the results of standard calculations given standard emissions data. We found that the magnitude of the effect of reducing emissions within a region varied greatly from substance to substance (Fig. 6).

**Fig. 6**  
Stacked bar graphs of PM<sub>2.5</sub> reduction rates in cities within and outside each region when emissions are reduced by 20% in each region



Our air pollution forecast system (VENUS; Visual atmospheric ENvironment Utility System) has been improved. The emissions data used in the system have been improved, and the calculation accuracy has been improved by a review of the calculation settings. In addition, the forecast period has been extended from 3 days to 4 days (i.e. it now ranges from the same day to 3 days later). Improvements have also been made to the display method, such as the display of a graph comparing observations and forecasts of average concentrations by prefecture. Through these

improvements, the accuracy of alert information transmission has been improved.

Particulate matter is measured at Fukue Island, Nagasaki, to investigate the influence of trans-boundary air pollution during winter and spring, because the seasonal monsoon prevails in these seasons and air pollutants are transported from the Asian continent. Concentrations of PM<sub>2.5</sub> and those of sulfate and nitrate were found to be lower in 2020 than in previous years. If we selected the ozone concentration only when the PM<sub>2.5</sub> concentration exceeded 35  $\mu\text{g m}^{-3}$ , the ozone concentration was also lower in 2020 than in previous years. These results suggest that transport of air pollutants decreased because of a reduction in emissions of air pollutants in China in spring 2020.

To evaluate cellular responses to atmospheric particulate matter *in vitro*, we developed an air–liquid interface (ALI) exposure system using Chinese hamster ovary cells transfected with a vector containing a firefly luciferase reporter gene and an antioxidant response element. The cells were directly exposed to diesel exhaust or diesel exhaust particles by using a gas exchange device for removing gas pollutants from diesel exhaust. The particles deposited on the cells were quantified by using the particle size distribution measured with a scanning mobility particle sizer. Diesel exhaust particles exposed in the ALI induced oxidative stress, despite low deposition amounts. This assay system is physiologically relevant and sensitive for examining the oxidative potential of particulate matter.

### **7. Research project to develop technologies and assessment methods for water quality conservation (Project 7)**

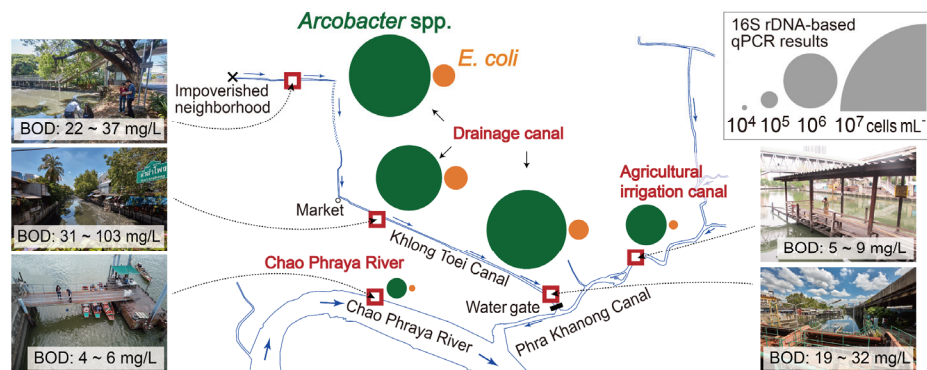
Installation of domestic wastewater treatment systems is often delayed in developing countries because of economic constraints. Therefore, hygiene risks caused by water pollution are a growing concern. The purpose of this project is to evaluate water quality, including fecal indicators caused by domestic drainage pollution, and to develop technologies for reducing pathogen loads in wastewater.

In Bangkok, surface water pollution caused by insufficient treatment of domestic wastewater is a serious issue. Quantitative sanitary survey data are required for assessing the hygiene risks of surface waters. We investigated the relationship between biochemical oxygen demand (BOD) and *Arcobacter* spp. (potential pathogens) and *Escherichia coli* (a fecal indicator). Sampling points in an agricultural irrigation canal (moderately clean), three drainage canals (poor to very polluted), and the Chao Phraya River (moderately clean) were investigated in cooperation with the Bangkok Metropolitan Administration. The water samples were collected over a 13-month period from 2017 to 2018. The concentrations of *E. coli* and *Arcobacter* spp. were determined by 16S rDNA-targeted real-time quantitative PCR.

## 4. Health and Environmental Safety Research Program

**Fig. 7**

Overview of the survey of *Arcobacter* spp. and *Escherichia coli* in the surface waters of drainage canals, an agricultural irrigation canal, and the Chao Phraya River. The sizes of the circles indicate bacterial concentrations as determined by 16S rDNA targeted real-time qPCR.



*Escherichia coli* was detected frequently all year round in the drainage canals (higher BOD) and at one order of magnitude higher than in the irrigation canal and the river samples (lower BOD), suggesting that untreated domestic wastewater was the source of the *E. coli* (Fig. 7). In contrast, *Arcobacter* spp. were detected at high concentrations even in water samples with relatively low BOD. Therefore, *Arcobacter* spp. may be more likely than *E. coli* to survive in the water environment. Phylogenetic analysis revealed that most of the *Arcobacter* spp. were *A. butzleri* and *A. cryaerophilus*, which are known to be pathogenic. The source of *Arcobacter* spp. is likely to be human-derived domestic wastewater.

We also evaluated the removal of these pathogens from domestic wastewater by using a pilot-scale aerobic trickling-filter (ATF) system placed in a housing complex of the Bongai community in Bangkok. This ATF system has been successfully demonstrated as a decentralized domestic wastewater treatment system because of its good removal efficiency of both organic matter and ammonium nitrogen under fluctuating flow conditions. Also, the ATF system achieved a higher removal rate (> 2 Log) for both *E. coli* and *Arcobacter* spp. The establishment of appropriate wastewater treatment facilities to improve water quality is desirable to minimize hygiene risks in the water environment.

### 8. Research project on risk assessment and management framework (Project 8)

A sound management framework to manage the risks posed by environmental chemicals to human health and the environment can be established by integrating the social context, public concerns, and accumulated social and natural scientific knowledge. The aim of this inter-disciplinary project is to develop a robust framework for managing environmental chemicals that reflects both the social context and the latest outcomes of Projects 1 to 7 and 9. To achieve this aim, this project is developing risk assessment and management strategies that are acceptable to the public and incorporate the latest scientific information on the impacts of environmental chemicals on human health and the environment. Furthermore, the project is developing an ecological management framework based on the comprehensive characterization of ecotoxicity by using a newly developed system

of testing protocols. It is also developing a system for the environmental management of coastal, oceanic, atmospheric, and aquatic pollution that will incorporate new technologies as they become available, and a management approach that incorporates comprehensive monitoring methodologies to assess new chemicals as they arise from technological development. Our aim is for Project 8 to summarize the scientific outcomes of all the other projects into the context of sound chemical management in our society.

This year we continued to study a new direction for incorporating the precautionary approach into chemical risk management on the basis of both the scientific nature of chemicals and their social context. We reevaluated several pollution incidents, including the one that caused Minamata disease, to explore how preliminary observations that may not be scientifically sufficient can still be used to trigger precautionary or other management actions. We tried to categorize the time series of scientific evidence of the above pollution incidents into three classes based on level of uncertainty, social conflict, and several other standpoints. These classes were discussed in terms of the precautionary approaches that could be applied to each. We also performed a study of the applicability domain of quantitative structure–activity relationships of chemical ecotoxicity on the basis of Project 3 and 4; the cumulative impact of multiple chemicals in the environment on the basis of Project 2, 4 and 5; and a possible direction for assessing the potential impact of the immunological effects of bisphenol A on the basis of Project 1 of the program. Part of the research above was done under close collaboration with the activities of the Risk Assessment Science Collaboration Office.

### **9. Research project on the global fate and risk management of mercury (Project 9)**

Establishment of a sound scientific basis to support the global management of mercury is essential for supporting the implementation of the Minamata Convention on Mercury. Project 9 aims to provide scientific information on the global fate of mercury in the environment, the material flows of mercury in the technosphere, and the combined health impacts of mercury and persistent organic pollutants.

It is important to determine a trophic magnification factor for fish methylmercury (MeHg) concentrations. We found that the ratios of tuna fish muscle MeHg concentrations to MeHg stomach contents ranged from 1.4 to 59. The ratios increased linearly with increasing fish body length ( $r^2 = 0.7$ ). This suggests that the ratios can be used to estimate MeHg concentrations in higher trophic fish by considering body length.

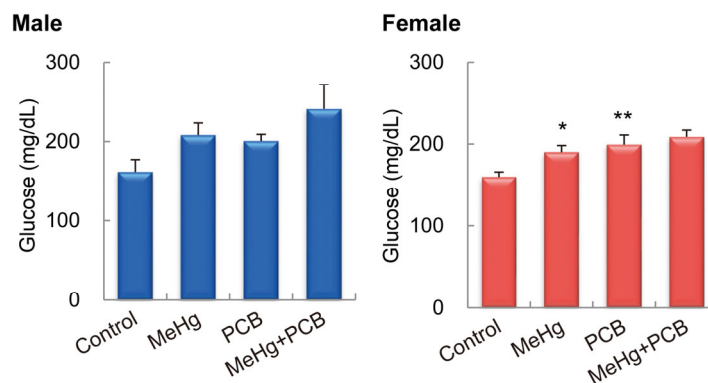
We performed past and future simulations (1750–2100) using our global model for mercury (FATE-Hg) under four different climate change scenarios (ssp1-2.6, ssp2-4.5, ssp3-7.0, and ssp5-8.5). We investigated the impacts of climate change on the global contents of total mercury ( $\text{Hg}^T$ ), without taking into account future

## 4. Health and Environmental Safety Research Program

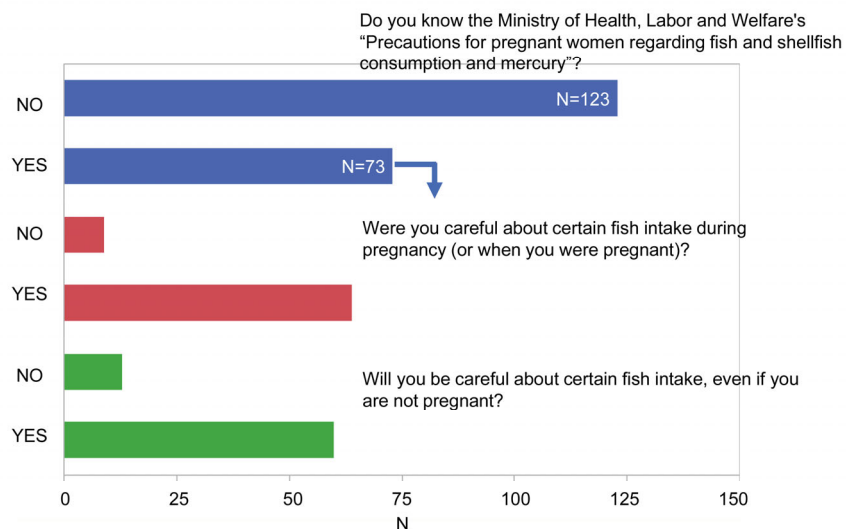
anthropogenic emission changes. The results showed that differences in  $Hg^T$  contents in the lower troposphere and the upper ocean between climate change scenarios became evident after about 2050, with higher contents in ssp5-8.5 (Fossil-Fueled Development) and lower contents in ssp1-2.6 (Sustainability).

We evaluated the effects of prenatal exposure to MeHg and polychlorinated biphenyls (PCBs) on the metabolic systems of offspring mice. We found that serum glucose levels were higher in the MeHg, PCB, and MeHg + PCB groups than in the control group in 4-week-old mice (Fig. 8). This difference was significant in the female but not the male offspring. Serum alkaline phosphatase levels significantly increased in the PCB group compared with the control group in both males and females. To reduce the exposure of pregnant women to mercury, we conducted a mercury awareness survey. Forty percent of women who had ever been pregnant were aware of the Ministry of Health, Labor and Welfare's "Precautions for Pregnant Women Regarding Fish and Shellfish Consumption and Mercury." Those women who were aware of the precautions were careful about eating fish during pregnancy (Fig. 9).

**Fig. 8**  
Effects of prenatal co-exposure to MeHg and PCBs on serum glucose levels in offspring mice. Data are expressed as means  $\pm$  SE for four to six animals per group. \* $P < 0.05$  vs. vehicle group; \*\* $P < 0.01$  vs. vehicle group.



**Fig. 9**  
Results of our mercury awareness survey: Answers from women who had ever been pregnant (N = 196)



We have improved the accuracy of our estimates of estimate mercury flows in global trade by eliminating outliers in the original trade data. We have also examined the domestic final demand sector, which indirectly requires products imported into Japan that may contain mercury. We added measurement data of mercury concentrations in effluent at several actual sewage treatment plants by using a highly sensitive analysis. On the basis of these data, we conducted a numerical analysis to refine the evaluation results of overestimation of the PRTR-reported amounts of mercury released into public waters.

To determine the effects of water quality change on microbial community composition, we examined the composition of the microbial community in sediment samples collected in August and November from Tokyo Bay. Microbial composition was determined by a metagenomic analysis based on *hgcA* genes (in mercury methylator bacteria). Across all sampling areas and both seasons, the most abundant phyla were Proteobacteria (50% to 70%), followed by Spirochaetes or Euryarchaeota (7% to 25%). Bacterial composition varied according to the sampling area and season, indicating that changes in the aquatic environment according to region or season affect the sediment microbial community that possesses mercury methylation genes.

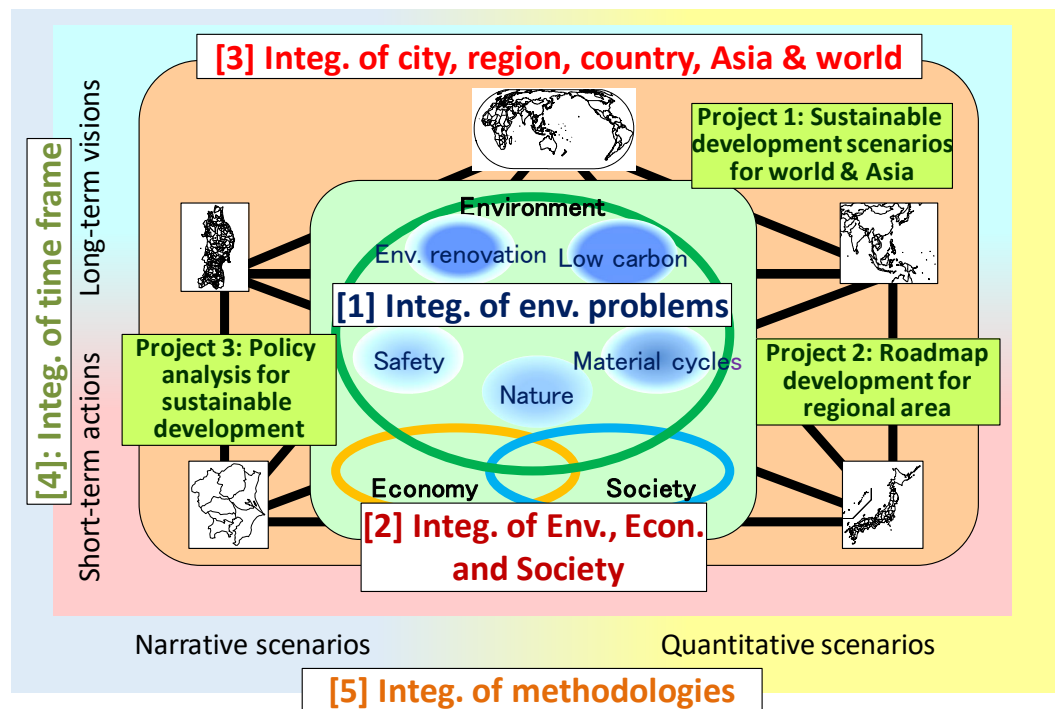
To discuss the further development of a method of passive sampling of atmospheric mercury, we reviewed earlier studies of the passive sampling of organic contaminants. Studies have pointed out that use of a strong sampling sorbent and sensitive analytical instrument is key to accurate measurement by atmospheric passive sampling methods. Past studies have also mentioned that there is a tradeoff between precise control of the sampling rate and the overall sensitivity of passive sampling measurement. These features appear to be common with passive sampling of atmospheric mercury.



**Environment-Economy-Society Integration Research Program**

Starting with integration of the mitigation of, and adaptation to, climate change, this program develops multilayered models that quantitatively analyze solutions to environmental problems. These problems include those related to socioeconomic activities and the need for sustainable material cycles, harmonization with nature, and health and environmental safety, on a variety of scales from urban and regional to national and global. From the perspectives of environmental, economic, and societal sustainability, the program conducts quantitative and qualitative analyses pertaining to the future visions of stakeholders at each scale. It also designs and evaluates the international and local or urban policies needed to realize these intended future visions. The program will establish a system to support the implementation and realization of proposed policies, countermeasures, and innovative green technologies. Figure 1 illustrates the framework of the program and five aspects of the research integration. The program consists of three projects: Project 1 provides sustainable development scenarios for the world and Asian countries; Project 2 develops a local environmental sociologic integration roadmap focusing on climate change mitigation and adaptation; and Project 3 evaluates policies for an environmentally sustainable society.

**Fig. 1** Framework of the Environment-Economy-Society Integration Research Program. Shown are the three projects and the five numbered aspects of the Program.



**1. Sustainable development scenarios for the world and Asian countries**

This project is developing integrated assessment models (IAMs) for analyzing sustainable development scenarios that pursue the simultaneous attainment of

global or regional societal goals, such as a low carbon society, resource recycling, natural symbiosis, and safety from various risks. The project consists of two sub-themes. Sub-theme 1 provides global sustainable development scenarios, and sub-theme 2 provides national sustainable development scenarios for Asian countries. Sub-theme 1 is also developing methodologies for downscaling global socioeconomic scenarios and will provide spatial socioeconomic scenarios with resolutions appropriate for supporting the regional or national-scale analyses conducted in the research program.

Actions tackling climate change can have co-benefits and trade-offs with Sustainable Development Goals (SDGs) concerned with air pollution, water scarcity, food security, land use, and sustainable energy. In sub-theme 1, to conclude the 5-year research program, we conducted integrated analyses of the impacts of climate mitigation policies on multiple indicators of SDGs. As SDG-related indicators, population at risk of hunger (SDG2), agricultural prices (SDG2), air pollution mortality (SDG3), population under water scarcity (SDG6), share of renewable energy (SDG7), energy intensity (SDG7), unemployment rate (SDG8), GDP per capita (SDG8), secondary industry share (SDG9), food waste (SDG12), forest area (SDG15), and mean species richness (SDG15) were considered. We developed “marginal SDG-emissions-reduction values” (MSVs), which represent the marginal impacts of a unit of CO<sub>2</sub> emissions reduction on SDG indicators. This metric is applicable to national assessments and was applied to Asia. We found clear relationships between CO<sub>2</sub> emissions reduction rates and many SDG targets. For instance, a 1% reduction in CO<sub>2</sub> can prevent 0.57% of air-pollution-related premature deaths (SDG3), whereas mean species richness (SDG15) is decreased by 0.026% with the same reduction (not including climate change impacts). Our findings are useful for assessing the SDG implications associated with CO<sub>2</sub> emissions reduction targets and will thus help to inform national climate policies.

We also analyzed how future socioeconomic conditions would affect the relationship between climate mitigation policies and the SDGs indicators. From the model analyses, we concluded that the advantages of a joint effort to implement climate policies and promulgate socioeconomic changes should be recognized by policy makers.

The government of Japan officially announced a new long-term greenhouse gas (GHG) emission reduction target in October 2020; net zero GHG emissions are to be achieved in Japan by 2050. In sub-theme 2, by using a simple account model that takes into account the dissemination of new technologies up to 2050, the possibility of achieving net zero GHG emissions in Japan was assessed. Three scenarios were prepared: (1) social change including low energy demand, (2) maximization of electrification, and (3) introduction of huge volumes of new synfuel and hydrogen. Under each scenario, GHG emissions in 2050 would be 20% of those in 2018; to achieve net zero GHG emissions in Japan these three

scenarios would have to be combined. As shown in Figure 2, under this “Zero scenario,” GHG emissions in 2050 would be about 10% of those in 2018, and these remaining emissions would be compensated for by the use of negative emission technologies, including carbon capture and storage and afforestation. These results shows that not only technologies such as renewable energy production and energy-saving technologies, but also socioeconomic conditions in the years approaching 2050, would become important in achieving net zero GHG emissions in Japan. In addition, sub-theme 2 has been supporting the assessment of long-term strategies to reduce GHG emissions in Asian countries such as Vietnam, Indonesia, and Thailand. ASEAN countries have not expressed their eagerness to achieve net zero GHG emissions before, but these countries are trying to pass the peak of GHG emissions by 2050.

**Fig. 2** GHG emissions by sector in Japan, 2018 to 2050.

Notes:

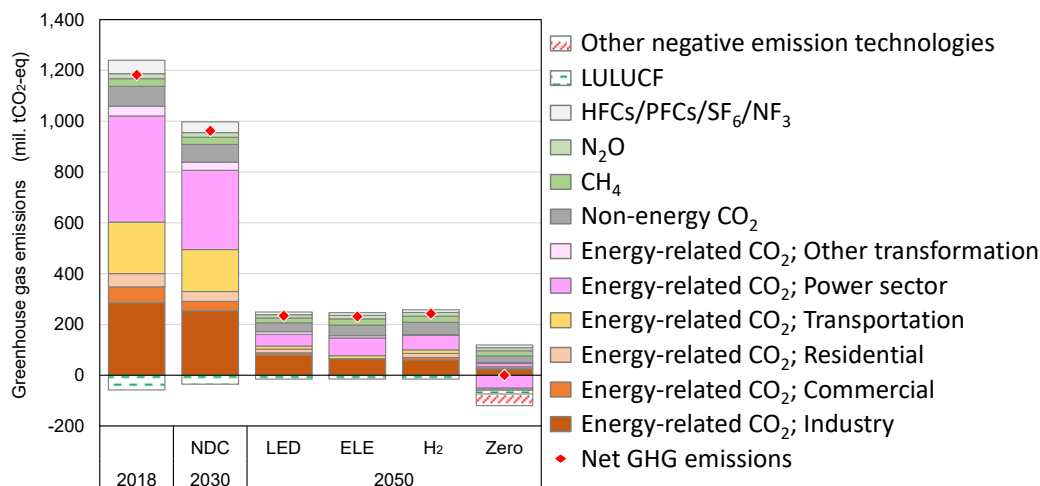
LED: Scenario of social change toward a carbon-neutral society

ELE: Scenario introducing electrification using renewable energy

H<sub>2</sub>: Scenario introducing synfuel and H<sub>2</sub>

Zero: Combining the above scenarios to achieve net zero GHG emissions in Japan.

LULUCF, land use, land-use change, and forestry; HFCs, hydrofluorocarbons; PFCs, perfluorocarbons; SF<sub>6</sub>, sulfur hexafluoride; NF<sub>3</sub>, nitrogen trifluoride



## 2. Research into a regional environmental sociologic integration roadmap focusing on climate change mitigation and adaptation

Sub-theme 1 is “Development of an Environmental Impact Assessment Model for Regions and Cities.” As a leading research institute for “Research into the Development of Technologies for the Assessment of Climate Change Impacts,” which is theme 3 of the Ministry of Education, Culture, Sports, Science, and Technology’s SI-CAT (Social Implementation Program on Climate Change Adaptation Technology), we continued to develop technologies to support local governments with the scientific knowledge they need for climate change impact assessment and examination of adaptation measures. Also, to develop an integrated assessment platform, we made a projection model of land-use change by using a cellular automaton. Last year, the land-use model was developed into a time-evolution cellular automaton model and applied to medium- and long-term forecasts (to 2030). A theory to optimize the amount of data for machine learning was developed by using adjustment coefficients. This year, we optimized the coefficients and validated the results. We confirmed that the land-use model had improved thanks to the adjustment coefficients. Moreover, we considered the

relationship between land use and inundation hazardous areas along the Tone River in Gumma and Saitama Prefectures in terms of climate change adaptation. Many building sites in this area are in inundation hazardous areas, and relocation of land-use patterns is required to alleviate the damage caused by floods. The challenge is how to give priority to relocations for immediate adaptation.

Sub-theme 2, “Development of an Integrated Evaluation Model of Economy, Society, and Technology for Countries, Regions, and Cities,” is aimed at an integrated roadmap analysis focusing on mitigation. For this purpose, we developed a series of analytical models, including a regional energy system model that designs an optimal energy system on the basis of a region’s energy demand and its supply of renewables, and a low-carbon policy evaluation model to design scenarios and roadmaps. We also developed a simplified analytical tool that employs both Excel macros and Web systems.

We improved the analytical model to design an energy system based on hourly demand and supply, and we developed a series of methodologies to determine the hourly energy demands of the industrial, commercial, and residential sectors and the hourly profiles of solar photovoltaic and wind power for 1741 municipalities in Japan. The model was applied to a few groups of municipalities located in the Tohoku and Kyushu areas, and the design of energy systems with maximum use of regional renewables was analyzed. In the analysis, two cases were established: with and without energy coalition (energy network) among municipalities. The results of the analysis for the group of municipalities in the Kyushu area, including one city, two towns, and one village, showed that, without energy coalition, the CO<sub>2</sub> emissions of the group can be reduced by 37% from the business-as-usual scenario by the use of local renewable energies (solar, onshore wind, mini-hydro, and geothermal). In contrast, energy coalition among municipalities in the group would extend the level of CO<sub>2</sub> reduction to 49%. The results showed that it is essential to build and utilize an energy coalition that allows local communities to cooperate and integrate local resources such as renewable energy in order to achieve a carbon-neutral society.

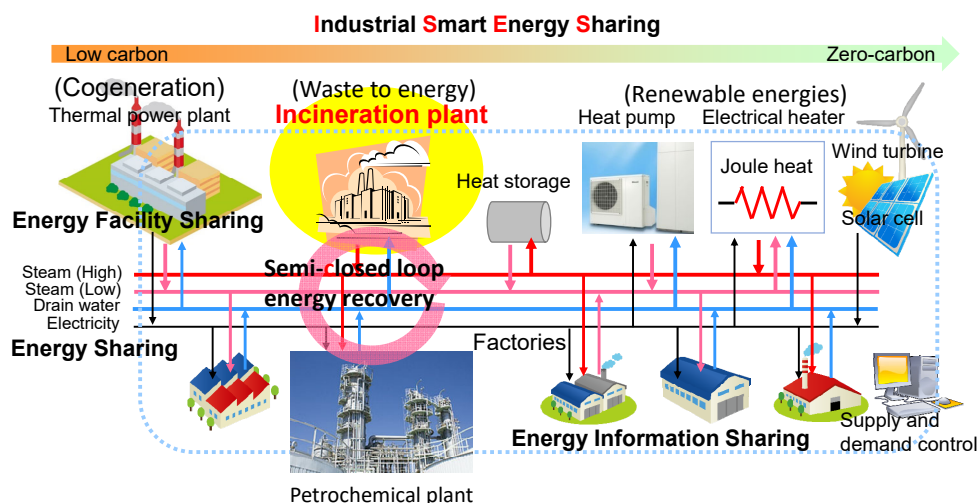
Sub-theme 3 is “Research into Social Implementation Support Measures and Social Monitoring for Sustainable Society Measures.” In Bogor City in Indonesia, the spatiotemporal distribution of electricity consumption on the scale of the entire city was estimated by combining the results of an analysis of electricity monitoring using artificial intelligence with the data from a questionnaire survey. In addition, workshops were held with stakeholders in Bogor City, including city government officials, to practice co-design of the city’s future environmental countermeasures.

In a study of the efficient low carbonization and future decarbonization of industrial thermal energy (steam) supplies (Fig. 3), we designed a technical system and evaluated its effect. In addition, we performed a feasibility study and

held discussions in collaboration with research institutes, governments, and companies in the cities of Kitakyushu and Kawasaki with the aim of social implementation of the system. In particular, our research finding that CO<sub>2</sub> emissions can be reduced economically and efficiently by using the heat from waste incineration by industries was employed by several expert meetings of the Ministry of the Environment and was positioned as an important decarbonization measure in the waste sector.

To implement this system in our society, we strengthened our stakeholder-related activities. For example, an Industrial Smart Energy Sharing Study Group was set up at the Kitakyushu Foundation for the Advancement of Industry, Science, and Technology in January 2019, and discussions have started with local municipalities and companies to implement low-carbon projects in industrial parks.

**Fig. 3** A system for the decarbonization of heat supply in industries



On the basis of the above three sub-themes, and by focusing on spatial information such as land-use and regional characteristics, the project brought results which could help in the planning and social implementation of adaptation and mitigation measures on various spatial scales, from the national level to the details of blocks in collaboration with local communities.

### 3. Evaluation of policies for an environmentally sustainable society

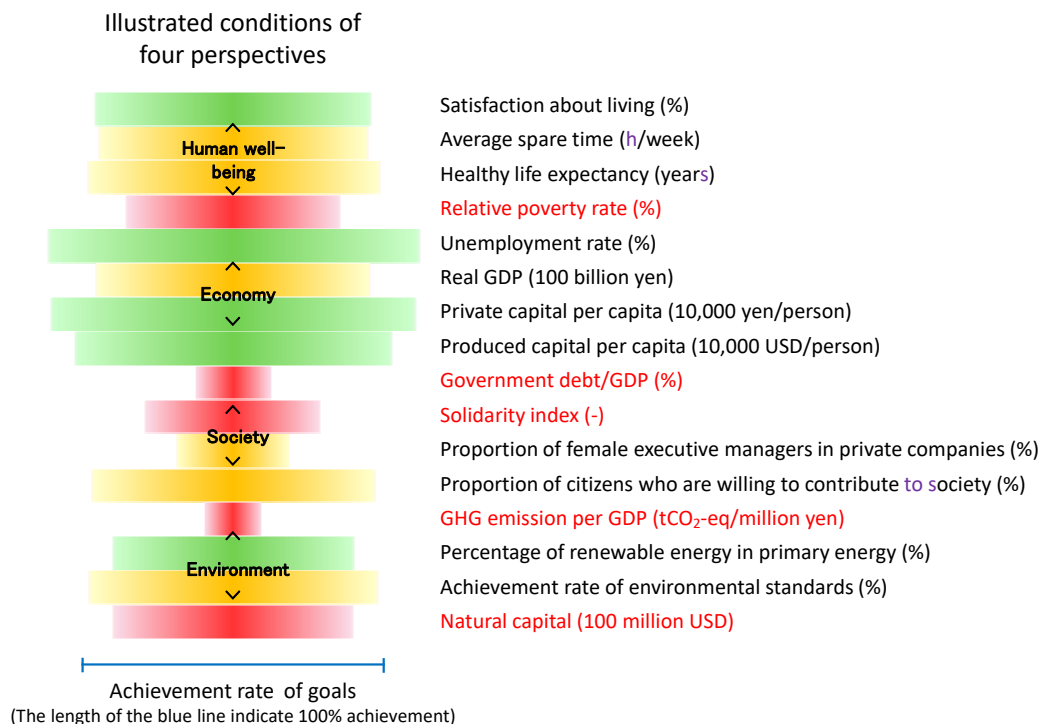
Project 3 aims to elucidate effective policy and planning for an environmentally sustainable society. In sub-theme 1, sustainable visions for various regions and lifestyles are designed and assessed, and the planning approaches and tools to accomplish these visions are developed. In sub-theme 2, national and regional laws and policies are evaluated and submitted from the perspective of their effectiveness and validity. Below are the main results for FY 2020.

In sub-theme 1, to design sustainable regions and lifestyles, we estimated the carbon emissions from the household and transportation sectors and showed them as tertiary mesh data. By using national survey data on household energy consumption, we constructed a new household emissions model that was based on average age of head of the household, carbon emission factor of electricity, average annual temperature, household size, total floor area of house, sunlight hours, densely populated area, elevation, and average annual rainfall.

A survey and discussion of the relationship between values related to everyday choices and attitudes toward sustainability measures were conducted, using transportation as an example. To broaden support for policies that favor economically, socially, and environmentally sustainable transportation over other modes, we showed that it is important not only to communicate the importance of a long-term perspective and detailed information about policies, but also to communicate the prospects for improving individual lifestyles through the choice of systems.

In sub-theme 2, to measure the sustainability of Japan and examine nexuses (interrelationships) between headline indicators, we developed SusBB (Sustainability Building Block) headline indicators based on time-series data collected over the past 4 years of the research period (Fig. 4). A total of 16 headline indicators were selected from the four perspectives of “human well-being,” “economy,” “environment,” and “society” to measure Japan's current situation from the perspective of sustainability and to understand whether the country is moving in a better direction. In the figure, the width indicates the degree of goal achievement; the wider the width, the closer to the goal. In addition, the green, yellow, and red color categories indicate the trend of improvement or degradation upon measurement of the amount of change for the last 5 years. The figure shows that the current situation in Japan is relatively favorable in terms of the economy but is getting worse in terms of society and some aspects of the environment. Human well-being is not in a good condition as it includes yellow and red indicators. Balances between the four aspects should thus be reconsidered in Japan.

**Fig. 4** Sustainability Building Block headline indicators that we developed



# Environmental Emergency Research Programs

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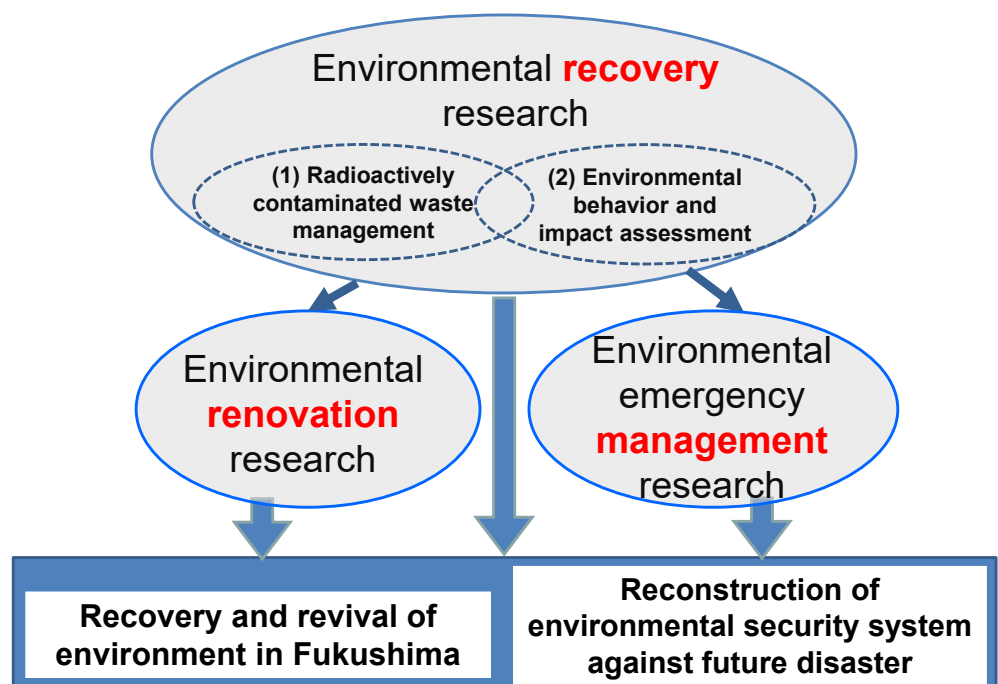
### Environmental Emergency Research Programs

Immediately after the Great East Japan Earthquake and the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident, NIES undertook disaster-related environmental research. This research has helped in the environmental restoration and recovery of the devastated areas. By using the accumulated outcomes of this research, and with the NIES Fukushima Branch (which was established at the Fukushima Prefectural Centre for Environmental Creation in April 2016) as a research hub, this program conducts Environmental Recovery research, Environmental Renovation research, and Environmental Emergency Management research in collaboration with the government of Fukushima Prefecture, the Japan Atomic Energy Agency, other related institutions in Japan and abroad, stakeholders, and other entities. In addition to contributing to environmental recovery in the devastated areas, Environmental Emergency Research Programs delineates paths leading to environmental restoration and creation and is helping to create a disaster-resilient society on the basis of the lessons of the Great East Japan Earthquake and other major disasters. Below, we outline the major projects conducted under the three sub-programs.

#### 1. Environmental Recovery Research Program

This program is conducting research and development for volume reduction and other technologies for the purposes of intermediate storage and final disposal of radioactively contaminated off-site waste; these are urgent tasks of the highest priority for the nation. The program will also perform research and development for technological solutions to problems related to the treatment and disposal of designated wastes and other contaminated wastes. Additionally, it will conduct

**Fig. 1** Outline of the Environmental Emergency research programs



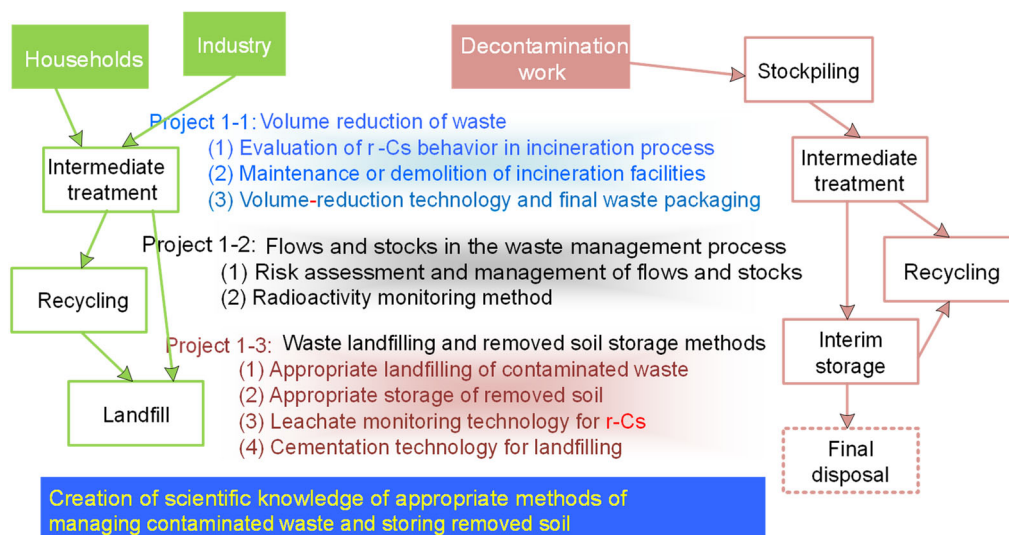
studies from a long-term perspective on the environmental fate of radioactive substances remaining in forests, water bodies, and other environments. Furthermore, it will apply long-term environmental risk-management methods to secure a livelihood platform where people can live safely and free of concern, and it will implement an ecosystem assessment that will include ecosystem services.

### 1.1 Development of management systems for radioactively contaminated off-site wastes

The FDNPP accident resulted in serious radiocesium contamination of solid wastes and soil in the surrounding area. We are performing various types of emergency response research into the appropriate management of waste contaminated by radioactive substances. We are also collaborating with central and local governments in the practical implementation of our research. Our research results are being reflected in various measures, including technical guidelines published by the Ministry of the Environment (MOE), discussions by an MOE panel, and implementation of the Act on Special Measures Concerning the Handling of Pollution by Radioactive Materials.

Our recent areas of interest are: 1) volume-reduction technologies for radioactively contaminated off-site wastes; 2) management and optimization of stocks and flows through recycling and disposal of radioactively contaminated off-site wastes; and 3) optimization and long-term management of processes in the final disposal (landfill) of radioactively contaminated off-site wastes and interim storage of removed soil (Fig. 2). Below are representative results of these studies in FY 2020.

**Fig. 2** Outline of the research project on the development of management systems for radioactively contaminated off-site waste. r-Cs, radioactive cesium



#### 1.1.1 Development of thermal treatments for contaminated incineration ash and woody biomass

To reduce the volumes of radioactively contaminated ash discharged during the incineration of decontamination waste, an ash-melting process has been started at the Ministry of the Environment’s Interim Storage Facility in Fukushima

Prefecture. From incineration ash, it produces recyclable clean slag and highly contaminated fly ash for disposal. To establish the optimum conditions for removing radiocesium from the slag during the ash-melting process, we investigated the effects of some key parameters, such as Cl content and basicity of feedstock (incineration ash and some additives), on the quality of both products by using a laboratory-scale ash-melting furnace. We revealed the relationships between the radiocesium removal ratio and these parameters, as well as some critical conditions for the formation of two heterogeneous liquid phases, which can decrease the ratio.

For successful co-combustion of wood chips and bark contaminated with radiocesium in a conventional woody biomass power generation plant, melting of their ash components has to be avoided during the co-combustion. We measured the melting properties of ash after burning wood chips and bark of four kinds of wood. From the results, we suggested some co-combustion conditions for preventing ash-melting.

### **1.1.2 Experimental study on the environmental safety of modified removed soil for potential future reuse**

We conducted two lysimeter tests of the same size (width: 2.0 × length: 2.0 × height: 1.5 m) on modified and unmodified removed soils to investigate the impact of a modification agent containing water-absorbing polymer powder on leachate quality. These tests lasted for more than 800 days. Soil modification (addition of 3% modification agent) reduced the accumulated leaching ratio of  $^{137}\text{Cs}$  from 0.21% to 0.08% and halved the peak  $^{137}\text{Cs}$  concentration in the leachate from 6.6 Bq/L to 3.3 Bq/L. We conducted batch-type adsorption tests by adding pure agent powder to filtered leachate (<0.45  $\mu\text{m}$ ) and confirmed that there was a decrease in  $^{137}\text{Cs}$  concentration. The environmental safety of two test embankments reusing removed soil as a geomaterial was continuously monitored with the cooperation of the Japan Environmental Storage & Safety Corporation. Removed soils after particle size improvement or modification by the application of an alkali modification agent were used in the test embankments; no leaching of r-Cs has been detected so far.

## **1.2 Analysis and prediction of behavior of radioactive substances in multimedia environments**

### **1.2.1 Medium- to long-term changes in particulate and dissolved $^{137}\text{Cs}$ concentrations in river water and the impact of Typhoon Hagibis in 2019**

In Fukushima Prefecture, radiocesium ( $^{137}\text{Cs}$ ) in particulate and dissolved forms has been discharging from the mountains and forests since the FDNPP accident in 2011. Moreover, the watershed around the FDNPP experienced extensive flooding from Typhoon Hagibis in October 2019, resulting in substantial changes in the hydrological environment. In this study, we investigated the characteristics of changing particulate and dissolved  $^{137}\text{Cs}$  concentrations in the three main rivers in the region to the north of the FDNPP 3 to 9 years after the nuclear accident, as well as the impact of Typhoon Hagibis on  $^{137}\text{Cs}$  dynamics in river waters. We found that

riverine dissolved  $^{137}\text{Cs}$  concentrations decreased with an environmental half-life of 2 to 10 years and showed seasonal variations, such as increasing in summer and decreasing in winter. The annual amplitude of dissolved  $^{137}\text{Cs}$  in water released from dams was smaller, and peak concentrations were observed later, than in rivers minimally influenced by dams.  $^{137}\text{Cs}$  concentrations in suspended solids showed no marked seasonal variations, and their environmental half-life was found to be 1 to 8 years—shorter than that of dissolved forms observed at the same site. Immediately after Typhoon Hagibis, dissolved  $^{137}\text{Cs}$  concentrations decreased significantly compared with those in previous years, especially at two dam discharge sites. Even 1 year after the typhoon, dissolved  $^{137}\text{Cs}$  concentrations had not returned to the levels predicted by pre-typhoon data. However, no significant decreases in  $^{137}\text{Cs}$  concentrations in suspended solids were observed after the typhoon. These differences in the environmental behavior of different forms of  $^{137}\text{Cs}$  suggest that there are limitations in predicting particulate and dissolved  $^{137}\text{Cs}$  concentrations by using fixed parameters such as the partition coefficient.

### **1.2.2 Radiocesium-bearing microparticles cause large variations in $^{137}\text{Cs}$ concentrations in the aquatic insect *Stenopsyche marmorata* in a forest river**

Radiocesium-bearing microparticles (CsMPs), which are insoluble Cs-bearing silicate glass particles, have been found in terrestrial and freshwater environments since TEPCO's FDNPP accident. Few studies have investigated the distribution of CsMPs in freshwater ecosystems and their uptake by aquatic organisms. In this study, we determined the uptake of CsMPs by aquatic insects in the Ota River in Fukushima. Although aquatic insects are usually assessed for radioactivity in bulk samples of several tens of insects, we investigated the variability of  $^{137}\text{Cs}$  concentrations in individual aquatic insects and the influence of CsMPs on them. Measurement of  $^{137}\text{Cs}$  concentrations in detritivorous caddisfly (*Stenopsyche marmorata*) larvae and carnivorous dragonfly (*Protohermes grandis*) larvae showed that three of 47 caddisfly larvae had considerably high radioactivity, whereas no such outliers were observed in the dragonfly larvae. By using a scanning electron microscope and radioactivity measurements after isolation of the CsMPs, these caddisfly larvae were confirmed to contain CsMPs emitted from Unit 2 of the FDNPP. CsMPs were also found in potential food sources of caddisfly larvae, such as periphyton and drifting particulate organic matter, indicating that the larvae may ingest CsMPs along with food particles of similar size. Our study demonstrated that CsMPs could be taken up by aquatic insects and possibly by the fish consuming them. The existence of CsMPs can result in sporadic, extremely high  $^{137}\text{Cs}$  concentrations and large variations in sample concentrations, and this can consequently obscure the actual transfer and temporal trends of  $^{137}\text{Cs}$  in freshwater ecosystems.

## **1.3 Research into impacts on organisms and ecosystems**

### **1.3.1 Monitoring biodiversity in the evacuation zone after the FNDPP accident**

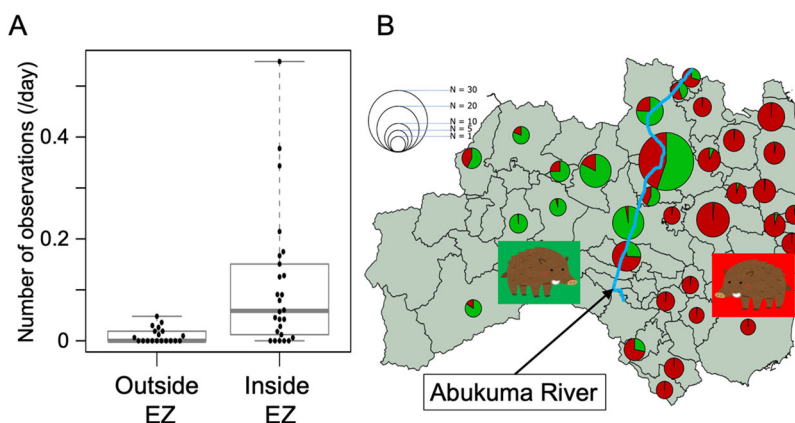
The FNDPP accident resulted in the declaration of a large evacuation zone. Given

the cessation of activities such as farming, changes in biodiversity and ecosystem status have been anticipated. We have therefore been monitoring targeted mammals, birds, frogs, and flying insects outside and inside the evacuation zone in Fukushima since 2014. This report focuses on mammals, which are monitored at 46 sites in nine municipalities inside and outside the evacuation zone. (Locations of monitoring sites can be seen at [http://www.nies.go.jp/biowm/map/en\\_mafu.html](http://www.nies.go.jp/biowm/map/en_mafu.html).) Infrared camera traps, which respond automatically to reflected infrared from homothermic animals, were employed so that investigators would need to visit only a few times per year to collect data and maintain the equipment.

The monitoring sites contained 16 different mammal species. Among these, wild boars (*Sus scrofa*) were caught on camera most often and at the most sites. Statistical analysis showed that wild boars were more abundant within the evacuation zone than outside it (Fig. 3), indicating that decreased human activity may have increased wild boar populations. The same trend was found, but to a lesser extent, in other species such as badger (*Meles meles*), Japanese macaque (*Macaca fuscata*), and Japanese hare (*Lepus brachyurus*). Indeed, increased wild boar populations in Fukushima have caused damage to agricultural operations and require control by state-funded hunting programs. Moreover, radiocesium levels in wild boar meat often exceed government guidelines for food consumption, not only around the evacuation zone but also in western Fukushima, such as in the Aizu area, more than 100 km from the FDNPP. It is therefore important to investigate the spread of radiocesium by wild boar migration from highly contaminated areas.

To clarify the population dynamics of wild boar in Fukushima, we recorded over 300 genetic markers in 179 wild boars in the prefecture and grouped the animals by their similarity of marker composition. The wild boar population in Fukushima is divided into western and eastern groups, which appear to be separated by the Abukuma River (Fig. 3). Although the degree to which the river is a major barrier to boar movement is still unclear, the river appears to hamper the ability of boars in the evacuation zone to migrate into western Fukushima, such as into the Aizu area. We have expanded our genetic analysis of wild boars into Ibaraki, Tochigi, and Miyagi, adjacent to Fukushima.

**Fig. 3** (A) Observation frequency of wild boars outside and inside the evacuation zone (EZ). (B) Genetic differentiation of wild boars in Fukushima into eastern (red) and western (green) groups (pie charts).

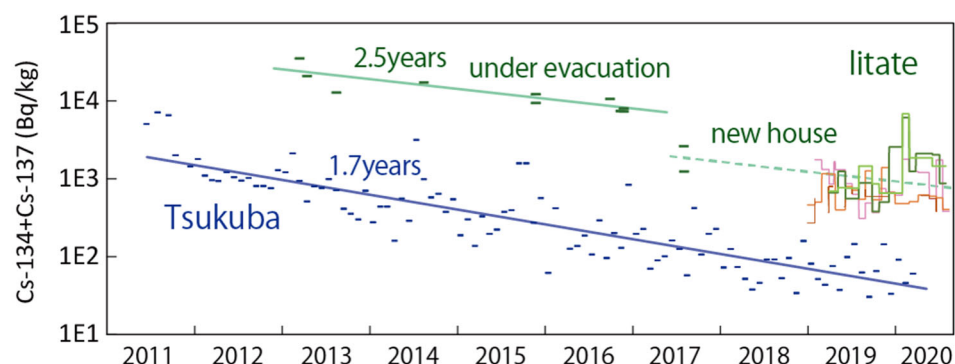


## 1.4 Exposure modeling of radiation and chemical contaminants in environmental emergencies

### 1.4.1 Observation of the recovery process of indoor radiation environments during the period of decontamination and lifting of evacuation orders

We have completed the observation of indoor dust that has been collected since 2013 from the village of Iitate in Fukushima Prefecture. In 2019 and 2020, we collected indoor dust samples from three collaborators almost every month. The temporal changes in radioactive cesium in indoor dust samples in Iitate and Tsukuba are shown in Figure 4. Tsukuba is located about 170 km south of the FDNPP and was not subject to the evacuation order. In contrast, the residents of Iitate remained evacuated until the end of March 2017. As a result of decontamination around residences and moving to newly constructed houses, the concentration of radiocesium in indoor dust was greatly reduced. The environmental half-life of radiocesium in indoor dust was 1.7 years in the Tsukuba samples. In contrast, the environmental half-life in the Iitate dust samples during the evacuation period was longer, at 2.5 years. The environmental half-life of radiocesium in suspended particulate matter in Iitate was 1.8 years—shorter than that in dust. Daily cleaning (through, for example, vacuum cleaning or wet wiping) after the lifting of the evacuation order may have accelerated unintended improvement of the radiation environment.

**Fig. 4** Temporal changes in radiocesium concentrations in house dust samples collected in the village of Iitate in Fukushima (green plots) and the city of Tsukuba in Ibaraki (blue plots). Environmental half-lives are shown on the regression curves.



### 1.4.2 Radiation doses from edible wild plants and mushrooms

Some wild edible plants and mushrooms collected in some areas of Fukushima still exceed the safe radioactivity limit for general food in Japan of 100 Bq/kg. To estimate radiation doses from edible wild plants and mushrooms, we have been investigating consumption rates and estimating rates of removal by cooking. First, we estimated the rates of removal of radiocesium from some edible wild plants by cooking. One or two minutes of boiling followed by soaking in water for 1 h removed more than half of the radiocesium in *koshiabura* (the young buds of *Chengiopanax sciadophylloides*), *taranome* (*Aralia elata*, Japanese angelica sprouts), and *fukinotou* (*Petasites japonicus*, butterbur shoots). Removal of astringent taste by using baking soda removed more than 90% of radiocesium in

warabi (*Pteridium aquilinum*, bracken shoots). In the future, we intend to develop a database of the consumption rates of edible wild plants and mushrooms and their rates of removal of radiocesium by various cooking procedures.

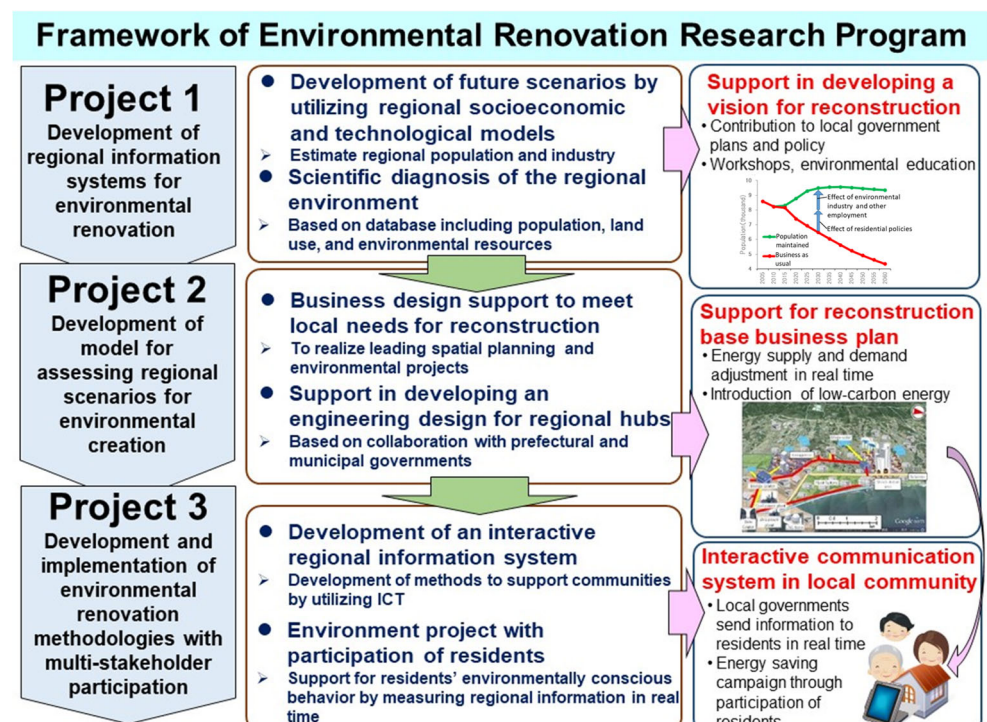
## 2. Environmental Renovation Research Program

Our aim is to develop a method for designing model environmental-creation projects that utilize regional environmental and energy resources and help with environmentally friendly regional reconstruction by building on the community development support research we have been conducting in the Hamadori region of Fukushima Prefecture. We also aim to build scenarios in which technologies and social systems are combined and to evaluate the resulting environmental and socioeconomic effects, as well as to propose systematic policies designed to achieve a sustainable community by developing and verifying a social monitoring system. Through these efforts, we propose sustainable future goals and roadmaps for the reconstruction region from multifaceted viewpoints. We are also contributing scientifically to reconstruction efforts through the social implementation of these goals and roadmaps.

### 2.1 Development of regional information systems for environmental renovation (Project 1)

We have continued to develop the Regional Spatial Database, which systematically summarizes natural, social, and economic data for Fukushima Prefecture. In addition to expanding the database to include indicators related to the development of a Regional Circular and Ecological Sphere (R-CES), we analyzed in detail the

Fig. 5 Outline of the Environmental Renovation Research Program. ICT, information and communications technology





home-returning status of residents evacuated following the FDNPP accident. We found that, in addition to the number of months before the lifting of evacuation orders, proximity to the nuclear power plant and the large proportion of residents from areas in which the orders have not yet been lifted in the same municipality may be factors that have slowed progress.

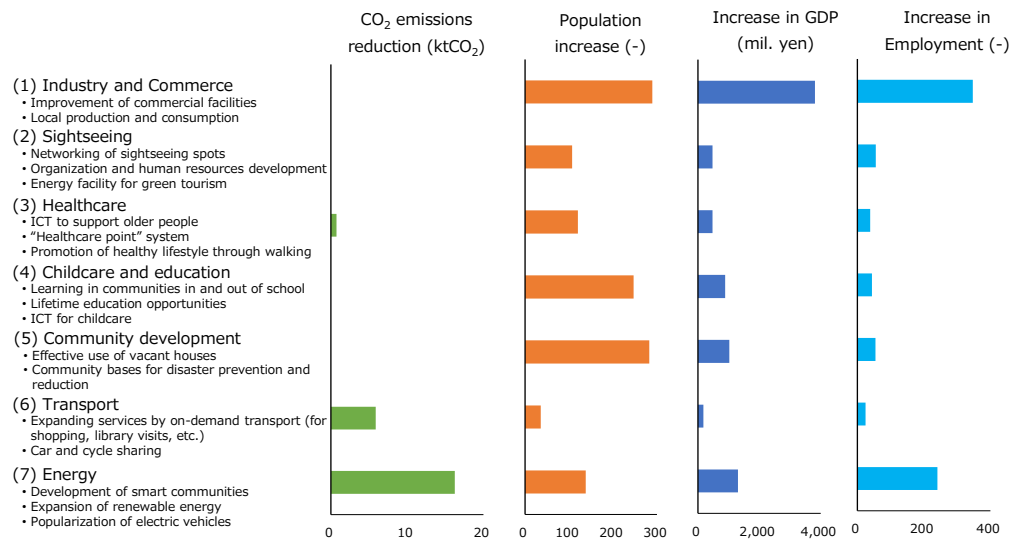
We investigated the structure of the Regional Integrated Assessment Model that we have been developing from the perspectives of Sustainable Development Goals and an R-CES, and we improved the model to enable the inclusion of wider sustainability viewpoints. The aging population is an especially important issue in the Fukushima region. To address this issue, we expanded the model to provide estimations related to elderly households. As an example of its application, we analyzed the degrees of contribution made by various initiatives in the town of Shinchi in Fukushima Prefecture from the viewpoints of population maintenance, economic production, employment, and decarbonization (Fig. 5). Moreover, for the town of Okuma, to help realize the town's Zero Carbon Declaration, we developed a basic methodology for formulating zero-carbon visions. In this way, we supported the competence development of town office staff while quantifying future decarbonization visions by using the model we developed.

By continuing the community governance research that we started in 2018, we collected information on and analyzed—through a literature review and aural surveys—the current status of initiatives on the impacts of, and adaptation measures for, climate change in the Greater Koriyama Region (the city of Koriyama and 16 neighboring municipalities). We also analyzed stakeholder needs related to such impacts and adaptation measures by local governments. In addition, we continued a demonstration experiment that we started in 2019 on community governance associated with forest resources in the Hamadori region. To assess the resumption of forest practices and the use of wooden biomass in Iitate, we analyzed the policymaking process in the village on the basis of an analysis of local documents and interviews conducted within organizations and groups involved in the use of forest resources.

### **2.2 Development of a model for assessing regional scenarios for environmental creation (Project 2)**

By building on our regional analysis of the community reconstruction support that we have provided to the Hamadori region of Fukushima in collaboration with local governments and businesses, as well as our social implementation research on the planning and evaluation of this support, we intend to analyze the environment and socioeconomic characteristics of reconstruction areas from this point onward.

**Fig. 6** Projected impacts of actions in seven fields on CO<sub>2</sub> emissions and population and economic indices in 2050 in comparison with the business-as-usual scenario in the town of Shinchi in Fukushima Prefecture. ICT, information and communications technology



In addition, we intend to develop a method for designing a model environmental creation project that plans and evaluates, over the short to long term, technologies and systems that use regional environmental and energy resources. We have developed future reconstruction scenarios that combine technologies and social systems; we have evaluated their environmental and socioeconomic effects and engage in research whereby a social implementation process that involves residents, local government, businesses, and other parties is developed. Specifically, we have created an inventory of low-carbon, resource circulation, and nature conservation/restoration technologies and policies that promote environmental creation in Fukushima Prefecture. We have also developed an Assessment System for Technology and Social Systems that can calculate the time-series effects of introducing technologies and systems at the city or district level. Finally, we have developed a framework that designs sustainable reconstruction roadmaps by calculating the wide-area ripple effects of the model reconstruction projects being pioneered by local governments in Fukushima Prefecture as part of their planning and development.

To implement socially the items in our inventory of technologies and policies that we had accumulated by last year, from the results of field studies on environmentally advanced cities and good practices in community reconstruction, we extracted those elements that occurred characteristically in community development processes and then extracted patterns based on a pattern language framework. Furthermore, we conducted a trial study in which the extracted patterns were organized in accordance with the actual circumstances in the Hamadori region. Then, in collaboration with local stakeholders that included residents, local government, and businesses, we used the study findings to provide a framework for designing sustainable reconstruction roadmaps.

We conducted laser measurements of town-owned forests at 10-cm intervals in the Asamata district of the town of Mishima and in the city of Tamura. We collected

tree-form data on coniferous and broad-leaved trees, as well as coordinates and other data (more than 100 sets of data when combined with local records). To use these data effectively, we modified the BaIM (Biomass Integrated Model) to allow tree-level estimation. We analyzed aerial photographs of former thinning-project sites and estimated the coordinates of the remaining trees. We plan to use these data to develop scenarios for renewing artificial forests and for transforming thinned sites into natural forests. In a joint study with Osaka University on the effects of climate change on forest management, we predicted growth amounts for 2050 by using LANDIS-II (a forest ecosystem model) and the RCP 2.6 and 8.5 climate scenarios. We predicted that, under the RCP 8.5 scenario, where warming proceeds rapidly, the existing number of trees—especially beech forests—would increase by 13% to 22% by 2050. We also estimated the distributions of species and age class for trees on the Okuaizu region's forest registration database by using a 500-m mesh, and we incorporated the results in various models. We analyzed data from Sentinel satellites and determined current vegetation distributions in detail. Furthermore, we calculated in detail the potential for renewable energy introduction by 2050 in Okuaizu region. We also attempted to apply hydrological and weather data to hydrological and forest ecosystem models. In addition, we identified real-life examples of the landslide-prevention functions of the planting of trees such as paulownia, and we shared the information with the appropriate officers of Mishima Town Office. We conducted tree-level forest surveys in town-owned forests in the town of Tomioka in Fukushima Prefecture, analyzed the results, and extracted those issues that will need to be overcome in applying modeling to forest phases different from those in the Aizu region of the same prefecture.

### **2.3 Development and implementation of environmental renovation methodologies with multi-stakeholder participation (Project 3)**

Throughout the processes of reconstruction from the 2011 earthquake and the subsequent creation of a regional environment, in close collaboration with local government and many stakeholders, we need to develop policies for revitalizing reconstruction communities and for realizing a sustainable regional environment. Therefore, we intend to develop methods for planning an appropriate living environment for residents and for evaluating this planning method with the aim of building a regional information network that provides a safe and secure community life and establishes an improved living environment; collecting and analyzing regional environment information that supports community reconstruction; and supporting the reactivation of local communities, among other goals.

As part of the Life Assist System (a regional information system in Shinchi), we developed a statistical electricity demand prediction model that analyzes electricity data, and we have used the model to evaluate the potential for solar power utilization. Together with this, to develop the study into one focusing on power data analysis, we designed a system that continually collects data, and we performed a system renewal to allow automatic data collection from the HEMS (home energy management system) server independent of the Life Assist System. Furthermore, to

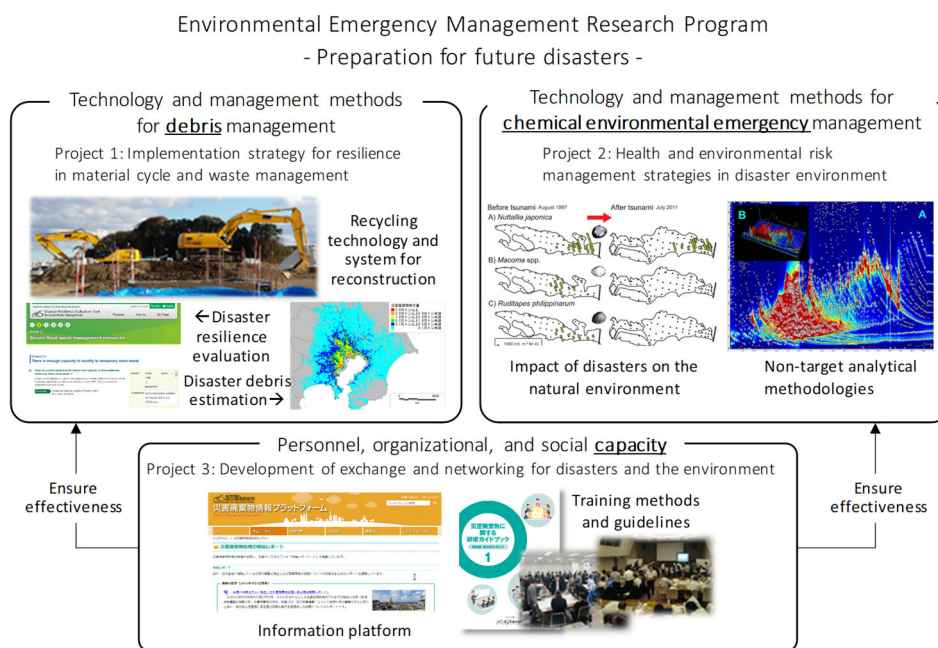
streamline the use of regionally produced energies, this fiscal year, we performed an energy-saving diagnosis at the Shinchi Energy Center and conducted a demonstration experiment that investigated the selection of heat-source equipment in accordance with heat load and equipment operation patterns with the aim of reducing auxiliary power consumption. We also used this energy-saving diagnosis, which contributed directly to the streamlining of energy use and cost reduction in Shinchi, to summarize our evaluation results as general findings with an eye to their application at other sites. To expand this evaluation and investigate the robustness of our model against the demand fluctuations that may occur with differences in weather conditions, building structure, and building use status, we conducted a detailed modeling of facilities around Shinchi Station to enable a simulation evaluation by using an air-conditioning load calculation model. We also continued our demonstration experiment in which local information is transmitted via the Life Assist System, which has been introduced to 26 households in Mishima. We provided observation data that we collected through the system, such as power consumption and indoor temperature data, to a study performed by the Town Office on environmentally conscious lifestyles. Through collaboration with Project 2, aimed at developing policies for utilizing forests and revitalizing local communities in hilly and mountainous areas, we analyzed the results of questionnaire surveys conducted in Mishima on awareness with respect to the forest environment and forest ownership. The forest ownership rate was 57%, with people in their 60s being the largest age group among owners. We found that 70% of owners did not have any future plans for their forests. The forests' commercial use rate over the past 5 years was 30%; the main reasons for forests not being used commercially were "income can't be expected from it," "forests roads are not present," and "forest borders are not clear," revealing the difficulties faced by owners in managing their resources. On the other hand, when questioned about the roles local forests were expected to play, elderly respondents cited "economic" functions, whereas respondents of all generations listed "disaster prevention," "landscape," and "environmental conservation" functions. When questioned as to the most suitable entities for managing currently unmanaged forests, respondents stated "the private sector" and "local government." These results were provided to the Mishima Town Office and contributed to discussions held by the Mishima Town R-CES Promotion Council.

### 3. Environmental Emergency Management Research Program

Our Environmental Emergency Management Research Program (Fig. 7) aims to establish practical management systems and technologies for handling disaster waste during and after disasters. It also aims to develop a strategy for environmental and health-risk management in times of emergency to create more resilient social environmental systems and foster the communities within them.

This program will devise technologies and systems for integrated disaster waste management aimed at achieving smooth and appropriate management of these types of wastes. Additionally, to create a strategy to manage the environmental and health risks associated with disasters, the program will investigate approaches to setting risk management targets, focusing especially on chemical risks when disasters strike and methods and organizational arrangements for emergency environmental surveys. Furthermore, to build a research hub for an environmental emergency research network, the program will design and develop an information platform and capacity-development system for environmental emergencies. This research will be pursued in collaboration with NIES's Environmental Emergency Management Office.

**Fig. 7** Outline of the Environmental Emergency Management Research Program



### **3.1 Establishment of disaster-resilient waste management systems and strategies (Projects 1 and 3)**

We studied factors related to people's disaster-waste disposal behaviors. We focused on disaster waste from the cleanup of damaged houses (cleanup waste, hereinafter), which in many cases has been disposed of in places other than temporary storage sites (TSSs), including on the curbside and in other open spaces, even when the local government policy is basically to dispose of such waste at TSSs. We studied the disposal behaviors of disaster victims in the city of Kurashiki after the July 2018 heavy rain disaster, as well as the potential determinants of these behaviors. The results and statistical analysis of a questionnaire survey suggested that people tended to dispose of cleanup waste at places other than TSSs when a) the TSS was a long way away; b) vehicles for transportation were not freely available; and c) public information regarding places to dispose of cleanup waste was not well understood. On the basis of these results, we presented recommendations on preparedness actions, such as identifying land that could be used as TSSs evenly across areas where disasters are expected.

Through a workshop involving 19 public officers with past experience in disaster waste management, we also collected data on the typical disaster waste management issues and situations faced by local authorities. The results were organized in a database that can be used by local authority officers to plan their preparedness plans and training programs. We also updated our online self-evaluation tool to a comprehensive management tool. Local government officials can use it to evaluate the disaster resilience of their waste management systems and develop plans to improve resilience on the basis of the newly installed database of preparedness actions.

We also undertook professional evaluation of our online disaster waste management information platform (<https://dwasteinfo.nies.go.jp/>; in Japanese) in terms of user interface and user experience design to improve user access to disaster waste management information. Articles, a database, and video clips were added to this information platform to help implement and study disaster waste management.

### **3.2 Health and environmental risk management strategies in disaster environments (Project 2)**

Health and environmental risk assessment and management of hazardous chemicals are currently general practices applied when such chemicals are used in normal environments. However, the risks posed by the accidental release of hazardous chemicals in disaster environments have not yet been sufficiently evaluated or managed.

This research project focuses on establishing a risk assessment and management methodology for the accidental release of hazardous chemicals in disaster

environments. The project consists of several sub-projects, which are briefly summarized as follows: Project 2-1, setting target control levels for chemical contamination in disaster environments; Project 2-2-1, establishing comprehensive analytical technologies and emergency response teams for contaminant chemicals; Project 2-2-2, establishing non-target analytical methodologies and sampling technologies for emergency contamination; Project 2-3, clarifying the impacts of emergency contamination events on terrestrial ecosystems and environmental epidemiology in emergency events; and Project 2-4, clarifying the long-term impacts of emergency contamination events on coastal ecosystems in the field. This fiscal year, we collected detailed information on past chemical plant accidents involving the release of chemicals into the environment and their emergency responses through questionnaires and interview surveys (Project 2-1); developed a rapid and comprehensive analytical screening method for gas chromatography–mass spectrometry that runs on a web browser (Project 2-2-1); conducted monitoring and performance tests of portable air samplers with different adsorption properties (Project 2-2-2); prepared tools and questionnaires for environmental epidemiology in emergency events in corporation with the U.S. National Institutes of Health (Project 2-3); and performed a field survey of the impact of a disaster on a coastal ecosystem (Project 2-4). Through these achievements, the project aims to demonstrate comprehensive strategies for managing the health and environmental risks posed by hazardous chemicals in a variety of disaster environments.

# Research Projects

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### Satellite Observation Center

The Satellite Observation Center (SOC) contributes to improved scientific understanding of the carbon cycle, more accurate prediction of the future climate, and climate-change-related policy-making by the Ministry of the Environment (MOE) through activities that use data from satellites of the GOSAT Series, namely Ibuki/GOSAT, launched in 2009; GOSAT-2, launched in 2018; and Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW; Fig. 1), to be launched in FY 2023. Activities include developing and operating data-processing systems for the GOSAT Series. These systems are being used to calculate the concentrations and fluxes of greenhouse gases (GHGs) and to verify, archive, or distribute GOSAT Series products. The GOSAT Series projects are jointly promoted by MOE, the Japan Aerospace Exploration Agency (JAXA), and NIES.

Major achievements of SOC in FY 2020 are as follows:

#### 1. GOSAT

Operational data processing for GOSAT, which has been in space for more than 12 years, continued, as did the generation, validation, and distribution of GOSAT products, such as the concentrations and fluxes of carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>). Concentration products up to February 2021, CO<sub>2</sub> flux products up to October 2017, and CH<sub>4</sub> flux products up to September 2018 are freely available from the data distribution website (GOSAT Data Archive Service, GDAS; <https://data2.gosat.nies.go.jp>). Maintenance and operation of GOSAT DHF (Data Handling Facility), which is the computer system needed for these activities, were also conducted. Most of the hardware used in GOSAT DHF (e.g., servers and storage) is being replaced because it has reached the end of its useful life. We have also continued to provide GOSAT FTS (Fourier Transform Spectrometer) Level 2 CO<sub>2</sub> data to the World Data Centre for Greenhouse Gases, which is operated by the Japan Meteorological Agency under an agreement with the World Meteorological Organization.

#### 2. GOSAT-2

GOSAT-2 data have been distributed by G2DPS (the GOSAT-2 Data Processing System) for Research Announcement users since May 2019 and for General Users since August 2019. In November 2020, public distribution of the FTS-2 SWIR (Short-Wavelength Infrared) Level 2 Column-averaged Dry-air Mole Fraction Product and the Chlorophyll Fluorescence and Proxy-method Product started from the GOSAT-2 Product Archive after validation by using ground-based data. The CAI-2 (Cloud and Aerosol Imager 2) Level 2 Aerosol Property Product up to September 2019 is also available, but currently only for Research Announcement users. FTS-2 TIR (Thermal Infra-Red) products are being investigated with

algorithm developers outside NIES. GOSAT-2 Science Team Meetings were held twice in FY 2020 to discuss the validation and release of the above-mentioned products.

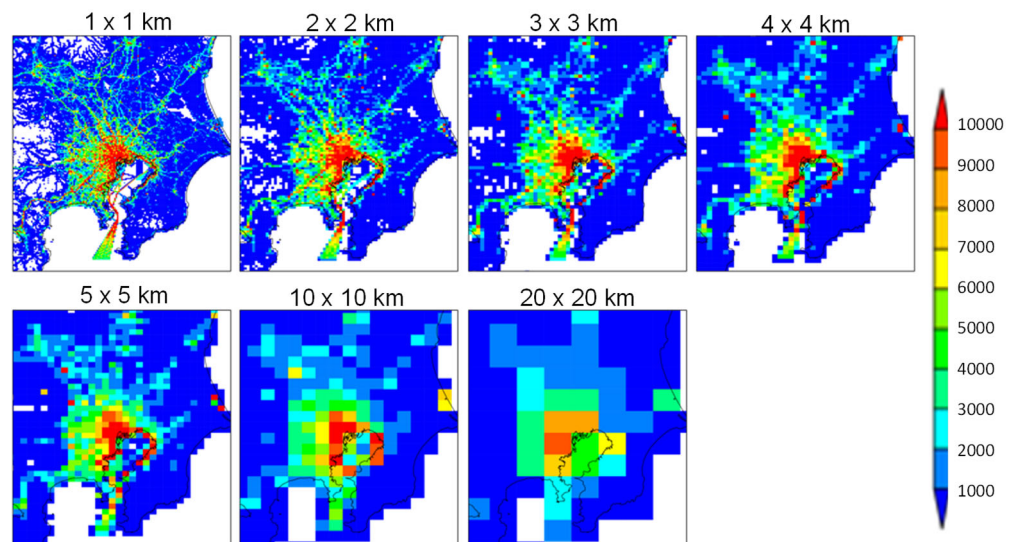
### 3. GOSAT-GW

Several design reviews and related meetings were held by JAXA and its contractors in FY 2020. Detailed information on GOSAT-GW designs was obtained through those meetings and reflected in activities at NIES, including discussions on the processing and validation of GOSAT-GW data.

Preliminary designs of data-processing systems for GOSAT-GW, G3DPS (the GOSAT third-generation Data Processing/operating System), and GNDPS (the GOSAT-GW Nitrogen dioxide (NO<sub>2</sub>) Data Processing System) have started. The design reviews will be conducted by the summer of FY 2021.

Meetings of the GOSAT-GW advisory board and working groups were held several times to obtain useful suggestions from domestic experts in space application, atmospheric science, and climate-change-related policies. The joint research agreement on NO<sub>2</sub> data from GOSAT-GW was concluded among JAMSTEC (the Japan Agency for Marine-Earth Science and Technology), NICT (the National Institute of Information and Communications Technology), and NIES in April 2020.

**Fig. 1** Emission maps of Tokyo and its surroundings at different spatial resolutions. The fine-mode observations of GOSAT-GW (Global Observing SATellite for Greenhouse gases and Water cycle)—1 to 3 km—can depict detailed spatial distributions that are not shown in coarse-resolution data.



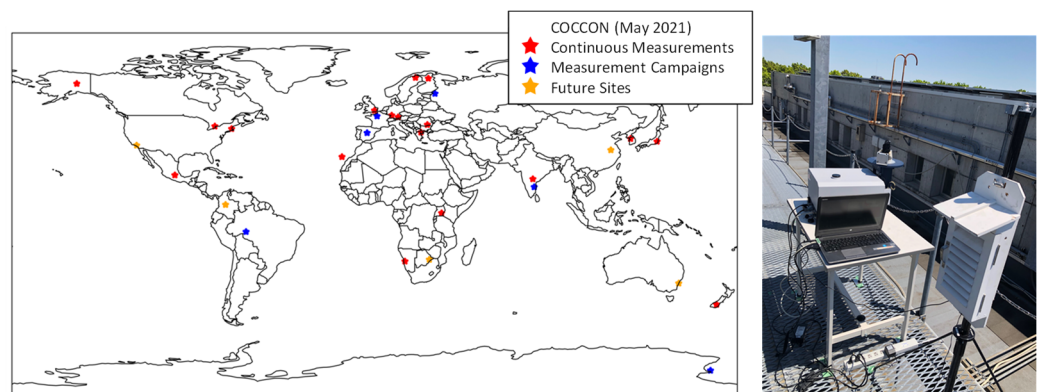
#### 4. Collaboration with other organizations

Research Announcements on the GOSAT Series (GOSAT Series RAs) have been issued jointly by MOE, JAXA, and NIES since 2018 to solicit research proposals covering both GOSAT and GOSAT-2 from around the world. Those proposals that are evaluated as appropriate by the GOSAT Series RA Selection and Evaluation Committee are adopted to conclude joint research agreements. The second GOSAT Series RA was issued in October 2019, and eight joint research agreements were signed. The third GOSAT Series RA was issued in November 2020, and evaluation of the proposals received is under way. Currently, a total of 44 joint studies are in progress, and new joint studies under the third RA will start in FY 2021.

In response to agreements concluded with NASA (the US National Aeronautics and Space Administration), ESA (the European Space Agency), CNES (the Centre National d'Etudes Spatiales), and DLR (Deutsches Zentrum für Luft- und Raumfahrt, the German Aerospace Center), several informal meetings were held to exchange technical information and discuss future collaboration. These meetings were held virtually (i.e., online) owing to the COVID-19 pandemic.

The Collaborative Carbon Column Observing Network (COCCON, <https://www.imk-asf.kit.edu/english/COCCON.php>) is a new network of GHG measurements that use portable Fourier transform spectrometers and are based on common instrumental standards and data analysis procedures. The COCCON data are expected to be substantially useful as next-generation validation data for satellite GHG observations. The Tsukuba site operated by NIES is one of the 19 COCCON operational sites (Fig. 2).

**Fig. 2** A map showing COCCON sites (left), and a portable Fourier transform spectrometer on the roof of Climate Change Research Hall, NIES (right)



### **5. Hosting of meetings**

The Second GOSAT Series RA PI (Principal Investigators) Meeting was originally planned to be held together with the 16th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-16) in Germany. Unfortunately, IWGGMS-16 was changed from an in-person meeting to a virtual meeting due to the COVID-19 pandemic. The Second GOSAT Series RA PI Meeting in FY 2020 was postponed and rescheduled to be held in July 2021 as a virtual meeting.

### **6. Participation in international events**

Amid the COVID-19 pandemic, many international events such as UNFCCC COP26 (United Nations Framework Convention on Climate Change 26th session of the Conference of the Parties) and WGIA18 (18th Workshop on Greenhouse Gas Inventories in Asia) have been cancelled or postponed, limiting participation by SOC in such events. Therefore, the possibility of online exhibitions was discussed and a trial was made at a domestic meeting.

The Atmospheric Composition Virtual Constellation (AC-VC) is a CEOS (Committee on Earth Observation Satellites)-led initiative to collect and deliver data to improve monitoring, assessment, and predictive capabilities for changes in the ozone layer, air quality, and climate forcing through the coordination of existing and future international space assets. GOSAT-GW activities were presented at the 16th Meeting of the AC-VC, which was held virtually in June 2020.

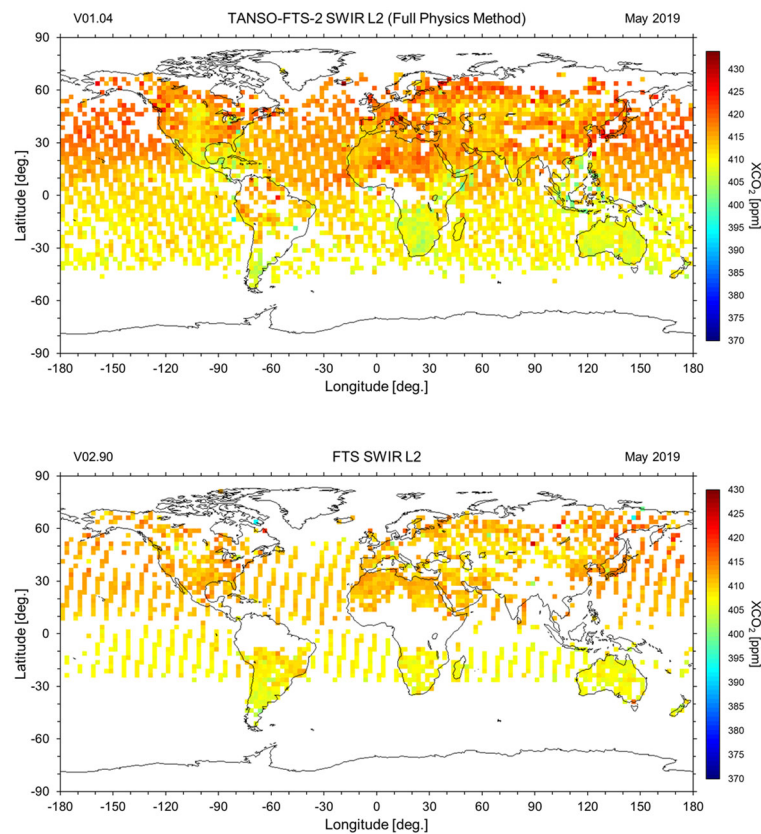
### **7. Press releases**

The following two press releases related to SOC were issued in FY 2020:

1) “Regarding results of GOSAT-2 observational data analysis (carbon dioxide, methane, and carbon monoxide) and the start of their public release” (November 2019) (Fig. 3).

See: <https://www.nies.go.jp/whatsnew/20201112/20201112-e.html>  
<https://www.eurekalert.org/news-releases/579518>

**Fig. 3** Distribution maps of column-averaged dry-air mole fractions of carbon dioxide ( $X_{CO_2}$ ) for May 2019, derived from GOSAT-2 data (upper) and GOSAT data (lower). The GOSAT-2  $X_{CO_2}$  data show more than twice the amount of  $X_{CO_2}$  data as in the GOSAT data, thanks to the larger pointing angle range and the intelligent pointing, which automatically avoids clouds.



2) “Correction of the error in methane concentration estimation by the proxy method applied to GOSAT data” (November 2020, in Japanese).

See: <https://www.nies.go.jp/whatsnew/20201117/20201117.html>

### **Japan Environment and Children's Study**

The Japan Environment and Children's Study (JECS) is a large-scale birth cohort study that aims to investigate the impact of the environment on children's health and development. NIES serves as the JECS Programme Office, supporting the Regional Centers that conduct surveys in 15 study areas throughout Japan in cooperation with the Medical Support Centre situated in the National Center for Child Health and Development, which provides medical expertise.

#### **1. Aim**

The aim of JECS is to identify environmental factors that affect children's health to develop better environmental risk management policies. Specifically, JECS focuses on the effects of exposure to chemical substances during the fetal period or in early childhood. JECS gives priority to five major health domains: reproduction and pregnancy complications; congenital anomalies; neuropsychiatric/developmental disorders; allergy and immune system disorders; and metabolic and endocrine system dysfunction. The environment is defined broadly as the global or ambient environment (including chemical substances and physical conditions), the built environment, behaviors and habits, socioeconomic factors, family and community support, and genetic factors.

#### **2. Study design and subjects**

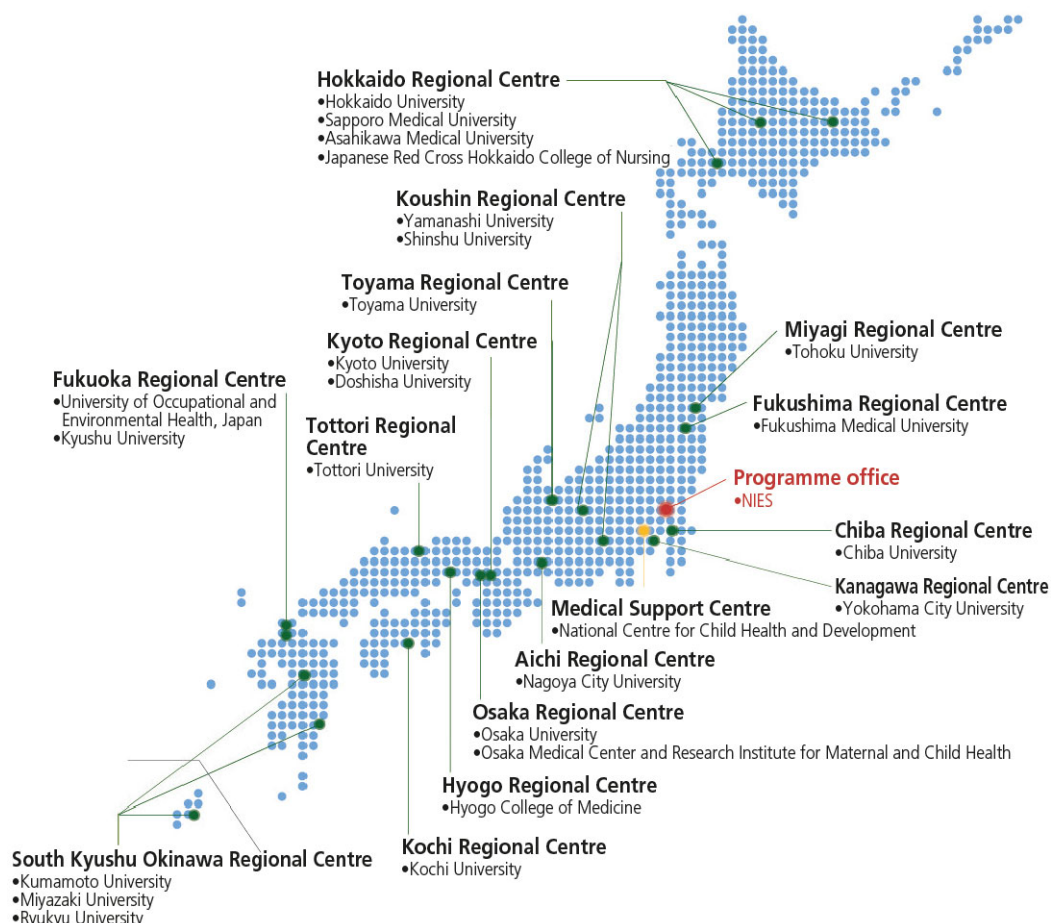
We started recruiting participants in January 2011, and recruitment continued until March 2014, by which time the number of participating mothers had reached 103,099. Recruited participants were pregnant women and their partners (when accessible). JECS began to collect data when the mothers were pregnant and plans to follow their children until they reach 13 years of age. For the Main Study, JECS acquires information about participant health and development and potentially relevant environmental factors by administering questionnaires twice a year. The Sub-Cohort Study, which involves 5000 children selected randomly from among participants in the Main Study, is also being conducted to investigate environmental factors and outcome variables more thoroughly. It includes extensive assessment through home visits, ambient air measurements, psycho-developmental testing, and examinations by pediatricians.

#### **3. JECS study organization and role of the Programme Office**

For appropriate data collection and analysis, the Programme Office plays key roles, including developing standard operation procedures; accumulating the data collected by the 15 Regional Centers (Fig. 1); operating the data management system; maintaining a repository of biological and environmental specimens; performing exposure and environmental measurements, including chemical analyses of biological samples; and administering questionnaires. The Programme

Office also performs administrative tasks, provides administrative and technical support for Regional Centers, and is responsible for risk management and public communications. The Programme Office strives to play a leadership role in facilitating collaboration among the different research groups conducting environmental birth-cohort studies in both Japan and other parts of the world, working as a platform for information exchange among researchers.

**Fig. 1** JECS organization



#### 4. Study protocols

Details of the study protocols of JECS can be found in the following literature:

1. Kawamoto T, Nitta H, Murata K, et al. (2014) Rationale and study design of the Japan environment and children's study (JECS). *BMC Public Health*, 14:25, doi:10.1186/1471-2458-14-25
2. Michikawa T, Nitta H, Nakayama SF, et al. (2018) Baseline profile of participants in the Japan Environment and Children's Study (JECS). *Journal of Epidemiology*, 28(2):99–104, doi:10.2188/jea.JE20170018



3. Sekiyama M, Yamazaki S, Michikawa T, et al. (2020) Study design and participants' profile in the Sub-Cohort Study in the Japan Environment and Children's Study (JECS). *Journal of Epidemiology* online ahead of print, doi:10.2188/jea.JE20200448

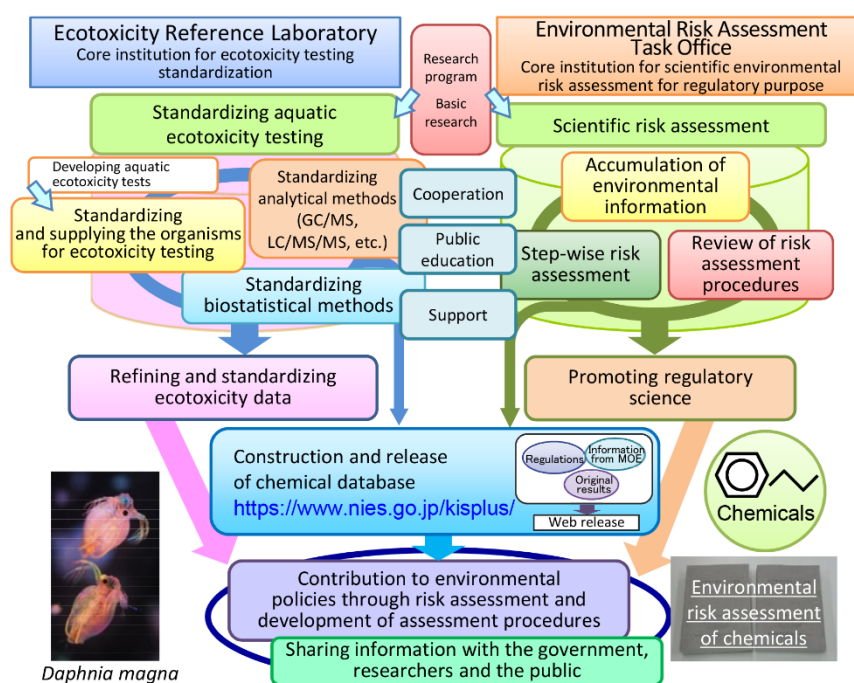
### **5. Activity report for FY 2020**

The children participating in the Main Study reached the ages of 6 to 9 years in FY 2020. We continued to administer questionnaires to participants to collect a wide range of information on the children's health and development and exposure to environmental factors. We analyzed 5000 maternal blood samples for aryl hydrocarbon receptor activity, 5000 cord blood samples for perfluoroalkyl substances, and 13,000 maternal blood samples for persistent organic pollutants. As the participants of the Sub-Cohort study became 6 years old, we completed the medical and developmental examinations and blood and urine sample collection.

### Risk Assessment Science Collaboration Office

The Risk Assessment Science Collaboration Office provides domestic leadership for the promotion of regulatory science with the aim of achieving a safe and secure society. The office consists of the Ecotoxicity Reference Laboratory and the Environmental Risk Assessment Task Office. The Laboratory conducts ecological toxicity research, international collaboration for the development of advanced testing methods, and standardization of test implementation. The Task Office conducts projects to assess environmental risks scientifically in collaboration with other organizations; it also constructs databases and disseminates knowledge and technical methodologies (Fig. 1).

**Fig. 1** The Ecotoxicity Reference Laboratory and Environmental Risk Assessment Task Office work in collaboration in regulatory risk assessment science through ecotoxicological testing, scientific risk assessment, and database development.



#### 1. Ecotoxicity Reference Laboratory

As a leading reference laboratory for ecotoxicological research and testing, the Ecotoxicity Reference Laboratory helps to realize and secure a safe society by proactively promoting regulatory science. Two kinds of new ecotoxicity test methods, namely a method of detecting anti-androgens by using medaka (juvenile medaka anti-androgen screening assay: JMASA) and a simple method of detecting juvenile-hormone-like chemicals by using *Daphnia magna* (juvenile hormone activity screening assay: JHASA), were proposed by our laboratory in 2016 for the Organisation for Economic Co-operation and Development (OECD). Ring tests for interlaboratory validation have continued to be conducted for JMASA. Moreover, we have been investigating the effects of non-chemical stresses (e.g., temperature,

hardness, light cycle, and population density) on the male production. We plan to complete our validation report to the meeting of the OECD's Validation Management Group for Ecotoxicity testing (VMG-eco) this year for approval in 2022 by the OECD's Working Group of the National Coordinators for the Test Guidelines Programme (WNT). The two methods contribute to the Extended Tasks on Endocrine Disruption (EXTEND) 2016 project of the Ministry of the Environment (MOE), namely "Future correspondence regarding the endocrine-disrupting action of chemical substances." To further validate and revise the statistical part of the medaka extended one-generation reproduction test (MEOGRT, OECD Guideline for Testing of Chemicals No. 240), we applied the test to a synthetic estrogen, 17 $\alpha$ -ethinylestradiol, to determine the lowest observed effect concentration.

We also submitted a standard project submission form to propose the revision of the algal growth inhibition test (OECD Guideline for Testing of Chemicals No. 201) to OECD and asked for national coordinators and experts in other OECD member countries to cooperate in interlaboratory ring tests to check the validity of the medium proposed for the test diatom.

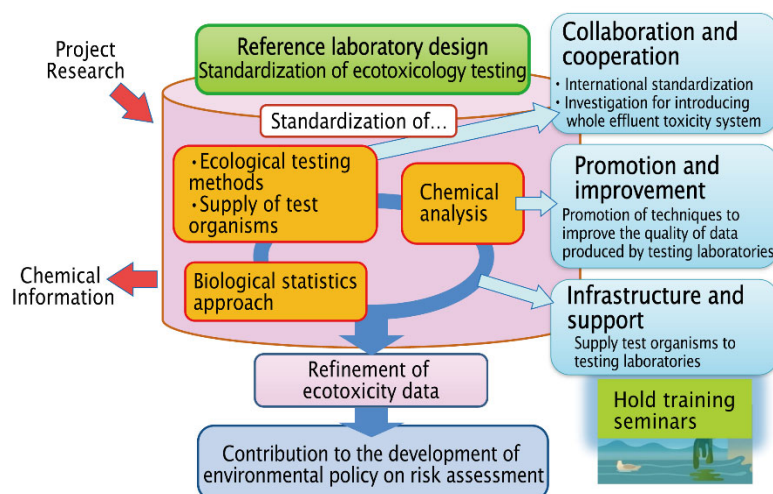
With experts and the MOE, we discussed revising the fish acute toxicity test (OECD Guideline for Testing of Chemicals No. 203) under the Chemical Substances Control Law (CSCL). We continued to collect data about sublethal clinical signs linked with lethality. Clinical signs highly linked to lethality were investigated in Japanese medaka (*Oryzias latipes*); some signs, such as loss of equilibrium, were closely linked to lethality and could be considered to indicate a moribund state.

We also investigated the effects of a different test medium on the toxicity of herbicides to duckweed (*Lemna minor*) and compared four endpoints: frond number, frond area, wet weight, and dry weight. We found that the toxicities of a few herbicides might be attenuable by using nutrient-rich medium.

The Laboratory continuously supplies stable test organisms (15 species in total, mostly fishes and crustaceans) to personnel in Japan, both outside and inside NIES, for ecotoxicity testing. In FY 2020 nearly 110 orders were received from contract laboratories, universities, and municipal institutes all over Japan.

In collaboration with universities, local environmental laboratories, and private enterprise, the Laboratory also promotes ecotoxicity testing and performs scientific risk assessments (Fig. 2).

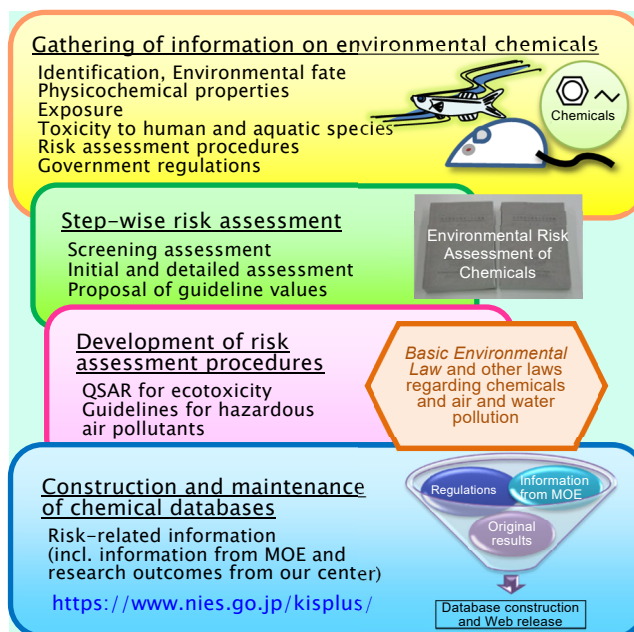
**Fig. 2** The Ecotoxicity Reference Laboratory functions as a core organization for the standardization of ecotoxicity testing, both domestically and internationally.



## 2. Environmental Risk Assessment Task Office

The Environmental Risk Assessment Task Office promotes research to support assessment and management of the risks posed by environmentally released anthropogenic chemicals. It also provides risk-related information to the government and the public. The Office collects a variety of information on the chemicals and assesses their environmental risks to help with the risk assessment activities conducted under the laws enacted by MOE. Our activities are outlined in Figure 3.

**Fig. 3** Activities and research projects of the Environmental Risk Assessment Task Office.



QSAR: Quantitative structure-activity relationship; MOE: Ministry of the Environment

Under the revised CSCL, all chemical substances, including existing chemicals but excluding chemicals subject to other laws (such as medicines and agrochemicals),

### 3. Risk Assessment Science Collaboration Office

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must be screened, i.e. screening assessments, to determine whether they need more detailed risk assessments, namely Risk Assessments I (I-1, I-2, and I-3) and II. The Task Office supports the implementation of the detailed risk assessments as well as the screening assessments. In FY 2020, as part of the screening assessments, we assessed the reliability of a hazard-ranking classification of the aquatic toxicity of 30 chemicals that were of a relatively high exposure class but had not yet been assessed. We also collected and evaluated information on the hazards to the aquatic environment of 14 chemicals on the basis of Risk Assessment I-2 of the detailed assessments.

Every year, MOE publishes an “Initial Environmental Risk Assessment of Chemicals.” In FY 2020, the Task Office supported the initial ecological risk assessment of 15 chemicals. To support the standards for registration of agricultural chemicals on the basis of the Agricultural Chemicals Regulation Law, information on the aquatic toxicity of nine substances was collected, and the reliability of the toxicity information was assessed.

The Task Office has started supporting the development of methods of assessing environmental risks to birds as terrestrial species. Hazard assessment methods for acute avian toxicity have been reviewed and considered under the Agricultural Chemicals Regulation Law, and hazard assessment methods for long-term toxicity have been investigated under the CSCL. In addition, as alternative animal test methods, we have started developing avian toxicity tests by ex-ovo administration to assess the reproductive and developmental toxicity of chemical substances.

We have been improving the Kashinhou Tool for Ecotoxicity (KATE) system for use in quantitative structure–activity relationship (QSAR) models. We updated KATE 2020 (<https://kate.nies.go.jp/>) from version 1.0 to 1.1 in April 2020 and to version 2.0 in January 2021. We have been continually updating our chemical substance databases and have renovated the related website, Webkis-Plus (available only in Japanese). Webkis-Plus contains information on about 10,000 substances, including their physicochemical properties; laws and regulations related to environmental pollution; environmental concentrations from surveys performed by MOE; amounts of chemical substances manufactured and imported; volumes of agricultural chemicals shipped into each prefecture; Pollutant Release and Transfer Register information; the results of risk assessments performed by several organizations; and details about the analytical methods developed by MOE for environmental surveys in Japan.

### **Environmental Emergency Management Office**

Through research collaboration with the relevant organizations in Japan, this office implements projects aimed at supporting effective and efficient environmental emergency management by emergency response personnel. This includes building and operating institutional and information network systems that serve as a foundation for developing environmental emergency management strategies; training personnel to develop practical expertise in environmental emergency management; providing on-site support for disaster responses; setting up research hubs for environmental emergency management; and training researchers.

More specifically, this office is establishing a new platform for enabling domestic institutions to cooperate in collecting and organizing the experiences and lessons gained from tackling environmental issues caused by past disasters, and in efficiently and effectively organizing new knowledge derived from environmental emergency management research. The office will focus in particular on the smooth management and operation of the central government's Disaster Waste Treatment Support Network (D.Waste-Net), and on building emergency environment monitoring systems centered on regional environmental research institutions.

This year, we have especially made a great effort to establish a system of contributing to efficient and effective disaster waste management. Below are the main results of our efforts.

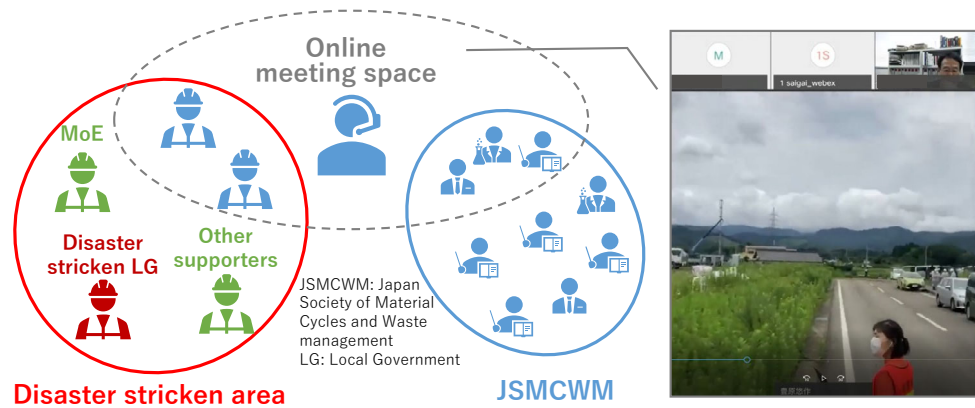
#### **1. Provision of off-site support for disaster responses in the 2020 Kyushu floods**

The heavy rain in parts of Kyushu in July 2020 caused extensive damage in some areas. In light of the COVID-19 situation, we provided on-site and off-site hybrid support jointly with the Japan Society of Material Cycles and Waste Management (JSMCWM) as follows:

- Two members of the JSMCWM entered the disaster-stricken area (Kumamoto Prefecture) to provide on-site support, with the backup of other members of JSMCWM and NIES through the use of a fixed online meeting space (Fig. 1).
- JSMCWM and NIES jointly provided advice on estimation of the amount of flood waste and on making public announcements on appropriate flood waste disposal.

## 4. Environmental Emergency Management Office

**Fig. 1** The on-site and off-site hybrid support system utilized after the 2020 Kyushu flood



### 2. Supporting capacity development and policy formation

Human resources are key to properly enhancing our potential to manage disaster waste in real, unexpected disaster situations. Our office provides practical support to local governments when they design training programs aimed at developing practical expertise for disaster waste management. This year we provided support to Aomori, Aichi, Gifu, and Okayama prefectures and the Tokyo metropolitan government. In terms of support for policy formation, we held a seminar to look back on the progress of disaster waste management policy and systems since the Tohoku earthquake in 2011 and discuss directions for further improvement. Improvements were acknowledged by the seminar participants in the areas of management technology; capacity-development methods and systems; laws and regulations; and a nationwide system to support disaster-stricken areas. Community, local, and regional governance was recognized as one of the key concepts for further improving the disaster waste management system.

### 3. Data collection and implementation of a disaster waste information platform

Data were collected on the operations of temporary storage sites after two heavy rain disasters in 2018. We also improved our online information platform on disaster waste management to help local authorities further enhance their disaster waste management skills. A short video clip explaining the importance of appropriate disaster waste disposal was made and released for use in awareness raising (Fig. 2). In addition, we updated our online database of the disaster waste management plans prepared by local governments. Other information updated on the platform included:

- lessons and strategies learned from central and local government responses to past disasters
- technical and managerial notes for disaster waste management projects
- reports of experiences and methods regarding preparedness planning and capacity development for disaster waste management.

**Fig. 2** Screen shots from a video clip for the public about the importance of appropriate disaster waste disposal





### Social Dialogue and Co-production Office

#### 1. About

The Social Dialogue and Co-Production Office (DaC) is an organization serving all departments of NIES (Fig. 1). It facilitates communication between various stakeholders in society and our institute to promote dialogue and co-production on environmental issues and environmental research.

Our mission statement is as follows:

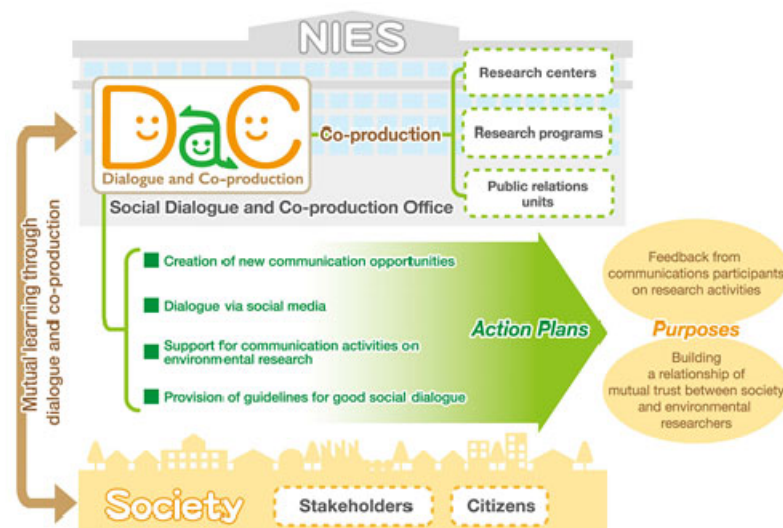
We will engage in dialogue and co-production to protect the environment and realize a sustainable society.

- We will respect diverse views and opinions in society and will learn from the public's voices to tackle environmental issues with them.
- We will disseminate the value of dialogue and co-production and support such activities by sharing the experience and the joy gained through them.
- We will create a relationship of mutual trust between NIES and society.

For example, we provide feedback from the voices of society to our research activities by providing opportunities for dialogue, such as stakeholder meetings and science cafés. We also provide opportunities for dialogue via social media and online content according to the needs of society. Furthermore, we organize and run in-house interview sessions and workshops to collect and analyze the existing experiences of members of NIES. The outcomes are published internally as guidelines.

Through these activities, we aim to improve our ability to engage in dialogue, to help build a relationship of mutual trust with society, and to receive more approval from society for the research we undertake.

**Fig. 1** DaC and its action plans within the NIES structure



## 2. Highlights of our activities in FY 2020

### 2.1 Creating opportunities for online dialogue

As a result of COVID-19, DaC was obliged to pursue online dialogue opportunities by using social media platforms such as YouTube and Zoom. In response to public interest, we distributed a range of digital content, including a video on plastic waste issues (Fig. 2) and a webinar discussing COVID-19 and the climate crisis.

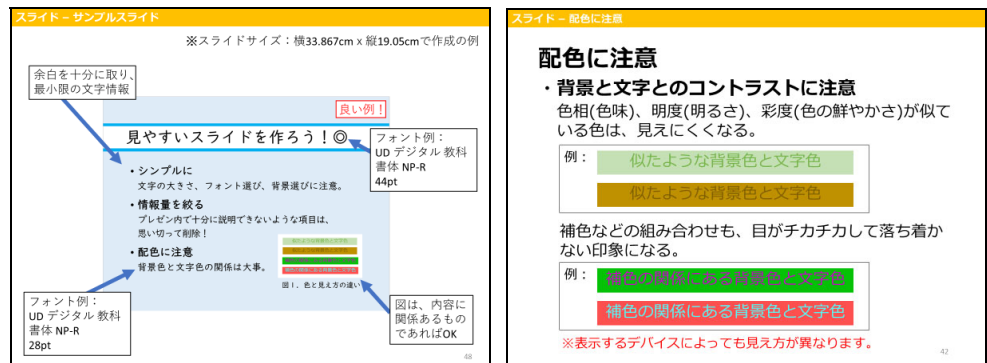
**Fig. 2** DaC broadcasted a variety of YouTube videos on environmental problems.



### 2.2 Guidebook on dialogue and communication

DaC has played a role in accumulating and disseminating knowledge on communication through our activities so far. One of our outcomes has been to create a guidebook that summarizes methods of communicating. The guidebook was shared with NIES staff (Fig. 3).

**Fig. 3** Part of the DaC guidebook on methods of communicating



### **3. Future outlook**

We intend to consider how the voices of society, obtained through dialogue, can be fed back to our research activities. We will continue to use social media, because it is an effective tool for reaching out to younger generations and those who are not necessarily interested in environmental problems. It is also important to enforce our work on co-production. We will try to gather existing experiences on co-production within NIES's research activities and will continue examining the roles that DaC can take in these co-production activities.

# Center for Climate Change Adaptation

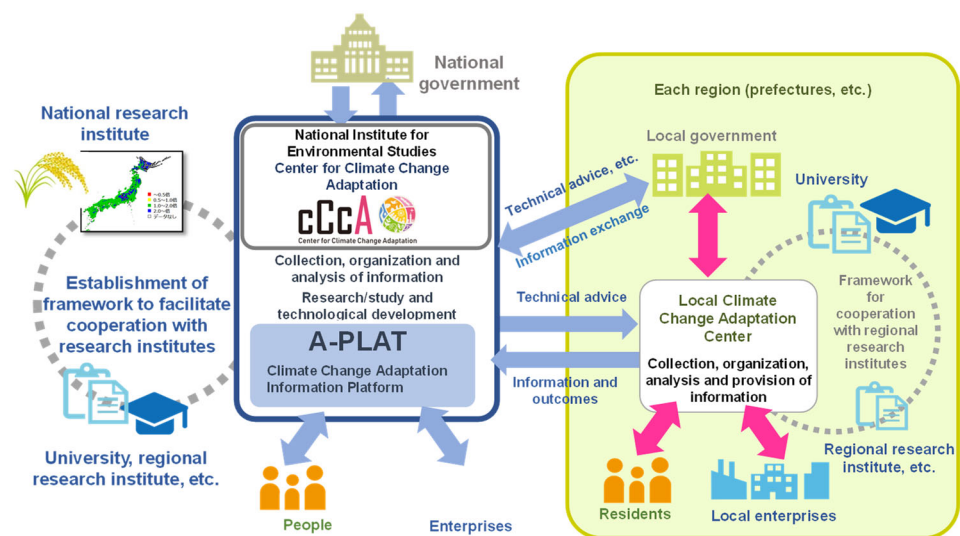
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## Center for Climate Change Adaptation

Under the Climate Change Adaptation Act enforced in December 2018, NIES is the core information platform for climate change adaptation in Japan. NIES established the Center for Climate Change Adaptation (CCCA) in the same month. It is tasked with collecting, organizing, analyzing, and providing information on the impacts of climate change and climate change adaptation, as well as supporting local governments and Local Climate Change Adaptation Centers (LCCACs) by providing technical advice for efforts on climate change adaptation (Fig. 1). Some of the activities of the Center in FY 2020 are described below.

**Fig. 1** Role of the Center for Climate Change Adaptation



### 1. Promotion of climate change adaptation

#### 1.1 Technical support for local public bodies

We distributed questionnaires to local government and LCCAC staff and held discussion meetings to identify their needs for technical assistance. On the basis of these needs, we developed a list of support strategies. Depending on the situation, we considered what support measures to take, such as technical advice, dispatch of experts, capacity building of personnel, enhancement of scientific knowledge in the region, and establishment of networks among regions.

As support measures, we:

- gave lectures to about 2500 local government staff, regional company employees, and local residents at regional meetings and study sessions to provide information on climate change adaptation
- participated in meetings of examination committees of LCCACs and other regional groups to provide scientific advice

- helped promote regional climate change adaptation policies by providing scientific advice, figures, and tables to be used in Local Climate Change Adaptation Plans, brochures, and websites developed by local public bodies
- participated as advisors to the seven Climate Change Adaptation Regional Councils organized by the Regional Environment Offices of the Ministry of the Environment (MOE) under the Climate Change Adaptation Act, and contributed to inter-regional cooperation with local governments.

In addition, the following projects were implemented to contribute to regional capacity building related to climate change:

- Four workshops were held in 2020 (Fig. 2) and a discussion meeting was held in October 2020 with the aim of sharing knowledge with local administrators to formulate regional climate change adaptation policies.
- The All-Japan Environmental Research Institutions Symposium was held in February 2021 with the theme of climate change adaptation, and related research was shared with regional environmental research institutes.
- In October 2020, NIES, with MOE, organized the “Third Workshop on Promoting Climate Change Adaptation by the Private Sector.” Companies, local administrators, and researchers attended the workshop to deepen their understanding and accelerate the private sector’s adaptation activities.

**Fig. 2** Participants at a workshop in 2020



## 1.2 Collecting, organizing, analyzing, and providing information related to climate change adaptation

CCCA operates the Climate Change Adaptation Information Platform (A-PLAT), a portal site for disseminating information on adaptation to the impacts of climate change (Fig. 3). The number of views of the Japanese pages of A-PLAT reached approximately 900,000 in 2020; the number of annual visitors has increased each year since the platform was launched. In addition, information on A-PLAT is being utilized in regional climate change policy-making. For example, information

provided in A-PLAT is quoted in many Local Climate Change Adaptation Plans and brochures and on websites formulated by local public bodies.

In addition, to share local actions for climate change adaptation by LCCACs, we established A-PLAT Lab, a new platform that can be used by LCCACs to exchange information on their activities.

To improve A-PLAT, we implemented the following:

- In line with the enforcement of the Climate Change Adaptation Act, in addition to posting related provisions such as the Climate Change Adaptation Plan and the Local Climate Change Adaptation Planning Manual, we renovated the website on local climate change adaptation actions including Local Climate Change Adaptation Plans and LCCACs.
- Articles were added to introduce the topic of adaptation planning efforts and highlight examples of adaptation measures.
- In the Adaptation Measures Database, examples of adaptation measures were added for reference use by local governments.
- We added case reports on Adaptation Business and Climate Risk Management to introduce adaptation efforts by private companies.
- To better understand climate change adaptation, the researchers in charge of each theme have created FAQs and started posting them on the web.

**Fig. 3** Home page of the A-PLAT website (<https://www.adaptation-platform.nies.go.jp/>)





### 1.3 International contributions to the development of an information platform for the Asia-Pacific region

In accordance with the Paris Agreement, to support adaptation planning for developing countries, we developed a prototype version of the “Asia-Pacific Adaptation Information Platform” (AP-PLAT). The platform was introduced at COP23 (the 23rd Annual Conference of the Parties to the 1992 UN Framework Convention on Climate Change) and included impact assessment data and information related to adaptation (Fig. 4). Having been given the opportunity to hold the G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth, in Karuizawa, Nagano, MOE held the AP-PLAT Launching Ceremony on 16 June 2019. New content, such as global news on climate change adaptation and information on vulnerable sectors in the Asia-Pacific region, was added to AP-PLAT.

We introduced AP-PLAT at 7th Asia-Pacific Climate Change Adaptation Forum in March 2021.

Furthermore, we supported the launch of T-PLAT (the Thailand Adaptation Information Platform), and provided scientific information on climate risk for Indonesia, Laos, and Myanmar.

ISO/TS 14092 (Adaptation to climate change—Requirements and guidance on adaptation planning for local governments and communities), which our staff edited as coordinators, was published in May 2020. It supports local governments and communities in adapting to climate change on the basis of vulnerability, impacts, and risk assessments.

**Fig. 4** Home page of the AP-PLAT website (<https://ap-plat.nies.go.jp/index.html>)



## 1.4 Contribution to climate change policy

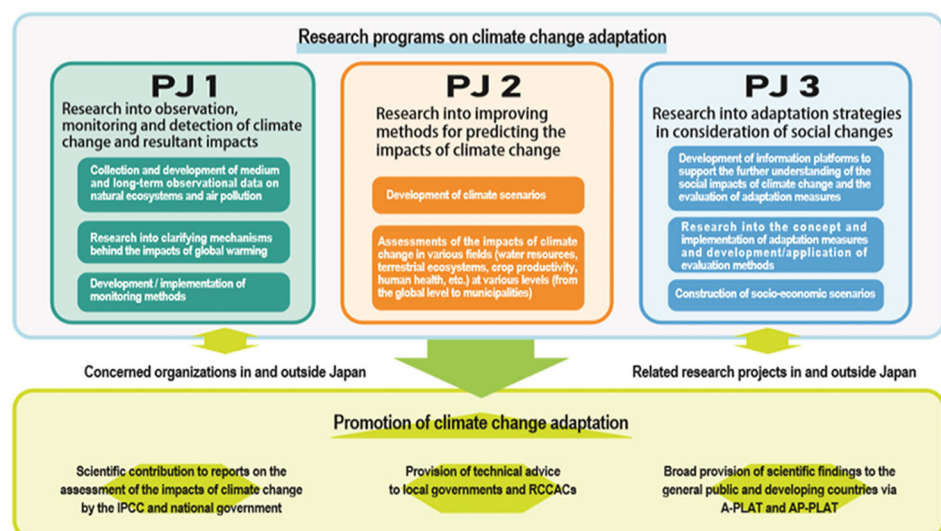
We managed a Study Team to Promote Climate Change Impact Observation and Monitoring and a Study Team to Collaborate and Promote Climate Change Projection and Impact Assessment, each of which comprises a group of experts. The first study team produced a report titled “Direction of Strategic Observations and Monitoring for Climate Change Impacts,” which described the direction of sectoral issues and solutions for climate change impacts, and the second produced a report that organized issues and approaches to climate change projection and impact assessment. The fruits of these two teams were also reflected in the Climate Change Impact Assessment Report, published in December 2020 by MOE. The reports were used as references for climate change policy-making.

Center staff members participated in deliberative councils and investigative conferences, such as Assessment Subcommittees of the Central Environment Council, and helped to promote climate change policy.

## 2. Climate change impact and adaptation research

We consolidated research into climate change impacts and adaptation. We also organized research programs to advance climate change adaptation research and development in an integrated manner and support climate change adaptation activities by national and regional governments. The program consists of three research projects; these are outlined in Figure 5 and discussed below.

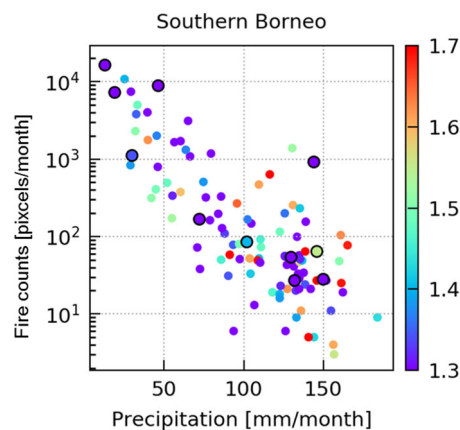
**Fig. 5** Structure of our research projects



## 2.1 Observation, monitoring, and detection of climate change and resultant impacts (PJ1)

To evaluate the impact of climate change on biodiversity and ecosystem processes, we collected data on ecosystem monitoring through the networks with universities and research institutes that we have built in past years. The targets of monitoring were terrestrial ecosystems, lake ecosystems, closed marine ecosystems, coastal ecosystems, and marine ecosystems. Satellite images were also used to monitor large-scale events. By using these data, we conducted a statistical analysis and confirmed that climate change has significant effects on the flora and fauna of multiple ecosystems and on disturbance regimes such as forest fires (Fig. 6). Furthermore, we conducted experiments to clarify the temperature effects on ecosystems and began to elucidate the mechanism of climate change effects.

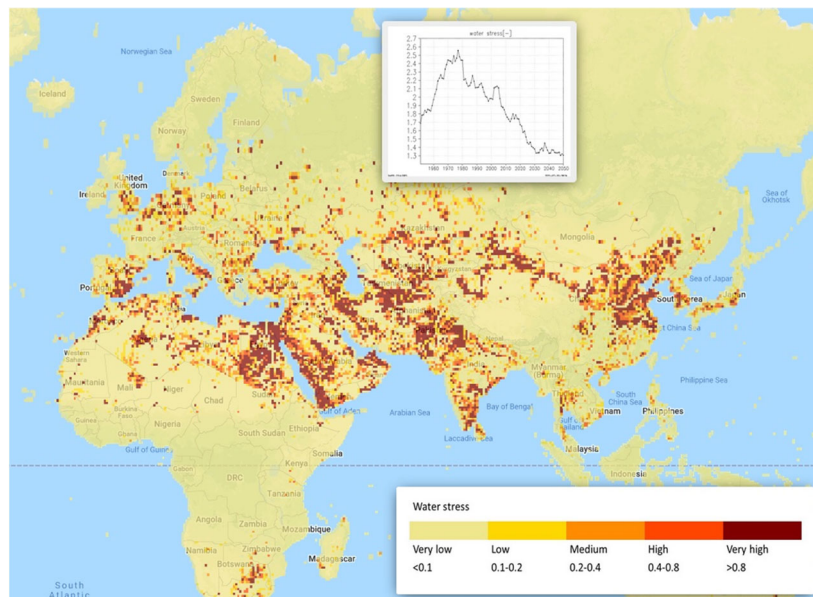
**Fig. 6** Relationship between monthly precipitation and forest-fire risk in southern Borneo



## 2.2 Enhancing methods for predicting the impacts of climate change (PJ2)

We worked on seven sub-projects to conduct climate change impact assessments at multiple scales (e.g. global, Asia-Pacific region, Japan, and local government) and across multiple sectors (e.g. water resources (Fig. 7), ecosystems, crop yields, and human health). To conduct cross-sectoral climate change impact assessments, we need reliable climate scenarios. We developed a set of new climate scenarios covering all of Japan at a spatial resolution of 1 km by statistically downscaling five latest CMIP6 (Coupled Model Intercomparison Project Phase 6) global climate models. We also started to provide a regular service to distribute various climate scenarios to a wider range of users.

**Fig. 7** Screen shot of the H08 water risk tool displaying the water stress of the world



### 2.3 Adaptation strategies in consideration of social changes (PJ3)

Project 3 consists of eight research themes with common ultimate objectives, namely (1) understanding the gaps that exist among adaptation planning, scientific knowledge, and adaptation implementation; and (2) exploring effective adaptation strategies for filling the gaps.

For example, as a part of analyses of climate change impacts on energy systems, we estimated the maximum impacts of climate change on electricity consumption and demand in the various regions across the climate zones of Japan from 2020 to 2080. Although nationwide total yearly consumption was predicted to increase by approximately 1.8% (0.3–3.0%) from 2020 to 2080, the increase in demand during the hot seasons was significant, as much as 14.2% (10.7–18.0%). The net impact was determined by the balance between the increase in electricity demand for cooling and the decrease in electricity demand for heating.



# Basis for Environmental Research

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### **Center for Global Environmental Research**

Global environmental change is an essential threat to a sustainable society and human life. Climate change, including global warming caused by increasing atmospheric greenhouse gas (GHG) concentrations, together with changes in the stratospheric ozone, is having serious impacts on all ecosystems and on humans. Considering the predicted impacts, it is urgent that we take measures to conserve the global environment so as to establish a sustainable society with lower emissions of GHGs. We must adopt a long-term perspective and recognize the importance of mid- and long-term continuous research because a lot of time is needed for the effects of climate change mitigation options to manifest.

The Center for Global Environmental Research (CGER) conducts strategic environmental monitoring across the atmospheric, oceanic, and terrestrial domains and distributes the resulting data through environmental databases to assess climate change and its impacts on society. CGER also implements proactive and predictive research on the global environment, develops new technologies, and conducts pioneering and fundamental research, especially in the field of climate change. CGER supports collaborative studies among domestic and international organizations, disseminates the scientific findings, and facilitates mutual understanding to raise public awareness of global environmental problems.

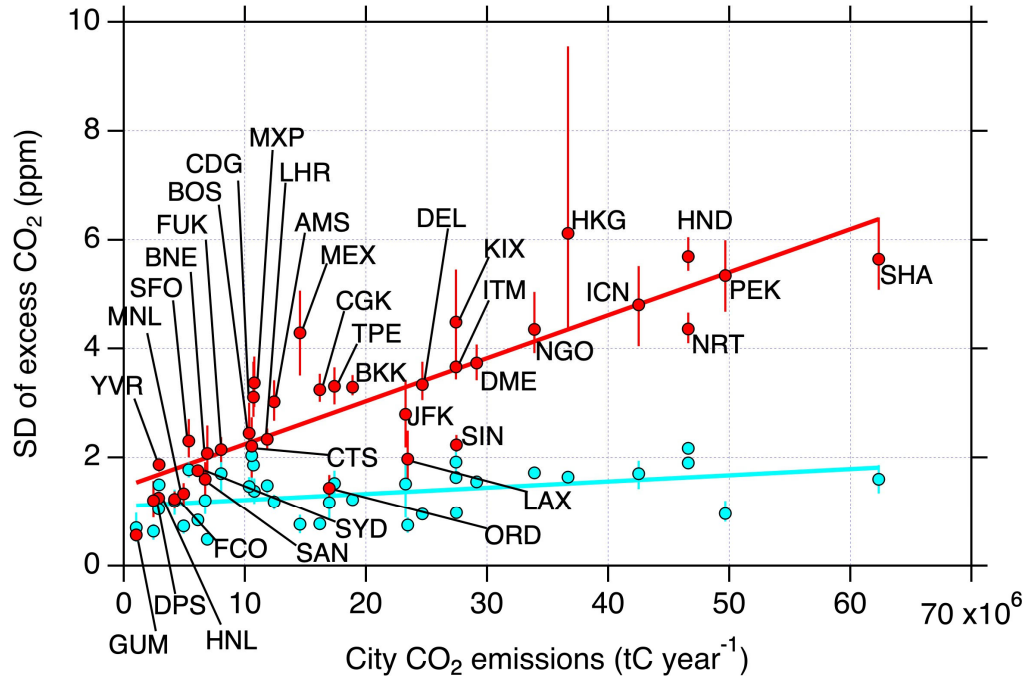
#### **1. CO<sub>2</sub> emissions signals from cities observed by commercial airliners**

Monitoring GHG emissions from cities is an important capability for supporting climate change mitigation activities in response to the Paris Agreement. Atmospheric CO<sub>2</sub> measurement data have been collected from different platforms, such as ground sites, aircraft, and satellites, to establish a science-based monitoring capability. The CONTRAIL (Comprehensive Observation Network for TRace gases by AirLiners) program has continued high-precision atmospheric CO<sub>2</sub> measurements using instruments onboard JAL (Japan Airlines) commercial airliners. As many airports are located close to large cities, measurement data from thousands of ascending and descending flights over airports were analyzed to characterize CO<sub>2</sub> emission signals from cities. At many airports worldwide, significant flight-to-flight variations in CO<sub>2</sub> enhancement were observed downwind of neighboring cities, and the observed CO<sub>2</sub> variability increased with decreasing altitude. The magnitude of CO<sub>2</sub> variability near the ground (~1 km altitude) at an airport was positively correlated with the intensity of CO<sub>2</sub> emissions from the nearby city (Fig. 1). Despite various factors that could contribute to CO<sub>2</sub> variability over airports, such as the upwind pattern of CO<sub>2</sub> emissions and uptakes, flight paths and their geographical positions relative to the locations of emissions and uptakes, and meteorological conditions during each flight, the relationship suggests that the intensity of nearby CO<sub>2</sub> emissions is the primary contributor to the magnitude of the observed CO<sub>2</sub> variability. This result shows that commercial-airliner-based CO<sub>2</sub>



measurements, when combined with an atmospheric modeling framework, can consistently provide anthropogenic emission estimates from cities.

**Fig. 1**  
Relationship of the standard deviation (SD) of CO<sub>2</sub> enhancements at altitudes of 1.0 to 1.5 km (red) and 4.0 to 4.5 km (light blue) and city CO<sub>2</sub> emissions based on the ODIAC (Open-source Data Inventory for Anthropogenic CO<sub>2</sub>) anthropogenic CO<sub>2</sub> emissions dataset. The acronyms represent airport names.



**Reference:**

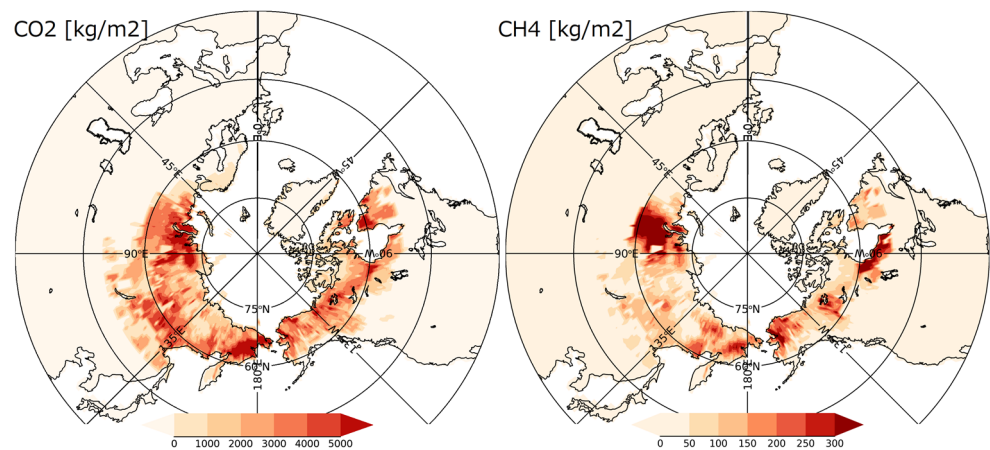
Umezawa T., Matsueda H., Oda T., Higuchi K., Sawa Y., Machida T., Niwa Y., Maksyutov S. (2020) Statistical characterization of urban CO<sub>2</sub> emission signals observed by commercial airliner measurements. *Scientific Reports*, 10(7963) doi:10.1038/s41598-020-64769-9

**2. GHG emissions from permafrost degradation**

Permafrost degradation is expected to cause GHG emissions, but many Earth system models for projecting future climate change have not yet incorporated this process. Therefore, we developed a model to evaluate the GHG emissions due to permafrost thawing, and we conducted numerical experiments for future projection. In general, the decomposition of organic matter in permafrost releases CH<sub>4</sub> in anaerobic soil environments such as wetlands, and mainly CO<sub>2</sub> in aerobic environments. Our model simulations showed that the total estimated GHG emission from permafrost degradation under the RCP8.5 scenario was 31 to 63 PgC for CO<sub>2</sub> and 1261 to 2821 TgCH<sub>4</sub> for CH<sub>4</sub> (68th percentile of the perturbed model simulations, corresponding to a global average surface air temperature change of 0.05 to 0.11 °C). Under the RCP2.6 scenario, the corresponding values were 14 to 28 PgC for CO<sub>2</sub> and 618 to 1341 TgCH<sub>4</sub> for CH<sub>4</sub> (0.03 to 0.07 °C). An advantage of our model is that the geographical distributions of GHG emissions can be estimated by combining a state-of-the-art land surface model featuring detailed

physical processes with a GHG release model using a simple scheme, enabling us to consider a broad range of uncertainty regarding model parameters. In regions with large GHG emissions due to permafrost thawing, it may be possible to help reduce GHG emissions by taking measures such as restraining land development (Fig. 2).

**Fig. 2**  
Cumulative greenhouse gas (CO<sub>2</sub> and CH<sub>4</sub>) emissions from permafrost thawing under the RCP8.5 scenario, in which greenhouse gas emissions would continue to increase in the future, up to 2100. The unit is the amount released per unit area [kg/m<sup>2</sup>]. CH<sub>4</sub> is easily generated in anaerobic environments such as wetlands, whereas CO<sub>2</sub> is likely to be generated in aerobic environments.



#### Reference:

Yokohata T., Saito K., Ito A., Ohno H., Tanaka K., Hajima T., Iwahana G. (2020) Future projection of greenhouse gas emissions due to permafrost degradation using a simple numerical scheme with a global land surface model, *Progress in Earth and Planetary Science*, 7, 56, <https://doi.org/10.1186/s40645-020-00366-8>

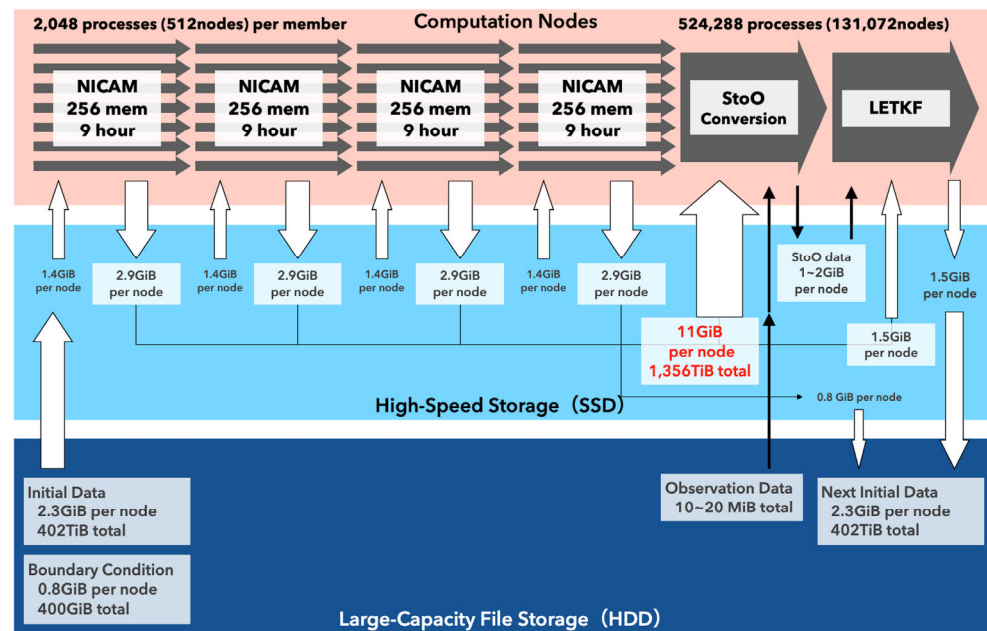
### 3. Grand challenge experiment on high-resolution large-ensemble atmospheric data assimilation

Improving spatial resolution is an important factor in improving prediction performance by atmospheric simulation. In addition, increasing the number of ensembles has recently become more important in improving the accuracy of prediction and inverse analysis by using ensemble-based data assimilation (DA). We have improved our simulation model and ensemble DA system in collaboration with the development of the supercomputer Fugaku. Fugaku is the new Japanese flagship machine that won first place in the world rankings of four categories of computational performance in 2020. We achieved a DA experiment with a global 3.5-km mesh and a 1024-member ensemble using 82% of Fugaku's compute nodes. This was the largest-ever meteorological calculation—more than 500 times the size of the operational weather DA system run by the world's national weather centers. Figure 3 shows the flow of the calculation and the amount of data input and output for each calculation. The first step is to run 256-member simulations by using NICAM (Nonhydrostatic ICosahedral Atmospheric Model); these are performed four times to obtain the 1024-member ensemble results. The total number of grid

points is about 4.4 trillion. In the subsequent DA part based on the Local Ensemble Transform Karman Filter (LETKF), 1.4 petabytes of output data were read all at once and analyzed. This series of calculations corresponds to one DA cycle. We have demonstrated that the calculations can be completed within 4 h by using Fugaku’s 131,072 nodes (6,291,456 computer cores). At the time, the effective computing performance of the simulation part was 29 petaflops, and that of the DA part was 79 petaflops.

The calculations we have achieved by using the DA system named NICAM-LETKF embody the future of weather forecasting services. DA is useful not only for weather forecasting but also for estimating the amount of GHGs absorbed and emitted by terrestrial ecosystems and cities, as well as optimizing the tunable parameters of submodels in climate models. In such usage, our DA system can further improve the accuracy of estimation. The paper summarizing this achievement was selected as the 2020 finalist for the ACM Gordon Bell Prize, one of the most prestigious awards in computational science.

**Fig. 3**  
Data flow diagram of NICAM-LETKF with a 3.5-km mesh and 1024-member ensemble. The calculation proceeds from left to right, and the arrows represent the amount of data movement during input and output. Data files move between large-capacity file storage, which consists of hard disk drives (HDDs), and high-speed storage, which consists of solid-state drives (SSDs). (modified from Yashiro et al., 2020)



**Reference:**

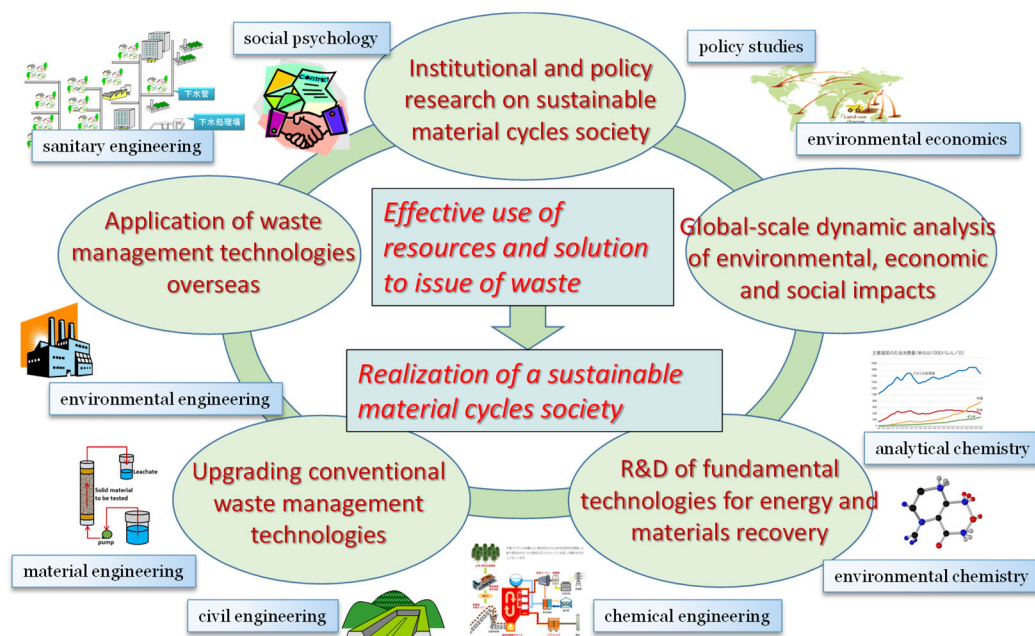
Yashiro H., Terasaki K., Kawai Y., Kudo S., Miyoshi T., Imamura T., Minami K., Inoue H., Nishiki T., Saji T., Satoh M., Tomita H. (2020) A 1024-member ensemble data assimilation with 3.5-km mesh global weather simulations. In *SC20: International Conference for High Performance Computing, Networking, Storage and Analysis (SC)*, Atlanta, GA, US, 2020 pp. 1–10. doi: 10.1109/SC41405.2020.00005

**Center for Material Cycles and Waste Management Research**

The Center for Material Cycles and Waste Management Research conducts a variety of studies to establish a political and academic base in the fields of materials cycling and waste management (Fig. 1). Currently our focus is the present state of, and mechanisms behind, the structure of material flows and the associated environmental burdens imposed by socioeconomic activities at local to international scales.

We intend to propose assessment methods and strategies for shifting to a sustainable, sound material-cycle society. We are also evaluating technologies and systems for treating and recycling waste and recyclable materials in Japan and other countries, and we are developing fundamental technologies for materials recycling and substance control in waste treatment and recycling processes.

**Fig. 1** Outline of fundamental research in material cycles and waste management



**1. Institutional and policy research on systems and measures for shaping a sound material-cycle society**

We analyzed the results of SCP (sustainable consumption and production) co-design workshops held the previous year. We found that the viewpoints of consumers and providers are important for idea generation, and that culture, infrastructure, and industry are major considerations for regional SCP policy. We then held an additional workshop with Thai SCP experts and discussed the implications and recommendations for Thai SCP policy. Policy implications include the following two. First, sustainability transitions, improvement of both quality of life and environmental performance, and digitalization offer important opportunities for SCP patterns in Bangkok and elsewhere. Second, SCP policies involve broader

considerations than conventional environmental policy instruments, and expansion of the scope of SCP policy should be discussed more by policymakers in Thailand and emerging economies that are experiencing compressed development. This larger focus is especially relevant when both industrialization and de-industrialization, as well as modernization and post-modernization, occur simultaneously.

In addition, considering the fact that the coronavirus has substantially influenced and changed consumption and production patterns across the world, we held another workshop to discuss SCP policy in the post-COVID period. Forty-eight changes in consumption and production patterns were identified, and the participants considered that about half of them would become the new normal, whereas the rest would return to the old normal. Consumption and production patterns in the domains of working and doing housework would more or less return to the old normal.

In another study, we surveyed the factors influencing collective pro-environmental behavior. These factors had been surveyed in Japan the previous year, but this year we targeted the Thai people. We found that behavioral intention toward collective pro-environmental behavior was higher in Thai people than it was in Japanese people. So was their satisfactory level of satisfaction with their collective behaviors was also higher. In Japan, it is important to create opportunities for collective behaviors that can increase people's their level of satisfaction with collective behaviors level.

### **2. Dynamic analysis of international material cycles and assessment of their environmental, economic, and social impacts**

It has been observed that market failure has hampered the development of sustainable forest ecosystem services such as CO<sub>2</sub> absorption and fixation, water retention, and biodiversity. One of the reasons for this is that the link between forest land use and the beneficiaries of that use has not been widely recognized or clearly established. To address this problem, we conducted a footprint analysis to clarify the linkage between Japanese taxpayers as the beneficiaries of forest land use and the use of tax revenue and monetary donations for forest management. This study focuses on how the current forest tax collected from Japanese taxpayers (63 billion Japanese yen per year) could be allocated more fairly. At the core of our analysis, we examined the carbon footprint and established a linkage between the origins and destinations of CO<sub>2</sub> emissions in Japan by using a subnational multiregional input–output database and building a base table focused on various land-use types and subnational regions at the municipality level. By clarifying these linkages and enhancing their transparency, we will provide a basis for developing alternative financing schemes involving both taxation and taxpayer donations in support of forest management activities and protection of biodiverse habitats.

We also estimated the CO<sub>2</sub> emissions produced by more than 40,000 international flights associated with Japan's two major airlines (Japan Airlines and All Nippon Airways), and we identified the drivers of these CO<sub>2</sub> emissions by using an index decomposition analysis conducted between 2005 and 2015. The results showed that introducing the more fuel-efficient Boeing 787 led to CO<sub>2</sub> emission reductions of 1.3 million tonnes by the two companies. However, these reductions were canceled out by an increase in the total number of flights and distances per passenger attributable to the airlines' operations. We concluded that the environmental and business strategy of introducing greener aircraft with better fuel efficiency was insufficient for mitigating the effects of aircraft emissions on climate.

### **3. Developmental and survey research on various types of fundamental technologies required for resource recycling and materials management**

We have been developing a method to prepare spherical nanosized particles of five major polymers (low-density polyethylene, high-density polyethylene, polypropylene, polyvinyl chloride, and polystyrene) without using any potential impurities, for the purpose of nanoplastics study.

To help promote environmentally sound management of waste containing new POPs (persistent organic pollutants), we developed simple quantitative methods for brominated flame retardants and chlorinated paraffins in plastic waste; international inter-laboratory studies of these methods were also conducted. We have started to conduct a survey of the environmental emissions of these compounds from a series of waste treatment facilities via fragmented plastics (microplastics).

We used both active and passive air-sampling methods to determine the particulate- and gas-phase concentrations of short- (SCCPs) and medium-chain chlorinated paraffins (MCCPs) and organophosphorus flame retardants (OPERs) in ambient air outside and inside both an automobile shredder-residue-processing facility and a waste plastic recycling facility. A comparison of concentrations among sampling points revealed some of the emission sources in the two facilities. In addition, the distributions of three chemical groups between both gas and particulate phases were analyzed. The analysis revealed that SCCPs with a lower molecular weight tended to exist in gas phase, whereas SCCPs with a higher molecular weight, as well as MCCPs and OPERs, existed in particulate phase.

We measured and predicted the physicochemical properties of the three chemical groups, and we have been applying an indoor-fate model to three waste recycling plants to estimate the emissions of SCCPs, MCCPs, and OPERs from the plants to the environment. Furthermore, we used the model to evaluate how a local ventilation device installed around a process that produced solid fuel from waste plastic flakes and constituted a major emission source was able to reduce emissions to the environment.

### **4. Advancement of testing and evaluation management systems related to landfill disposal and the use of waste as construction materials**

As part of the development of a method for determining the origin of toxic element contained in soil, we have completed developing a “repetitive reduction extraction method” focusing on arsenic as the target element. Additional studies on the application of this method to other elements have been started, with the aim of incorporating it in the Soil Contamination Countermeasures Law Guidelines as a method of determining contaminant origins. Regarding the column percolation test method, preparations for JIS (Japanese Industrial Standards) conversion were started in 2020, following the establishment of ISO (International Organization for Standardization) in September 2019. To control the highly alkaline solutions generated from incinerator ash and cement-improved soil, we continued to elucidate the mechanism of high-pH-liquid generation and soil neutralization, focusing on ion balance. Through on-site verification tests, we proposed a method of calculating the scale requirement of the inland water pond by using the concept of CO<sub>2</sub> absorption flux and reaction rate. In addition, a database of the construction and maintenance costs of final disposal sites constructed after 2008 was created from a questionnaire survey.

### **5. Fundamental research into the application of waste management technologies in Japan and overseas**

We are studying fundamental technological issues associated with the improvement of waste management systems in Japan and Asia. In FY 2020, our studies included the following.

We conducted bench-scale experiments of *Johkasou*, a household wastewater treatment system. We revealed that relatively low nitrogen removal efficiency could occur because of the depletion of organics in households with small numbers of occupants. The concentrations of greenhouse gases—especially methane—were highly dependent on the number of household members.

For sustainable management of construction and demolition waste in Vietnam, economic parameters on the use of recycled concrete aggregate (RCA) were collected, and fundamental studies leading to the proposal of a business model were conducted. Indicators such as the net present value and the internal rate of return were revealed to be strongly influenced by the sales price of RCA. An examination of technologies identified the procurement of waste concrete and bricks as raw materials as a key parameter for implementing a project based on fixed-location (i.e. centralized) treatment. In contrast, site selection to minimize transportation distances and the costs of procuring heavy machinery was identified as a key parameter for a project based on mobile treatment.

We confirmed that sulfur-oxidizing bacteria accelerated the deterioration of the products of sulfur polymer stabilization/solidification of elemental mercury and caused the volatilization of mercury. Furthermore, the rate and amount of mercury volatilization were shown to vary with the species of sulfur-oxidizing bacteria.

We investigated the biodegradability of OPFRs and decabrominated diphenyl ether (DBDE) in anaerobic digestion of the organic fraction of municipal solid waste. DBDE was very persistent, whereas OPFRs were readily degraded to methane by anaerobic microorganisms. DBDE was degraded only to lower brominated congeners such as hepta- and octa-BDEs. The rate of debromination was higher under thermophilic conditions than under mesophilic conditions.

### **6. Waste management research collaboration and research into practice projects with Asian countries**

We conducted a study of solid waste management in drains and waterways for flood prevention in urban Asia (Fig. 2). Waste management in low-income communities along Bangkok's waterways was studied in collaboration with Thammasat University as an action research project. We analysed residents' behaviors that led to unintentional discharge of waste into the canals. Public participation in the proper administration of waste management was promoted in the communities.

We participated in technical committees for both ISO TC297 (Waste Collection and Transportation Management) and TC300 (Solid Recovered Fuels). We used our expertise to chair, and provide advice to, Japanese mirror committees, and we proposed new standards and led discussions on their standardization processes at ISO committees. In addition, we shared our knowledge of standardization with emerging Asian countries.

A comparative analysis of decentralized wastewater management within the ASEAN region was conducted by examining the technology and institutional systems in each member states. Policy dialogues were held for local and national practitioners and policymakers on the proper operation, maintenance, and certification of decentralized systems. Existing issues and possible solutions in each relevant sector were assessed, and the policy recommendations and regional policy roadmaps were adopted. Appropriate management of the composition of construction and demolition waste (CDW) in Vietnam was examined as a JICA (Japan International Cooperation Agency)/JST (Japan Science and Technology Agency) SATREPS (Science and Technology Research Partnership for Sustainable Development) study, and a collaborative activity to promote CDW recycling was initiated between the local administration and experts, including NIES researchers.



#### **Center for Health and Environmental Risk Research**

The Center for Health and Environmental Risk Research conducts research in the Environmental Risk Research Field and Environmental Health Research Field. The two research fields form the basis of two projects administered by the Risk Assessment Science Collaboration Office (RASCO) and the Japan Environment and Children's Study (JECS). The Center leads the Health and Environmental Safety Research Program with other research centers. Here, we report the current outcomes of research in the environmental risk and environmental health research fields.

#### **1. Upgrade of ecotoxicity testing and development of a novel system to evaluate the ecotoxicological effects of chemicals**

We continued our collaboration with the quantitative structure–activity relationship (QSAR) research team at the University of Gdansk, Poland, to develop ecotoxicity prediction models by using a category approach with a kernel-weighted local polynomial approach algorithm, which was demonstrated to be better than the k-nearest-neighbor approach tested the previous year. We also conducted a study on the interface between science and policy in the context of evidence-based policy-making practice (EBPM).

To improve the ecological risk assessment of insecticides, we conducted water-spiked sediment toxicity tests with a chironomid (*Chironomus yoshimatsui*) and compared the results with those of a water-only acute immobilization test to better determine the acute to chronic ratio. We also continued to conduct short-term chronic toxicity tests in a green alga and a daphnid (*Ceriodaphnia dubia*) and in zebrafish (*Danio rerio*) embryos for an additional 10 selected human pharmaceuticals. The toxicity values were compared with the QSAR predictions in collaboration with National Institute of Health Sciences. Finally, we conducted literature reviews of adverse outcome pathways in the field of ecotoxicology.

We also conducted a comprehensive transcriptomic analysis by using RNA-seq on various strains of *Daphnia magna* and the green alga *Raphidocelis subcapitata*. A gene ontology analysis was conducted to investigate the sensitivity of physiological functions such as ecdysis in the daphnid to specific chemicals; mutations in the gene encoding small-conductance mechanosensitive ion channels may lead to protein truncation and loss of function.

#### **2. Fundamental study of integrated approaches to assessing chemical exposure and environmental effects**

We are comprehensively analyzing the relationship between chemical exposure and effects on humans and organisms by investigating PM<sub>2.5</sub> (particles with a diameter of 2.5 μm or less) and their carcinogen-related activities (i.e., DNA damage).

Evaluations of the DNA damage caused by PM<sub>2.5</sub> samples that were collected from various sites or experimentally generated revealed that carcinogen-related activities from diesel particles were high, whereas those of particles from cooked samples were poor. By using these data, we estimated the contributions of different PM<sub>2.5</sub> sources to the overall toxicity of urban PM<sub>2.5</sub> samples and confirmed that the contribution of automobile exhausts was high, followed by the influence of open burning. In addition, we measured PM<sub>2.5</sub> concentrations in the atmosphere in Yangon by using an improved device that embeds GPS and data logger functions in a small, commercially available PM<sub>2.5</sub> sensor. Concentrations during the COVID-19 lockdown period were significantly lower than before the period. There is a need to verify the seasonal differences in concentrations, and we are continuing to measure them locally. Notably, long-term measurement led to some problems, including missing data, and we recognized the need for further improvement. In addition to the PM<sub>2.5</sub> research, we developed an analytical method to measure the freely dissolved concentrations of hydrophobic chemicals in sediment pore water, which are useful to evaluate exposure of benthic organisms to chemicals. We also investigated the environmental properties of new persistent organic pollutants experimentally and theoretically for the purpose of understanding their environmental behavior.

#### **3. Consecutive sexual maturation observed in a rock shell population near the Fukushima Daiichi Nuclear Power Plant, Japan**

In 2012, after the accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP) that followed the Tohoku earthquake and tsunami in March 2011, no specimens of rock shell (*Thais clavigera*; currently recognized as *Reishia clavigera*; Gastropoda, Neogastropoda, Muricidae) were found near the plant from Hirono to Futaba Beach (a distance of approximately 30 km). In July 2016, however, rock shells were again found to be inhabiting the area. From April 2017 to May 2019, we collected rock shell specimens monthly at two sites near the FDNPP (Okuma and Tomioka) and at a reference site about 120 km south of the FDNPP (Hiraiso). We examined the gonads of the specimens histologically to evaluate their reproductive cycle and sexual maturation. The gonads of the rock shells collected at Okuma, about 1 km south of the FDNPP, exhibited consecutive sexual maturation during the 2 years from April 2017 to May 2019, whereas sexual maturation of the gonads of specimens collected at Hiraiso was observed only in summer (Fig. 1). The consecutive sexual maturation of the gonads of the specimens collected at Okuma might not represent a temporary phenomenon but rather a site-specific phenotype, possibly caused by specific environmental factors near the FDNPP.

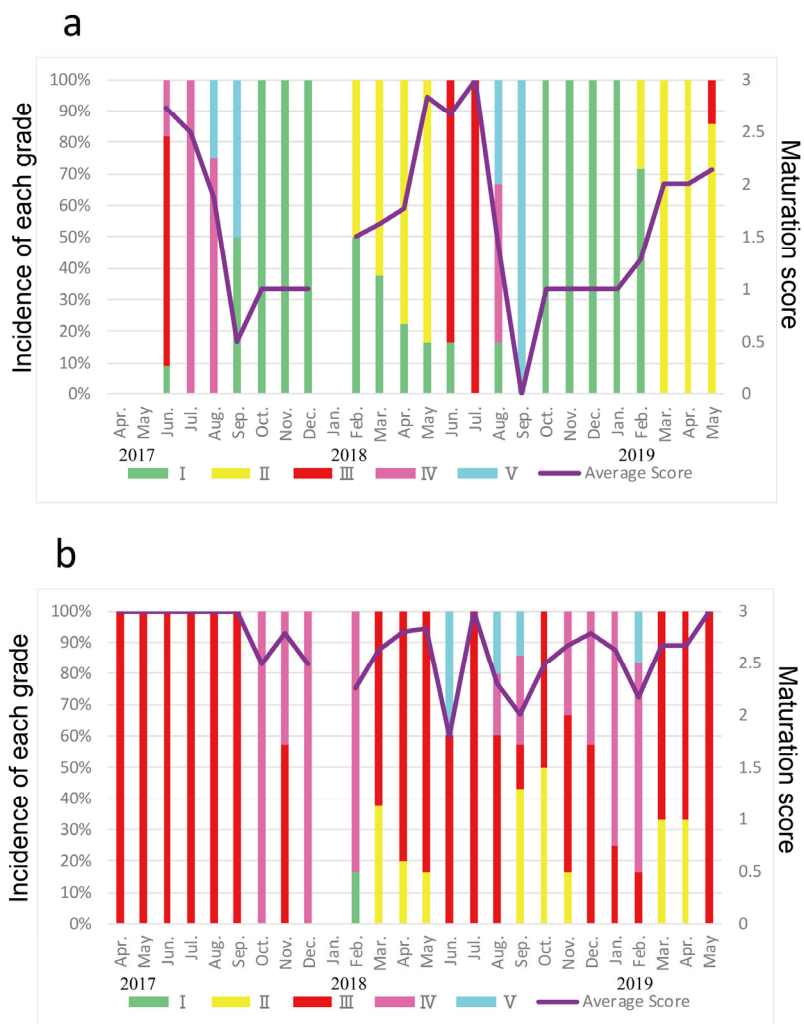
#### **Reference:**

Horiguchi T., Kawamura K., Ohta Y. (2021) Consecutive sexual maturation observed in a rock shell population in the vicinity of the Fukushima Daiichi Nuclear Power Plant, Japan. *Scientific Reports*, 11, 560. doi:10.1038/s41598-020-80686-3; licensed under Creative Commons Attribution 4.0 International License

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**Fig. 1**  
Time series of maturation scores (purple line) and developmental grades (colored vertical bars) of female *Thais clavigera* at (a) Hiraiso and (b) Okuma. Grade I: Recovery stage; Grade II: Active stage; Grades III and IV: Mature stage; Grade V: Spent stage

(Horiguchi et al. 2021, licensed under CC BY 4.0; this figure is a partial modification of the original)



#### 4. Basic study for strategic risk management

We are studying the factors that are important for modeling the environmental fate and emissions of chemicals; assessing exposure to, and risks posed by, environmental chemicals; assessing the ecological impacts of environmental disturbances; and systematically managing the risks to health and the environment posed by environmental chemicals, while taking into consideration the many risk factors.

This fiscal year we performed studies on modeling the global fate of mercury; the behavior of chemicals by using multimedia environmental fate models (G-CIEMS and FATE); the emission of additives from products; environmental monitoring and risk management during and after accidents and natural disasters; the bioaccumulation of chemicals in the aquatic environment; the impacts of chemicals

on the community structures of benthic animals in the field; and the management of wild mammals in cooperation with local governments. We utilized the results as the basis for research projects in Issue-Oriented Research Programs and for projects related to the strategic management of risks. In our multimedia model study, we revised the G-CIEMS by incorporating the sewerage network and sewage treatment, and we validated the revised model by using linear alkylbenzene sulfonates, the major part of the load of which to rivers comes from household applications. Comparison with the concentrations measured nationwide in rivers demonstrated improved accuracy of the model.

#### **5. Fundamental study of integrated health-risk evaluation**

This fundamental study aims to develop advanced toxicity evaluation methods and biomarkers of neurotoxicity, immunotoxicity, reproductive and developmental toxicity, genotoxicity, and inhalation toxicity on the basis of the physicochemical characteristics of harmful environmental substances such as nanomaterials, PM2.5, metals, and microplastics.

PM2.5 exposure is considered a potential risk factor for pulmonary and cardiovascular diseases, including lifestyle-related diseases such as high blood pressure and diabetes, allergy, and tumors. Subpopulations of T cells influence the pathophysiology of these diseases. To investigate the effect of PM2.5 exposure on T-cell differentiation during mammalian developmental stages, we examined the expression of transcription factors specific to each T-cell subpopulation in the thymus and lungs of mice that inhaled diesel exhaust during the fetal and neonatal periods. Expression of the genes *Foxp3*, *Rorc*, and *Tbx21* was markedly suppressed, and the expression of *Gata3* was significantly increased, in the thymus. These results suggest that diesel exhaust exposure during the fetal and neonatal periods may promote the differentiation of Th2 subpopulations.

#### **6. Genome-wide DNA methylation analysis in cord blood DNA of pregnant women in an area with high PM2.5 concentrations**

Particulate matter pollution has been shown to cause a number of health-related deleterious effects, including cardiovascular, respiratory, and neurological effects as well as adverse birth-related outcomes. PM2.5 exerts deleterious effects not only on adult humans exposed to it directly but also on children exposed prenatally. In this study, we investigated the genome-wide DNA methylation profiles of cord blood DNA of pregnant woman in an area with high PM2.5 concentrations, with the aim of developing DNA methylation makers to detect health effects in children exposed gestationally to PM2.5. Concentrations were measured with a Pocket PM2.5 Sensor (Yaguchi Electric Co., Ltd., Miyagi, Japan) in Yangon (a city with high PM2.5 concentrations) and Taunggyi (a city in Myanmar with low PM2.5 concentrations). We performed reduced representation bisulfite sequencing (RRBS) by using a next-generation sequencer. We detected about 7000 hypo-differentially

methylated cytosines (hypoDMCs) and hyper-differentially methylated cytosines (hyperDMCs); between the area of high PM<sub>2.5</sub> concentrations and that of low PM<sub>2.5</sub> concentrations, the differences in methylation in both hypoDMCs and hyperDMCs were not less than 25%. In addition, we found that hypoDMCs and hyperDMCs are enriched in short interspersed nuclear element (SINE) retrotransposon regions in the cord blood DNA of pregnant woman in the area with high PM<sub>2.5</sub> concentrations. These results suggest that DNA methylation changes in the SINE regions of cord blood DNA could be useful markers for health assessment in PM<sub>2.5</sub> exposure. Additional studies will be needed to clarify the association between PM<sub>2.5</sub> exposure during pregnancy and the risk of deleterious effects in children.

#### **7. Fundamental evaluation of the health impacts of environmental factors**

This fundamental study aims to develop methodologies for evaluating the neuropathological and social behavioral effects of environmental factors. Its goal is to help identify health-threatening chemicals, reduce the adverse effects of environmental chemicals, and develop precautionary approaches to these threats.

Disabilities in sociality and communication are typical signs of autism, the prevalence of which is suspected to be related to environmental factors. We previously revealed aberrant ultrasonic vocalization and disability in adaptation to novel environments in genetically modified mice with autism-like signs. This fiscal year, we examined the details of behavioral abnormalities in mice that lacked either vasopressin 1a or 1b receptors or both, and we analyzed the patterns of the aberrant behaviors induced by abnormalities of the genes encoding these receptor. Developmental exposure to diesel-exhaust-derived secondary organic aerosol (DE-SOA) produces significant effects on social behaviors in rats. This fiscal year, we observed an increase in glutamate concentrations in the frontal cortex of rats exposed developmentally to DE-SOA, suggesting that this substance causes developmental neurotoxicity. We also studied a system that measured membrane potential and calcium influx in neurons induced from mouse embryonic stem cells to evaluate the effects of chemicals on neural activity. In addition, we observed that diphenylarsenic acid influenced extracellular dopamine levels in the mouse striatum in a biphasic dose-response relationship.

#### **8. Method development and application for quantifying environmental exposures**

It is essential for understanding human disease etiology to determine human exposure to environmental factors. We have been developing quantitative methods of determining environmental exposure by using biomonitoring, pharmacokinetic modelling, and exposure modelling. To build pharmacokinetic models of chemical substances in personal care products (PCPs), we conducted an interventional study that introduced predesigned meals and PCPs to participants for a week, followed by

blood and urine samplings. Collected samples were analyzed for chemicals such as parabens and phthalates. Meals, PCPs, and biological samples were archived for further studies.

#### **9. Adverse health effects of ambient air pollution**

We conducted a case-control study to investigate the association between short-term exposure to PM<sub>2.5</sub> and the incidence of out-of-hospital cardiac arrests (OHCAs) of cardiac origin (Kojima et al. 2020). In total, 103,189 OHCAs witnessed by bystanders were included in the final analysis. Point estimates of the percentage increase in OHCA after a 10- $\mu\text{g}/\text{m}^3$  increase in PM<sub>2.5</sub> with a lag of 0 – 1 (the difference in mean PM<sub>2.5</sub> concentrations measured on the case day and 1 day before) demonstrated a significantly higher incidence of OHCA (1.6% increase; 95% CI, 0.1% to 3.1%). An initial nonshockable rhythm, such as pulseless electrical activity and asystole, was associated with PM<sub>2.5</sub> exposure (1.4% increase; 95% CI, 0.1% to 2.7%). These findings suggest that increased PM<sub>2.5</sub> concentrations are associated with an increased incidence of bystander-witnessed OHCA of cardiac origin that commonly presents with a nonshockable rhythm.

#### **Reference:**

Kojima S., Michikawa T., Matsui K., et al. (2020) Association of fine particulate matter exposure with bystander-witnessed out-of-hospital cardiac arrest of cardiac origin in Japan. *JAMA Network Open*, 3(4):e203043. doi: 10.1001/jamanetworkopen.2020.3043.

### **Center for Regional Environmental Research**

Human activities have a substantial impact on both human life and ecosystems through environmental media such as the atmosphere, water, and soil. To provide a sound scientific basis for minimizing the environmental impacts of human activities, the Center for Regional Environmental Research is investigating the mechanisms by which regional environmental issues develop at multiple scales (local, urban, and transboundary) in both Japan and Asia as a whole. Furthermore, we are studying solutions to these regional environmental issues and how to apply them to real-world issues and situations.

The center consists of six sections (Regional Atmospheric Modeling Section, Regional Atmospheric Environment Section, Lake and River Environment Section, Marine Environment Section, Soil Environment Section, and Regional Environmental Systems Section) and has one Principal Researcher.

In FY 2020, we implemented many research projects covering a wide range of regional environmental issues. Our main research projects were as follows:

- Model, field, and laboratory studies on source apportionment of anthropogenic and biogenic organic aerosol
- Development and investigation of an in situ method of remediating eutrophic lake sediments by using microbial fuel-cell technology
- Evaluation of pasture carrying capacity and its vulnerability on the basis of water resources in arid and semi-arid regions
- Mixing in deep lakes as a sensitive indicator of the influence of climate change

Most of the projects are collaborations with other NIES centers. Additionally, there are two long-term monitoring programs: the Regional Atmospheric Monitoring Program and the GEMS (Global Environment Monitoring System)/Water Program, which is a collaboration with the Center for Environmental Biology and Ecosystem Studies.

Below, we briefly describe some of the important results of the Center's research in FY 2020.

#### **1. Basic research**

##### **1.1 Model, field, and laboratory studies on source apportionment of anthropogenic and biogenic organic aerosol**

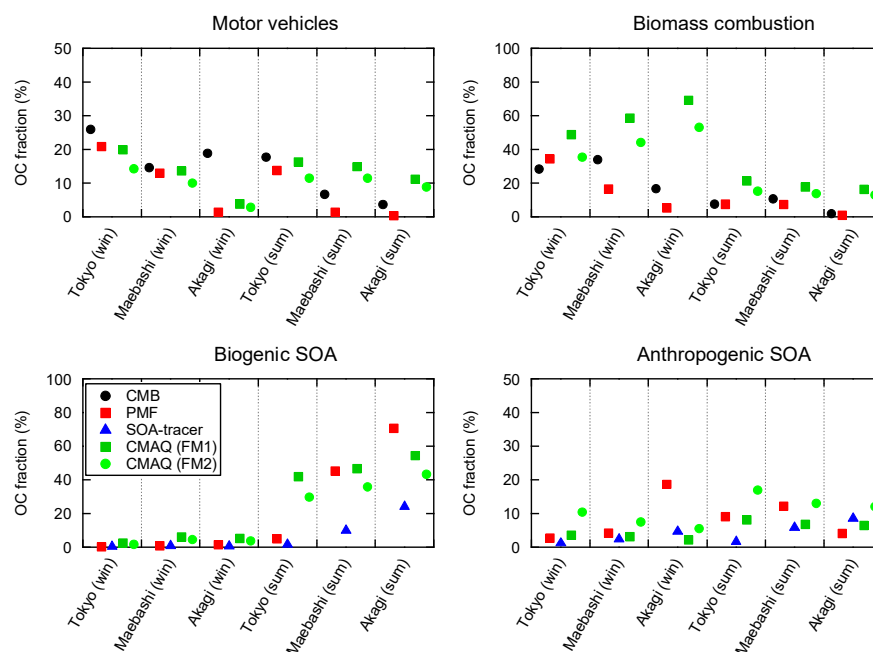
Organic aerosol (OA) represents a large fraction (20% to 90%) of PM<sub>2.5</sub>; accurate knowledge of the contributions of OA sources is therefore crucial for effective control strategies to reduce ambient PM<sub>2.5</sub> concentrations. However, the sources and formation pathways of OA are complicated, and not yet well characterized. For accurate source apportionment of OA, we conducted smog-chamber experiments, field measurements, and forward and receptor model

simulations.

Production yields of 28 organic markers for anthropogenic and biogenic secondary organic aerosol (SOA) were determined in smog-chamber experiments. By careful evaluation of these production yields with the vapor pressures and ambient behaviors of these marker compounds, five markers were identified as suitable for application to source apportionment of anthropogenic SOA and five were identified as suitable for source apportionment of biogenic SOA.

We estimated the source contributions of OA by conducting simulations with three receptor models (positive matrix factorization (PMF), SOA-tracer, and chemical mass balance (CMB) models) using the ambient concentrations (field measurements in the Kanto Area) and production yields (chamber experiments) of the OA markers. The forward model was modified by including condensable particulate matter emission and SOA formation from intermediate volatility organic compounds. The source contributions estimated by using the forward model were consistent with those from three receptor models for the major OA sources (Fig. 1), suggesting that the estimated source contributions were reliable. Our estimates show that stationary combustion sources, biomass burning, cooking, biogenic volatile organic compounds, and stationary evaporative sources contribute substantially to ambient OA in the Kanto Area.

**Fig. 1** Simulated source contributions of organic carbon concentrations in Tokyo, Maebashi, and Akagi in winter 2018 and summer 2019. Results of a forward model (FM1 and FM2 with different intermediate volatility organic compound modules) and three receptor models (PMF, SOA-tracer, and CMB models) are shown. OC, organic carbon; win, winter; sum, summer



## 1.2 Development and investigation of an in situ method of remediating eutrophic lake sediments by using microbial fuel-cell technology

Cultural eutrophication has become the primary water and sediment quality issue in closed waterbodies near populated areas. Phosphorus released from sediments triggers algae blooms, which have negative impacts on aquatic ecosystems. We



proposed the use of sediment microbial fuel cells (SMFCs) to promote sediment remediation. SMFCs have the potential for sediment remediation (i.e., an increase in oxidation–reduction potential and oxidation of both organic matter and sulfide, as well as a decrease in phosphorus concentration, in the sediment). However, the phosphorus regulation mechanism remains unclear. Hence, the aim of this study was to clarify the mechanism by which SMFCs suppress phosphorus in order to use them reliably.

A lab-scale SMFC was applied to acetate-spiked sediments (ace+) and unspiked sediments (sed) with closed-circuit (CC)/open-circuit (OC) columns, and the circuitry was switched to investigate the relationship between electron transfer and phosphorus concentration. Sediment and water samples were collected from Lake Kasumigaura. A plastic cylinder was used to construct SMFC reactors with a sediment depth of 120 mm and a water depth of 170 mm. The electrodes were made of non-woven carbon fabric that was wound around a cylindrical polypropylene net. The interstitial water in the sediment was collected by an interstitial water sampler from the center position of the anode. Four types of column (CC/sed, CC/ace+, OC/sed, and OC/ace+) were prepared in duplicate and set in a thermostat chamber at 25 °C in the dark. After 9 weeks of operation, the CC and OC were switched.

**Table 1** Operating conditions of the columns, including results for DTP in interstitial water and anode capacitances at the end of the experimental period. sed: unspiked Lake Kasumigaura sediment; ace+: sediment spiked with acetate; OC: open-circuit; CC: closed-circuit (sediment microbial fuel cell); DTP: dissolved total phosphorus

Column	Sediment type	Electrical circuit		DTP (mg/L) in pore water (day 210)	Anode capacitance (nF) (day 223)
		Day 0–63	→ Day 64–223		
Column A	sed	OC	→ CC	0.10 ± 0.02	2.05 ± 0.49
Column B	ace+	OC	→ CC	0.03 ± 0.00	5.15 ± 0.14
Column C	sed	CC	→ OC	0.82 ± 0.01	0.72 ± 0.19
Column D	ace+	CC	→ OC	1.66 ± 0.12	0.71 ± 0.12

In the first 9 weeks, the dissolved total phosphorus (DTP) concentration in the sediment interstitial water in the CC columns decreased markedly to below 0.1 mg/L, whereas the DTP in OC columns remained high (>2 mg/L). After switching of the circuit, the DTP in the OC→CC columns dropped but that in the CC→OC columns increased. From these results, we hypothesized that the phosphorus was electrochemically adsorbed onto the anode by forming an electrical double layer under CC conditions. Therefore, the anode capacitances were estimated by electrochemical impedance spectroscopy testing to evaluate the formation of the electrical double layer. Table 1 shows the DTP concentrations and anode capacitances at the end of the experimental period. The anode capacitances of CC columns were clearly higher than those of OC columns. The decreased DTP concentrations in ace+ (Column D to Column B) and sed (Column C to Column A) were 1.63 and 0.72 mg/L, respectively. The ratio of decreased DTP concentrations in the ace+ and sed columns was 2.3—similar to the ratio of anode capacitances between Column B and Column A (2.5). Hence, the anode capacitance and the amount of adsorbed phosphorus were strongly correlated.

We concluded that the phosphorus may have been electrochemically attracted to,

and retained on, the anode in the sediment. Therefore, SMFCs can be used to suppress phosphorus release from eutrophic lake sediments.

### **1.3 Evaluation of pasture carrying capacity and its vulnerability on the basis of water resources in arid and semi-arid regions**

This study aims to assess the impact of both climate change and human-induced disturbances such as mining development and urbanization on pasture carrying capacity and its vulnerability on the basis of water resources in key regions of Mongolia, a typical country distributed in arid and semi-arid areas. First, to quantify spatiotemporal variations in water availability, we applied a process-based NICE (National Integrated Catchment-based Eco-hydrology) model to two river basins: the Tuul River Basin, which is characteristic of northern grassland and steppe, and the Galba River Basin, which is characteristic of the southern Gobi Desert. The model simulation showed a clear difference in hydrologic cycles between the two basins, suggesting the impact of urbanization and mining on regional eco-hydrological degradation. Although drinking by herders' livestock has had some impact on the hydrologic change, we showed that the groundwater level in the Tuul River has been extremely degraded by water use in Ulaanbaatar over the last few decades, whereas that in the Galba River has declined markedly because of mining at Oyu Tolgoi since 2010. These results clarified the large impact of water use due to urbanization and mining on groundwater degradation around the water sources.

Next, to assess the impacts of both climate change and human-induced disturbances on pasture ecosystems, we developed an integrated model to evaluate the pasture carrying capacity (CC), grazing pressure (GP), and vulnerability index (VI). The input data included high-precision topographical data (ALOS World 3D-30m) and land-use data, MODIS Normalized Difference Vegetation Index and Leaf Area Index data, and ECMWF (European Centre for Medium-Range Weather Forecasts) meteorological reanalysis data for 2000–2019. In addition, statistical data on population, industry, and livestock (e.g., cattle, horses, sheep, goats, camels) were collected to estimate indicators of human-induced disturbances.

Finally, we applied the model to four target areas: an urban area (Ulaanbaatar City) and a steppe area (Altanbulag Sum) in semi-arid regions and a mining area (Khanbogd Sum) and desert (Manlai Sum) in arid regions. The evaluation results revealed that GP greatly exceeded pasture CC in the urban and mining areas. The order of CC, GP, and VI was as follows:

- CC: steppe area > urban area > desert area > mining area
- GP: urban area > steppe area > mining area > desert area
- VI: urban area > mining area > desert area > steppe area.

We are now trying to use the integrated model to evaluate the efficiency of adaptation strategies, such as well construction to enhance groundwater use and forage planting to enhance the harvest index.

### 1.4 Mixing in deep lakes as a sensitive indicator to detect the influence of climate change

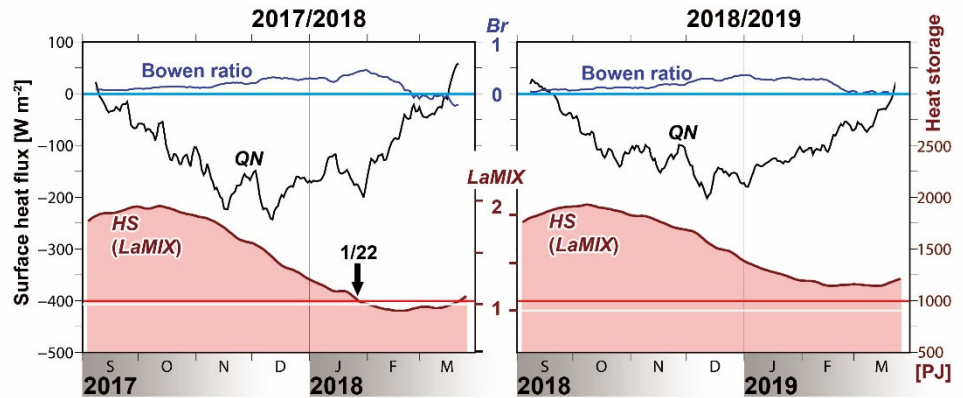
How deeply are lake waters mixed? Answering this question will increase our understanding of the impact of climate change or global warming on deep lakes. In response to future climate change, mixing in many lakes around the world will be less frequent and its regime altered. Therefore, mixing in deep lakes could be used as a sensitive indicator to detect the influence of climate change. Studies identifying mixing regime shifts in deep lakes are important, as they increase our understanding of ongoing climate change. In Lake Biwa—the largest lake in Japan, with a surface area of 674 km<sup>2</sup> and maximum depth of 104 m—the vertical mixing (overturn), which is important for supplying dissolved oxygen to the deeper layer, was partially unreachd to the lake bottom (i.e., there was incomplete full overturn) in winter 2018/2019. Under climate change, Lake Biwa may be experiencing a transitional period of shifting from the full overturn that occurred once every year to full overturn occurring once every few years. Focusing on this event as a favorable precursor of the impact of climate change on deep lakes, we created a realistic lake simulation reproducing incomplete full overturn to identify its factors.

We conducted a heat budget analysis focusing on surface cooling from autumn to the following spring by using a realistic, three-dimensional lake circulation model. The net surface heat flux  $QN$  (mainly surface cooling) inducing the overturn in Lake Biwa was evaluated as a function of meteorological conditions such as air and water temperatures, humidity, and wind speed. Furthermore, the study attempted to define an appropriate index for detecting interannual alterations in full overturn. On the basis of the simulated water temperature, a novel index for lake mixing ( $LaMIX$ ) in the present year was defined as the heat storage ( $HS$ ) in Lake Biwa normalized by the minimum total heat storage ( $HS_{min(PY)}$ ) in the previous year in which full-overturn occurred; this was calculated by using the equation  $LaMIX = HS/HS_{min(PY)}$ , where  $PY$  indicates the previous year. The analytic period was defined as the cooling season from September to March, and the previous year ( $PY$ ) was defined as the period from 1 April to 31 March. Therefore, the cooling season in 2017/2018 (2018/2019) was defined as the period from September 2017 (2018) to March 2018 (2019).

The temporal variations in net surface heat flux,  $QN$ , on Lake Biwa in 2017/2018 followed a pattern different from those in 2018/2019 (Fig. 2):  $QN$  in 2017/2018 decreased to a larger extent in the period from November to December, although temporal fluctuations in  $QN$  were similarly apparent in both years. The increase in  $QN$  from January onward was milder in 2019 than in 2018. This was primarily caused by a decrease in wind speeds in 2019, rather than by increased air and water temperatures. We confirmed that there was full overturn in the entire lake (monomictic mixing) on 22 January 2018; the lake mixing index,  $LaMIX$ , in 2017/2018 decreased to just below 1 and underran this value from January to March in 2018. In contrast,  $LaMIX$  in 2018/2019 never fell below 1.  $LaMIX$  was larger in

2018/2019 than in 2017/2018 because of the lower water temperature in March 2017. Therefore, the mixing patterns in Lake Biwa in both years were accurately represented by the mixing index, *LaMIX*, which was calculated by using the heat storage.

**Fig. 2** Heat budget analyses of Lake Biwa during cooling periods in 2017/2018 (left panels) and 2018/2019 (right panels). Shown are the surface heat flux of the lake, as represented by the Bowen ratio (*Br*) and net surface heat flux (*QN*), and the heat storage (*HS*) corresponding to the mixing index (*LaMIX*) scaled by the vertical axis located between the panels. Lateral red lines indicate  $HS = 1000$  in petajoules (PJ). White lines indicate  $LaMIX = 1$  in each year, indicating that there was a monomictic mixing regime in the lake.



Our analysis suggested that lake overturn declined because of a weakening of surface cooling, primarily because of wind speed reduction during the winter, rather than an air temperature increase. It is essential that we identify mixing regime shifts to better evaluate the vulnerability of habitats to climate change and to create adaptations in deep lakes worldwide. Our results may help to identify shifts in the mixing regimes of deep lakes and help us to understand diminishing overturns due to ongoing climate change, as well as the increasing environmental risks to, and vulnerabilities faced by, deep lakes.

## 2. Long-term monitoring

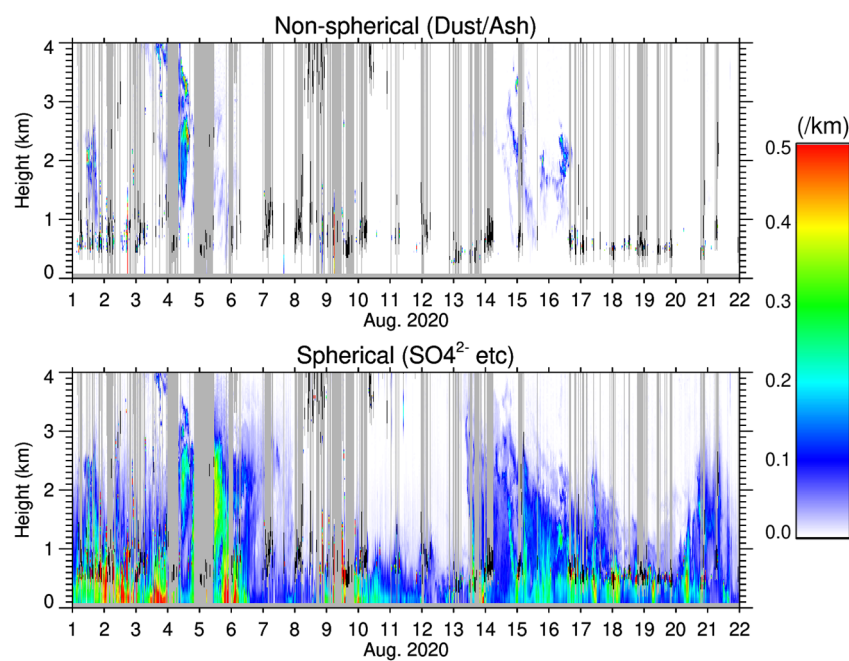
### 2.1 Long-term monitoring of atmospheric pollutants at Cape Hedo, Okinawa, and Fukuejima, Nagasaki, to monitor air quality in East Asia

Long-term monitoring of atmospheric pollutants, including aerosols and gaseous species, has been conducted by our Center at Cape Hedo Atmosphere and Aerosol Monitoring Station (CHAAMS) on Okinawa Island and at Fukuejima (Fukue Island) Observatory in Nagasaki Prefecture, Kyushu, to observe changes in the atmospheric environment of the East Asian region. Observations of optical, physical, and chemical characteristics, including the scattering coefficient, chemical composition, mass concentration, and vertical distribution of aerosols, have been conducted since spring 2004 at CHAAMS and since autumn 2008 at Fukuejima.

Two major atmospheric pollution events were identified in FY 2020. In August 2020, aerosols originating from the Nishinoshima volcano (27.2°N, 140.8°E) arrived at CHAAMS and the lidar equipment captured their optical properties (Fig. 3). It was revealed that the main component of the air mass was sulfate, which was photochemically converted from sulfur dioxide released from the volcano. The

hourly peak PM<sub>2.5</sub> concentration rose to 66  $\mu\text{g}/\text{m}^3$  on 5 August. Another major event was the arrival of Asian dust at Fukuejima at the end of March 2021. The thickness of the dust layer was about 1 km, and the hourly peak PM<sub>2.5</sub> concentration was 135  $\mu\text{g}/\text{m}^3$  at 10 AM on March 30.

**Fig. 3** Time–height sections of (top) the extinction coefficient of non-spherical particles and (bottom) the extinction coefficient of spherical particles. Both were observed by the lidar at CHAAMS.



These types of long-term monitoring data contribute to our understanding of the current status and trends of atmospheric pollutants in the East Asian region and of trans-boundary pollution entering Japan. Some of these measurement data and a list of peer-reviewed papers are available to the public on the NIES web pages (<http://www.nies.go.jp/asia/hedomisaki/home-e.html>).

### 2.2 Long-term monitoring at Lake Kasumigaura

We have been monitoring Lake Kasumigaura, the second-largest lake in Japan, monthly for nearly four decades in collaboration with the Center for Environmental Biology and Ecosystem Studies. This lake is registered as a trend-monitoring station of the United Nations Environment Programme's GEMS (Global Environment Monitoring System) Water Programme, a core site of JaLTER (the Japan Long-Term Ecological Research Network), and GBIF (Global Biodiversity Information Facility).

We measure a wide range of environmental variables (water temperature, water depth, and transparency), water quality (electronic conductivity, chlorophyll *a*, nitrogen, and phosphorus), plankton (bacteria, phytoplankton, and zooplankton), benthos (chironomids and oligochaetes), and primary production. Detailed information and the database for this monitoring program have been released on the following website:

<http://db.cger.nies.go.jp/gem/moni-e/inter/GEMS/database/kasumi/index.html>.

Along with the monthly survey, this fiscal year we performed high frequency, in situ measurements by using sensors. We are starting a survey of the methane (CH<sub>4</sub>) concentration in the atmosphere at 10 Hz (every 0.1 s) and the dissolved oxygen (DO) concentration in the surface and bottom layers every 15 min. By integrating meteorology and the CH<sub>4</sub> concentration, the CH<sub>4</sub> flux is estimated every 30 min by using the eddy covariance technique. The measurements of DO concentration are performed in collaboration with the Lake Biwa Branch Office of NIES. Long-term (28 years) temperature measurements have clarified that there has been a significant water temperature increase in springtime in Lake Kasumigaura.

We are also starting to monitor temperature, pH, electrical conductivity, DO, turbidity, chlorophyll *a*, and phycocyanin at Hirayama Station by deploying a buoy on which auto sensors are installed. These variables are being monitored every 10 min. Our preliminary high-frequency observations have shown a marked decrease in DO at the lake bottom during summer and diurnal stratification at the station. Analyses of long-term monitoring data on dissolved radiocesium suggest that intermittent hypoxic events may enhance radiocesium remobilization from the sediments; remobilization of the radiocesium can then cause seasonal changes in radiocesium concentrations in fishes. Finally, we have newly joined two international projects of GLEON (Global Lake Ecological Observatory Network) to evaluate the quality and quantity of microplastics and dissolved organic matter in lakes globally.

### **Center for Environmental Biology and Ecosystem Studies**

The Center for Environmental Biology and Ecosystem Studies (CEBES) performs various types of research aimed at understanding ecosystem composition and function and the relationships between these two factors, as well as the effects of human activity on biodiversity.

The center is responsible for leading the Biodiversity Research Program (one of the five Issue-Oriented Research Programs in the fourth NIES five-year plan), with the aim of helping to implement the Strategic Plan for Biodiversity 2011–2020, including the Aichi Biodiversity Targets of the Convention on Biological Diversity. Moreover, CEBES conducts long-term ecological monitoring, preserves biological resources, and establishes biodiversity databases. We have also studied the effects of the Great East Japan Earthquake on organisms and ecosystems. In 2017, we established the Lake Biwa Branch Office in cooperation with the Center for Regional Environmental Research.

CEBES considers commitment to national and international frameworks and policies to be an important task in the conservation of biodiversity and ecosystem services. During the third NIES five-year plan, some of the CEBES researchers were selected as experts and contributed as lead authors to the assessment reports of IPBES (the Inter-governmental Platform on Biodiversity and Ecosystem Services). We also responded to notifications from the Secretariat of the Convention on Biological Diversity, such as requests for peer review of documents. In addition, to lead and coordinate participation in these activities by the scientific community in Japan, CEBES set up the Secretariat of J-BON (the Japanese Biodiversity Observation Network) in 2014; its role is to act as an interface between the scientific community and other sectors.

#### **1. Studies of the conservation and ecosystem management of Lake Biwa**

The NIES Lake Biwa Branch Office aims to restore the ecosystem of Lake Biwa, the largest and oldest lake in Japan. The Biodiversity group at the branch office focuses on the recovery of native fishes that have dramatically decreased in abundance since the late 1980s. For their recovery, conservation and restoration of the lakeshore vegetation zone are indispensable, because the submerged part of this zone is used as a spawning site by many native fishes, including three endemic ones. Although the submerged-plant zone, which consists mainly of common reed (*Phragmites australis*), had a total area of about 130 ha in 1976, by the mid-1980s 70% of the zones were no longer available as spawning grounds because of the construction of lake banks. The extent of the submerged-reed zone depends on the water level of the lake. Therefore, the artificially low summer water levels that began in 1992 also hinder spawning.

For effective conservation and management of the zone and the native fishes, the spawning-site performances of various reed zones need to be evaluated and monitored adequately. In the second year after opening the branch office, we started to monitor five areas, including two natural and three artificially developed reed zones. Fish eggs attached to plants were collected through the spawning season, with the collection point of each egg population sample recorded as GPS (global positioning system) data, and each egg was DNA identified in the laboratory. The results were then mapped to the vegetation map of each survey area. Monitoring for the past 3 years has revealed differences in spawning habitat among fish species or subspecies. As an example, one of the three artificially developed reed zones located in the northeastern part of the lake was used in different ways as a spawning ground by three *Carassius* species and subspecies (Fig. 1): *Carassius buergeri grandoculis* and triploid *Carassius* mainly used the planted reed area, whereas *Carassius cuvieri* mainly used the open water behind (to the right in the photo) the reed area (Fig. 2).

**Fig. 1** Three *Carassius* fishes spawn in the lakeshore vegetation zones of Lake Biwa: *C. buergeri grandoculis* (left), triploid *Carassius* (middle), and *C. cuvieri* (right).



**Fig. 2** An artificially developed reed zone in northeastern Lake Biwa. The planted reed area has been invaded on the lake side by willow trees, and there is open water behind (to the right in the photo) the reed area.



## 2. Environmental genomics studies

NIES preserves highly endangered Japanese domestic species, such as the Okinawa rail and white stork. Some of these are protected and propagated by the national government. For efficient protection and propagation, we need to perform genome-wide analyses of these species and determine their genetic diversity. Because of the restrictions of the Washington Convention, it is difficult to conduct whole-genome analyses of such species at overseas research institutes. Therefore, the analyses must be conducted, and the genome data released, by NIES.

In this project, a draft analysis of the whole genome will be performed for highly endangered Japanese domestic species, species causing environmental problems, and indicator organisms widely distributed in Japan. By 2020, whole-genome draft analyses of 23 endangered avian species and six mammals had been completed. These data were released on the NIES homepage (<https://www.nies.go.jp/genome/index.html>; in Japanese). Figure 3 shows



## 5. Center for Environmental Biology and Ecosystem Studies

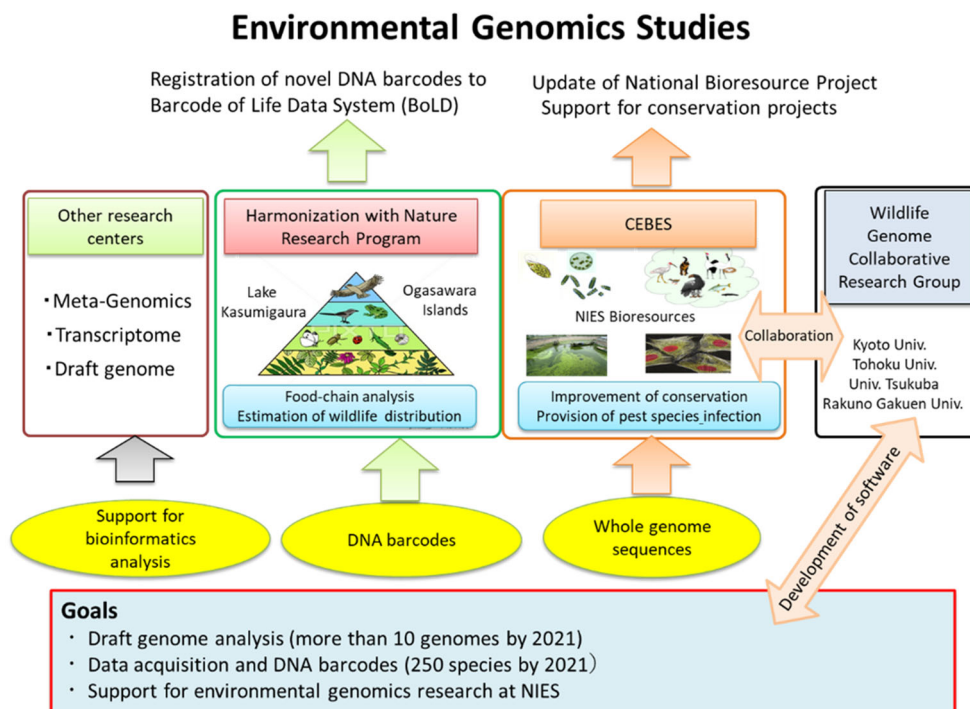
representative species for which we have released data.

In addition, by using environmental DNA analysis methods, NIES plans to perform a detailed food-chain analysis and distribution survey in lakes Kasumigaura and Biwa, and on the Ogasawara Islands. To achieve more reliable results, highly accurate DNA barcode data for species identification are essential, and we are acquiring the DNA barcodes of those organisms in these areas that are targeted for environmental research. To date, DNA barcode sequences from 769 species have been identified, and these are being used in other NIES research projects. Moreover, as part of this project, we have consolidated a platform for bioinformatics analyses and support for our research collaborators (Fig. 4).

**Fig. 3** The endangered species Steller's sea eagle (*Haliaeetus pelagicus*, left) and Bali myna (*Leucopsar rothschildi*, right)



**Fig. 4** Outline of the Project for Environmental Genomics Studies



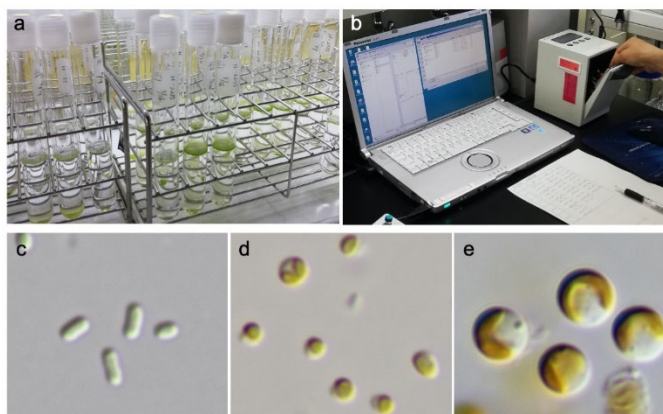
### 3. Delayed fluorescence assay of differential heavy metal sensitivity in marine algal species from the NIES microbial culture collection

Seafloor massive sulfide deposits in hydrothermal fields are targeted as potential metallic resources, and these deposits are likely to be mined in the near future. However, there is a risk of accidental spillage or leakage of both the recovered ores and mining wastewater to the ocean surface. We therefore need to develop a system for monitoring water quality and assessing the impact of these metals on phytoplankton communities on site. The International Seabed Authority also recommends the rapid assessment of ore and plume toxicity onboard vessels during both the exploration and exploitation phases. To address these issues, we have developed an environmental impact assessment method that uses delayed fluorescence (DF) of the weak photons emitted by plants or algae.

We previously established a protocol for DF-based bioassay by using test strain NIES-981, a marine cyanobacterium species (Fig. 5). To apply the method to the various types of phytoplankton in marine surface waters, it is essential that we accumulate basic data on the metal sensitivity of not only NIES-981 but also a wide variety of algae. MCC-NIES, NIES's Microbial Culture Collection, maintains nearly 4000 microalgal strains, covering most of the major marine phytoplankton groups. We have used these strains to investigate the metal sensitivity of the different algal species.

In our study, we evaluated the toxic effects of leachable metal ions such as zinc (Zn), copper (Cu), and lead (Pb) on representative marine microalgae. Cyanobacterial species such as *Synechococcus* and *Cyanobium* were sensitive to Zn and Cu, whereas eukaryotic microalgae showed various responses to different metals. Notably, the prasinophycean *Bathycoccus prasinus* (NIES-2670), a representative pelagic species, was highly sensitive to all the metals we investigated, suggesting that this species is vulnerable in the pelagic environment. In addition, co-culture experiments showed that different metals can have different impacts on community structure. For example, the ratio of populations of *Emiliana huxleyi* (a eukaryotic strain of phytoplankton) to *Synechococcus* (a prokaryotic strain) changed significantly during experimental exposure to Zn and Cu, but not to Pb. Our study suggests that monitoring across multiple taxonomic groups would be helpful to understand and evaluate impacts on ocean ecosystems.

**Fig. 5**  
Delayed fluorescence  
assay of the effects of  
metal ions on marine  
microalgae. (a)  
Subcultures of test  
strains; (b) Delayed  
fluorescence  
measurement; (c to e)  
Light micrographs of  
representative test  
strains from MCC-  
NIES. (c) *Cyanobium*  
sp. NIES-981; (d)  
*Bathycoccus prasinos*  
NIES-2670; and (e)  
*Emiliana huxleyi* NIES-  
1310.



### Center for Social and Environmental Systems Research

The Center for Social and Environmental Systems Research targets linkages between human activities and the natural environment to identify the relationships among socioeconomic systems and environmental issues. The work of the Center results in important academic findings as well as policy recommendations for environmental issues, covering a broad area, from global environmental issues to local sustainable cities and regions.

The Center consists of five research sections:

1. The **Integrated Environment and Economy Section** analyzes the structure of causes and effects of various environmental problems, considering the inter-relationships among multiple sectors (such as household, government, and enterprise) and multiple scales (including world, country, and city), and explores solutions to these problems.
2. The **Trans-boundary Impacts and Mitigation Modeling Section** develops and utilizes analytical models to quantify the impacts of various environmental changes at transboundary and national scales—including the impact of climate change—and to examine measures for mitigating these changes.
3. The **Regional Environmental Impact Assessment Section** investigates solutions for environmental problems by developing methods and models to assess various environmental impacts at country, local, and city levels.
4. Through social transition research for innovative technological and social systems, the **Eco-society Innovation Section** conducts system design, evaluation, and support for the implementation of environmentally friendly technologies and policies to foster the transition to a sustainable environmental society.
5. The **Environmental Policy Section** aims to elucidate pathways to sustainable social systems by assessing the effectiveness of environmental policies and analyzing the roles and activities of multiple stakeholders.

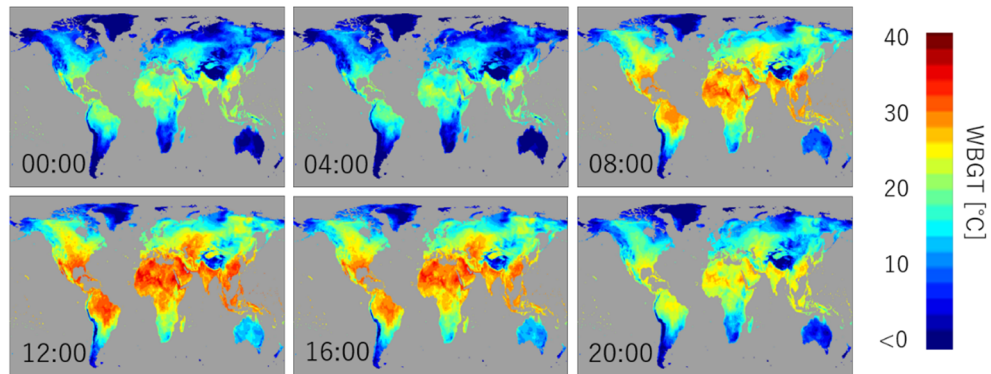
Researchers at the Center are involved in at least one of two major research programs, namely the Environment-Economy-Society Integration Research Program and the Low-Carbon Research Program. Basic research that supports these project-oriented programs, together with any other research activities, is categorized as part of our Center's research sections. In FY 2020—the final year of the fourth mid-term plan of NIES—our goal was to coordinate various research activities to be able to arrive at tangible outputs by March 2021. Another goal was to start discussing what research agenda should be set under the Center in the fifth mid-term plan, which started in April 2021. The future activities need to cover a variety of research projects regarded as “seeds” for future large-scale projects. Included are those related to data collection for model development, development of new methodologies to assess resource management, and outreach-related activities. Some of our outputs are described below.

**1. Collection and maintenance of statistical information and future scenarios related to the United Nations’ Sustainable Development Goals**

We collect and update statistical information and future scenario data related to the United Nations’ SDGs (Sustainable Development Goals) for the integrated analysis of global-scale environmental problems. In addition, we grasp the latest trends in methods of integrated analysis of global-scale environmental impacts and countermeasures through literature surveys and participation in model comparison studies.

As an indicator related to climate change impacts, we developed a temporally and spatially detailed dataset of wet bulb globe temperature (WBGT), a heat index, for the entire globe. Specifically, hourly WBGT values were calculated by applying statistical WBGT estimation and downscaling methods to observed daily data from 1958 to 2013 and daily values of climate variables estimated by climate models until the end of the 21st century based on RCPs (representative concentration pathway scenarios) (Fig. 1). Conventionally, many global-scale impact assessment studies have used daily average values of WBGT and have not been able to take into account changes in the index within a day. We expect that, by using the results of this study, it will be possible to implement impact assessment and adaptation measures that take into account the living conditions of each region.

**Fig. 1** Sample estimates of WBGT (wet bulb globe temperature) by time of day for 1 day in the Northern Hemisphere summer. (Times shown are local times in each grid.)



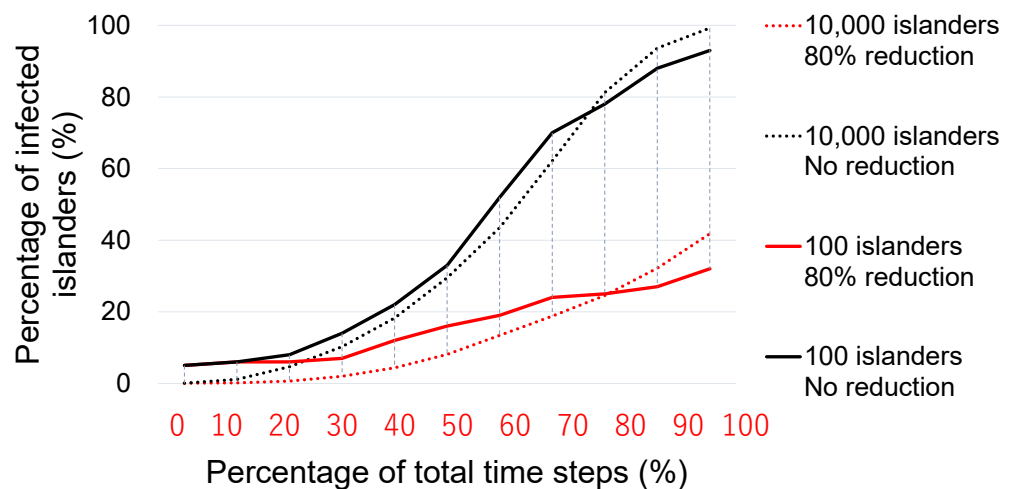
In implementing the abovementioned global-scale impact assessment by using detailed temporal and spatial information, the increase in the time required for the calculation process becomes an issue. We investigated the usefulness of GPGPU (General-Purpose computing on Graphics Processing Units) and computing resources in the cloud. When we ran statistical machine-learning algorithms on NVIDIA graphics processing units, we confirmed that the processing speed could be increased by several tens of times, depending on the type of the process. We also confirmed that it is possible to flexibly configure and use computing configurations according to the amount of computational processing by using resources such as Amazon Web Service’s EC2 (Elastic Compute Cloud).

## 2. Verification of COVID infection control by using a spatial random walk model

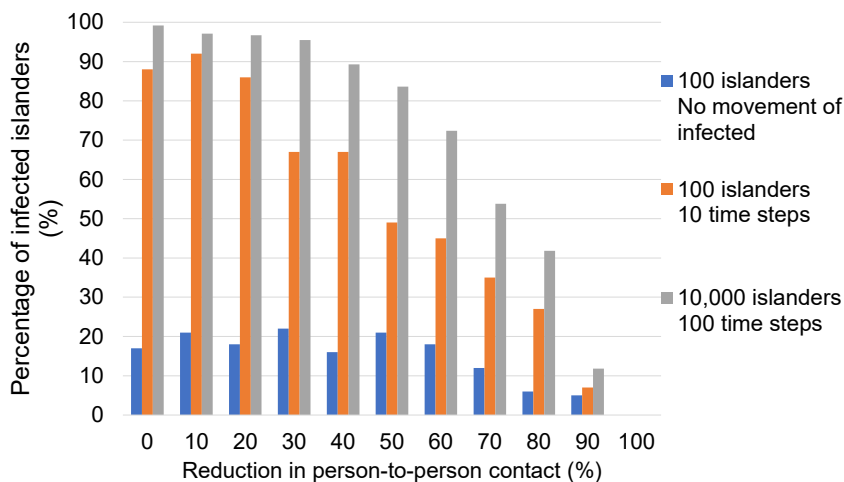
To stop the pandemic caused by the 2019 novel coronavirus (COVID-19), an 80 percent reduction of person-to-person contact opportunities was proposed by the Japanese government. This guideline was based on the results of a macroscopic differential equation model akin to the SIR (Susceptible-Infected-Recovered) model. To simplify the detection of person-to-person infection mechanisms, we built a new model to calculate infection rates between two people who are in contact with each other. We used a spatial random walk model to express the random movement of people in a specific two-dimensional geographical space. The model was used to verify the effect of the proposed infection control procedure, namely an 80% reduction.

The results indicated that, although both isolating infected individuals (restriction of movement) and reducing contact are important (Fig. 2), restricting movement has by far the greatest effect (Fig. 3). Figure 3 shows the comparative infection rates at the final time step for different rates of contact reduction. With unrestricted post-infection movement, the spread of infection was almost contained when contact was reduced by 90%. In this study we postulated that the figures intermediate between the two cases of post-infection movement or no movement should perhaps be considered as a more realistic scenario. For this reason, we did not express post-infection isolation in terms of the cessation of movement or removal from the system. The 80% reduction in contact ought to be applied to individuals who are either uninfected or unaware that they are infected, and not to people who are aware that they are infected. The results of our numerical simulation of a temporospatial random walk model are consistent with the rationale for the 80% reduction derived from a different approach, namely, the SIR model.

**Fig. 2** Spread of infection in each scenario: 100 islanders (10 time steps) versus 10,000 islanders (100 time steps) at different rates of reduction of person-to-person contact



**Fig. 3** Infection rates at the final time step in each scenario: 100 islanders (10 time steps) versus 10,000 islanders (100 time steps)



### 3. Characteristics of farmers adopting environmentally friendly cultivation

Although the pursuit of efficiency is essential in the Japanese agricultural sector, which is in decline because of population aging and labor shortages, excessive fertilizer and pesticide use leads to increases in water pollution and eutrophication in the surrounding waters, greenhouse gas emissions, and adverse effects on soils and ecosystems. However, Japan’s efforts in environmental conservation in the agricultural sector lag behind those of other developed countries. The reasons for the lack of widespread adoption of environmental conservation in agriculture lie in the hands of both consumers and producers. This study focused on the management efficiency relationship between producers and consumers; it utilized a stochastic frontier model analysis to obtain policy suggestions for promoting environmental conservation in the agricultural sector.

We targeted farmers in Ibaraki Prefecture. After estimating the production frontier by using stochastic frontier analysis, we conducted a regression analysis of the factors that cause inefficiency (distance from the frontier) for each management unit. The results showed that farmers working to reduce chemical fertilizer use and rice farmers working to reduce pesticide use were highly efficient. No statistically significant coefficients were obtained for the use of compost. As reductions in chemical fertilizer and pesticide use can meet the needs of consumers for safety and security, farmers who are willing to manage their farms in this way are likely to be strategically cultivating environmentally friendly crops, but the market share for their products is only a few percent in Japan. Vegetable farmers in Ibaraki Prefecture ship large quantities of vegetables to the Tokyo metropolitan area—a large consumption area—so it is likely that the mainstay of their management strategy is to provide a stable supply at a stable price. We were able to clarify current issues, such as the fact that the cultivation of environmentally friendly crops will not be adopted if it is not commensurate with market prices because production costs will increase owing to the increased labor costs of reduced agricultural chemical use.

#### 4. Factors related to being asked to participate in volunteer activities

We explored the factors that motivate people to participate in volunteer activities. Social background and psychological elements have been discussed in other studies as factors related to volunteering. The social background elements include income, education, gender, religion, and socialization agents (the important individuals, groups, or institutions that influence our sense of self and the behaviors, norms, and values that help us function in society), whereas the psychological elements include empathy and altruism. However, many existing studies have not used multiple regression techniques and therefore have not been able to separate the effects of individual factors. Moreover, some studies have observed that “being asked” is an important reason for participating in volunteer activities. However, this element had not been analyzed statistically. We used the results of two national online questionnaire surveys: one that was performed in 2019 another conducted in 2020 and targeting the same individuals. The relationships between volunteer participation and social background or psychological elements, as well as factors connected to being asked—such as number of volunteering friends—were then analyzed. Because present behavior may influence present factors, we also analyzed the relation between present factors and future behavior. The results of a multiple regression analysis and logistic regression analysis indicated that factors related to being asked were relatively strong predictors, whereas social background and psychological factors did not predict participation. These results suggest that several strategies that encourage volunteers to ask others to join in their next activities are effective for recruiting volunteers.

**Fig. 4** Volunteers who have picked trash on a beach





### Center for Environmental Measurement and Analysis

The goals of the Center for Environmental Measurement and Analysis (CEMA) are to help develop better scientific methodologies that will enable the early detection of environmental issues and changes, give us a deeper understanding of environmental issues, and improve the assessment of current and future environmental concerns. CEMA also helps manage the quality of chemical analyses of environmental samples. Furthermore, we have continued our environmental specimen banking as important work that complements the archiving of environmental changes.

To achieve these goals, the six research sections of CEMA have been conducting a variety of studies. The **Fundamental Analytical Chemistry Section** has been in charge of an environmental specimen banking program; it collects bivalve specimens annually to complete a round of sampling from many sites along the Japanese coast. The section has also been preparing and distributing environmental Certified Reference Materials to meet the demand for environmental chemical analysis. The **Advanced Analytical Chemistry Section** has been developing techniques for the comprehensive analysis of organic pollutants; for example, they have coupled a two-dimensional gas chromatograph to a high-resolution time-of-flight mass spectrometer. The **Environmental Chemodynamics Section** has been monitoring the temporal and spatial variation of chemical species in the atmosphere to gain an understanding of the sources and sinks of anthropogenic and natural substances. A microscale radiocarbon ( $^{14}\text{C}$ ) analysis has also been conducted by this section to distinguish the fossil fuel and biogenic sources of carbon-containing materials such as airborne particulate matter. The **Advanced Remote Sensing Section** has been developing advanced techniques for remote sensing, such as lidar (laser radar), to monitor the temporal and spatial distribution of the main aerosol components (e.g., mineral dust, sea salt, and black carbon) in the atmosphere. The **Environmental Reaction Chemistry Section** has been tackling the development of methods to help us understand the mechanisms and efficiency of the production and chemical conversion of atmospheric fine particles—especially organic particles. The **Environmental Imaging and Spectrum Measurement Section** has been involved in the development of non-invasive and non-destructive techniques for monitoring the human brain by using a magnetic resonance (MR) imaging system. The possibility of utilizing measured MR images as *in vivo* biomarkers has been assessed by this section.

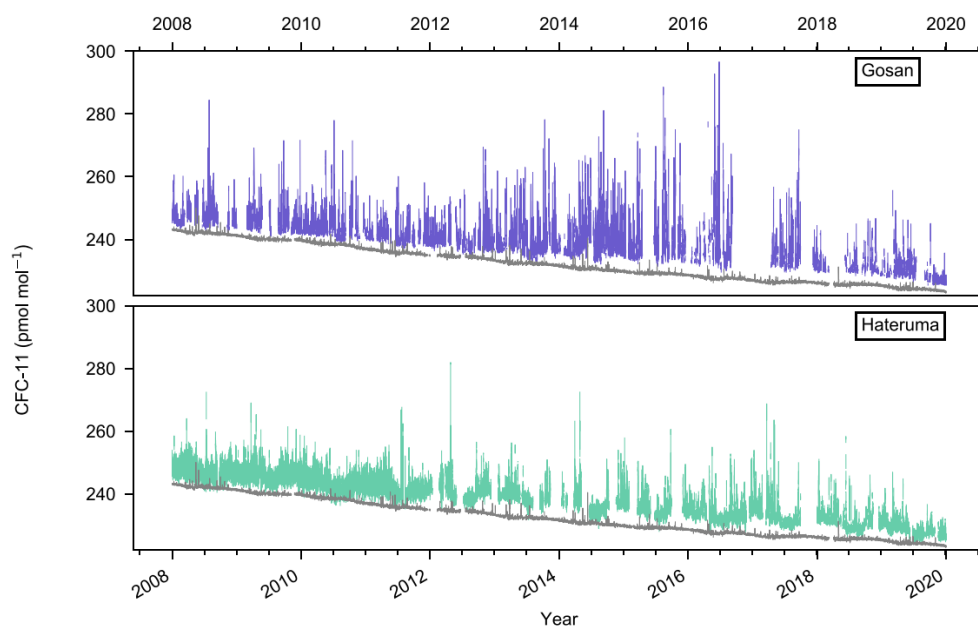
Below are brief accounts of some of the important results of our research in FY 2020.

### **1. Decline in CFC-11 emissions from China revealed by atmospheric observations**

Trichlorofluoromethane (CFC-11), a widely used agent (mainly in foam manufacturing), was globally banned in 2010 under the Montreal Protocol on Substances that Deplete the Ozone Layer owing to its harmful impacts on stratospheric ozone. In response to such regulations, the atmospheric mole fraction began to decline in the mid-1990s. However, the rate of decline has recently slowed, and an increase in emissions from eastern China after 2013 is suspected to be the major cause of the unexpected slowdown.

Previous reports on Chinese CFC-11 emissions were based on in situ high-frequency atmospheric monitoring of halocarbons, including CFC-11, at Hateruma station on Hateruma Island in Okinawa, as part of global environmental monitoring conducted by CGER (Center for Global Environmental Research) and at Gosan station on Jeju Island, South Korea. We have continued atmospheric measurements at these two east Asian sites and have shown that both the magnitude and frequency of enhancements of the mole fractions of CFC-11 decreased in 2018 and 2019 (Fig. 1), indicating that CFC-11 emissions from nearby sources had decreased. We analyzed the atmospheric observations by using atmospheric chemical transport model simulations. The results indicated that CFC-11 emissions have decreased since 2018 and returned to pre-2013 levels in 2019. We estimate that the amount of CFC-11 bank (the amount of CFC-11 produced, but not yet emitted) in eastern China is up to 112 gigagrams larger in 2019 compared to pre-2013 levels. We estimated the environmental impact of the increased bank and concluded that substantial future stratospheric ozone depletion from unreported production of CFC-11 and associated chemicals from eastern China has been avoided, perhaps as a result of the timely reporting of increased emissions.

**Fig. 1** Dry-air mole fractions of CFC-11 measured at Gosan, Jeju Island, South Korea (33.3°N, 126.2°E) and Hateruma, Japan (24.1°N, 123.8°E). Gray lines show the mole fraction observations at Cape Grim, Tasmania, Australia (40.7°S, 144.7°E) for comparison (adapted from Park et al. 2021)



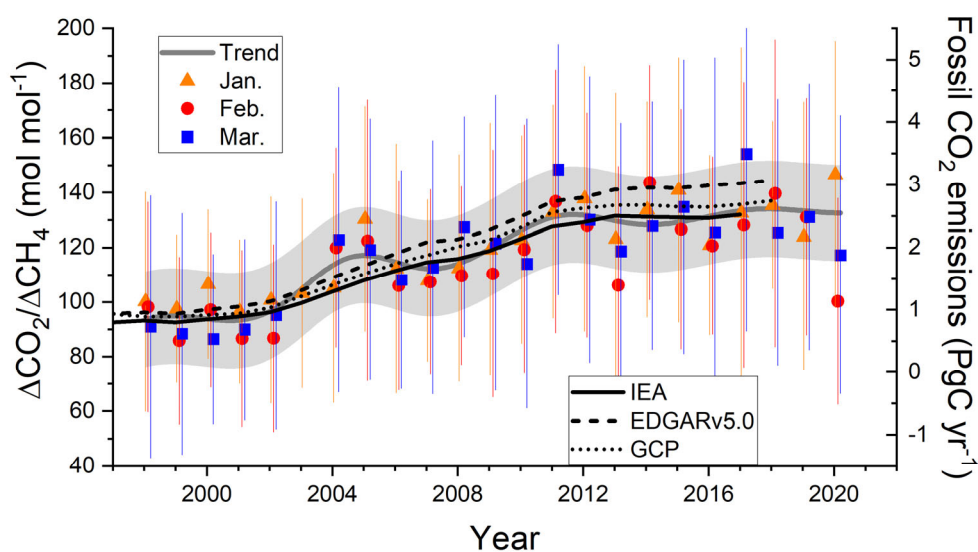
## 2. Decrease in fossil-fuel CO<sub>2</sub> emissions due to COVID-19 detected by atmospheric CO<sub>2</sub> and CH<sub>4</sub> observations

Tracking emissions of anthropogenic greenhouse gases (GHGs) by atmospheric observations is a major challenge for policymaking, such as in the Paris Agreement. Huge atmospheric observation networks comprised of a variety of platforms, including satellites, have been developed to monitor regional- or country-scale changes in the anthropogenic GHG emissions. The outbreak of the new coronavirus (COVID-19) has been affecting global socioeconomic activity, leading to substantial reductions in emissions of fossil-fuel-derived CO<sub>2</sub> (FFCO<sub>2</sub>) and other anthropogenic air pollutants globally. This situation has given us a unique opportunity to assess our ability to quantify the changes in regional FFCO<sub>2</sub> emissions by using atmospheric observations.

NIES and JAMSTEC (the Japan Agency for Marine-Earth Science and Technology) have been focusing on the atmospheric CO<sub>2</sub> and CH<sub>4</sub> concentrations observed at Hateruma Island, Japan, which is located on the continental margin of East Asia. A previous study revealed that temporal changes in the ratio of CO<sub>2</sub> to CH<sub>4</sub> ( $\Delta\text{CO}_2/\Delta\text{CH}_4$ ) during winter were useful for evaluating temporal changes in the ratio of emissions of these pollutants from China. We have therefore analyzed  $\Delta\text{CO}_2/\Delta\text{CH}_4$  ratios during winter for the past 20 years. The results show that the monthly average  $\Delta\text{CO}_2/\Delta\text{CH}_4$  in January, February, and March tracked the yearly increase in FFCO<sub>2</sub> emissions from China during 1998–2019. However, the ratios showed marked decreases in February and March 2020, which coincided with the coronavirus lockdown period in China (Fig. 2). We evaluated the relationship between  $\Delta\text{CO}_2/\Delta\text{CH}_4$  at Hateruma and the FFCO<sub>2</sub> emissions from China by using

an atmospheric transport model and a set of CO<sub>2</sub> and CH<sub>4</sub> flux maps. Finally, by applying the observed  $\Delta\text{CO}_2/\Delta\text{CH}_4$  to the simulated relationship, we found that China's FFCO<sub>2</sub> emissions decreased by about 30% in February 2020 and by about 20% in March 2020. Our approach has the potential to detect signals of emissions reduction from any specific region in near-real time by using continuous and highly precise measurements of CO<sub>2</sub> and CH<sub>4</sub>.

**Fig. 2** Temporal variations in monthly average  $\Delta\text{CO}_2/\Delta\text{CH}_4$  for January, February, and March since 1998. The thick gray line represents the trend curve of  $\Delta\text{CO}_2/\Delta\text{CH}_4$ , and the gray-shaded area represents the 95% range of the variations from the trend curve. Thin lines are the estimations of FFCO<sub>2</sub> emissions from China based on data from International Energy Agency (IEA), Emission Database for Global Atmospheric Research (EDGAR v5.0), and Global Carbon Project (GCP). The position of the right y-axis is adjusted so that the FFCO<sub>2</sub> temporal variations visually fit the trend curve of the  $\Delta\text{CO}_2/\Delta\text{CH}_4$  ratio. Vertical bars represent the standard deviations ( $1\sigma$ ) of the monthly values.

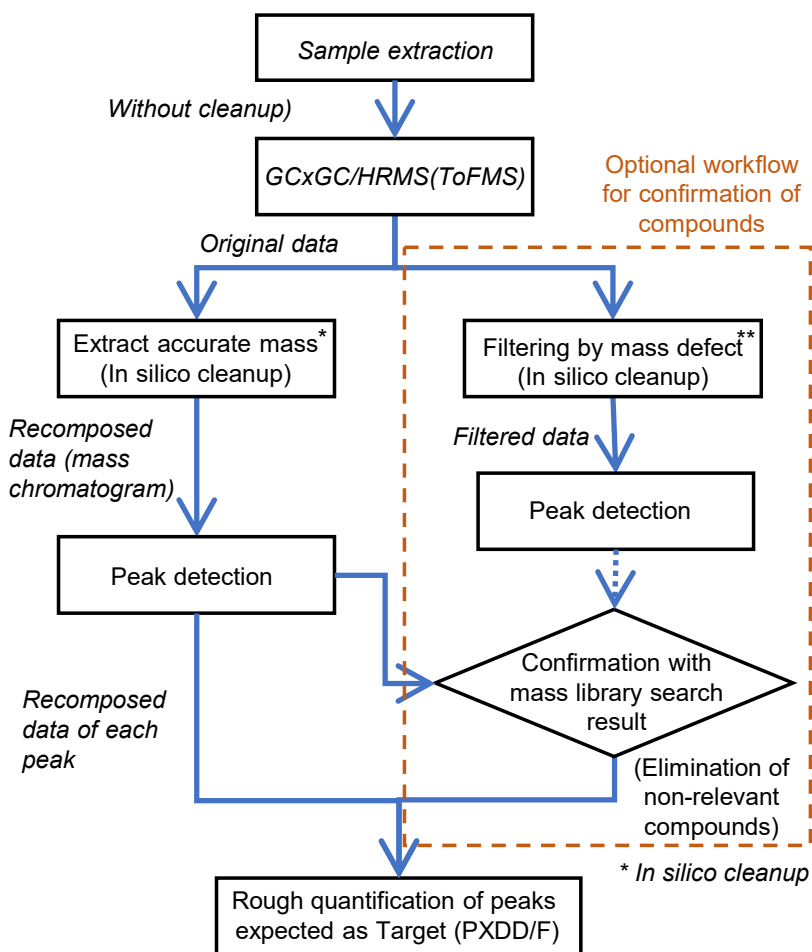


### 3. Comprehensive screening of mixed halogenated compounds in wastewater samples by GC×GC/ToFMS and post-data processing

Enormous numbers of pollutants must be investigated to enable us to understand which types threaten human health and environmental biota. In this study, we proposed a workflow for screening for polybromochlorodibenzo-*p*-dioxins and dibenzofurans (PBCDD/Fs, PXDD/Fs), which are compounds that have thousands of isomers and congeners and typical groups of mixed halogenated compounds of risk concern, by combining measurement of samples without any in-laboratory cleanup with the results of comprehensive GC×GC/ToFMS (two-dimensional gas chromatography/time-of flight mass spectrometry) and post-data processing (Fig. 3). This process can be regarded as “in silico sample cleanup.” The post-data-processing stage comprises two methods in which the extracted mass spectra are matched to exact mass and isotopic ratios specified as formulae and filtering via mass deficiency. The post-data processing stage comprises two steps, namely matching of the extracted mass spectra to exact mass and isotopic ratios specified as formulae, followed by filtering via mass deficiency. We applied this workflow to wastewater samples from industrial facilities to identify mixtures of halogenated dioxins. We estimated that dioxins in absolute quantities of 10 to 500 pg could be detected with sufficient accuracy by recovery testing of a standard mixture against sample crude extracts. Tri- to octa- halogenated dioxins were detected in eight of 13 samples. Leachate from an industrial landfill was found to contain relatively large numbers of PXDD/Fs, and several congeners were found in wastewater from an industrial fabric facility that handles decabromodiphenyl ether.

The workflow, including the post-data-processing method developed and applied in this study, has the advantage that additional identifications can be performed at any time from a single set of measurement data. This also enables the screening of substances that have thousands of homologous isomers, such as chlorinated and brominated dioxins, as well as other non-halogenated compounds.

**Fig. 3** Workflow and data flow for screening of mix-halogenated dioxins by GC×GC/ToFMS and post-data processing without any need for standard compounds. \* Accurate mass spectra are extracted from the accurate mass spectra of all isotopes on the basis of compositional equations. \*\* Mass spectra of compounds that consist only of carbon and hydrogen (i.e., hydrocarbons) are removed by filtering the accurate mass spectra of certain molecules or fragment ions by using the mass defects of the elements. HRMS, high-resolution mass spectrometry



### **4. Hg isotopic composition and total Hg mass fraction in NIES Certified Reference Material No. 28 Urban Aerosols**

NIES has been preparing and distributing environmental and biological CRMs (Certified Reference Materials) since 1980. We have provided 52 countries with thousands of bottles for the past 20 years.

NIES CRM No. 28, collected on the filters of a central ventilating system in a building in Beijing city center, was selected to determine the Hg isotopic reference values of aerosol referenced materials to meet the growing demand for understanding of Hg emission sources. Because south and north Asia are areas of major concern in terms of the atmospheric pollution problem, NIES CRM No. 28 will be an appropriate CRM to use when attempting to identify the sources of particulate matter emissions. As an interlaboratory study on the CRM, isotopic composition was measured at NIES and at IPREM (the Institut des Sciences Analytiques et de Physico-chimie pour l'Environnement et les Matériaux), in Pau, France, by using CV-MC-ICP-MS (cold vapor generation coupled with multicollector inductively coupled plasma mass spectrometry). Subsequently, a conventional dissolution method that uses a mixture of HNO<sub>3</sub>/HCl/H<sub>2</sub>O<sub>2</sub> in Hotblock® (TJ Environmental, The Netherlands), and two different dissolution methods that use a mixture of HNO<sub>3</sub>/HCl with a microwave and a digestion bomb were applied. Moreover, the total Hg (THg) mass fraction was determined by four organizations using atomic absorption spectrometry.

Quantification of the THg mass fraction gave a mean value of  $1.19 \pm 0.12$  mg/kg (2 SD, n = 24). The Hg isotopic compositions were  $\delta^{202}\text{Hg} = -1.26 \pm 0.17\text{‰}$ ,  $\Delta^{199}\text{Hg} = -0.23 \pm 0.06\text{‰}$ ,  $\Delta^{200}\text{Hg} = 0.01 \pm 0.07\text{‰}$ , and  $\Delta^{201}\text{Hg} = -0.22 \pm 0.09\text{‰}$  (2SD, n = 18) for the conventional method (Fig. 4); these agreed well with those obtained by using microwave and bomb digestion. Our results indicated that, for the quality control of particulate matter analyses, this CRM is appropriate for use in environmental and geochemical studies.

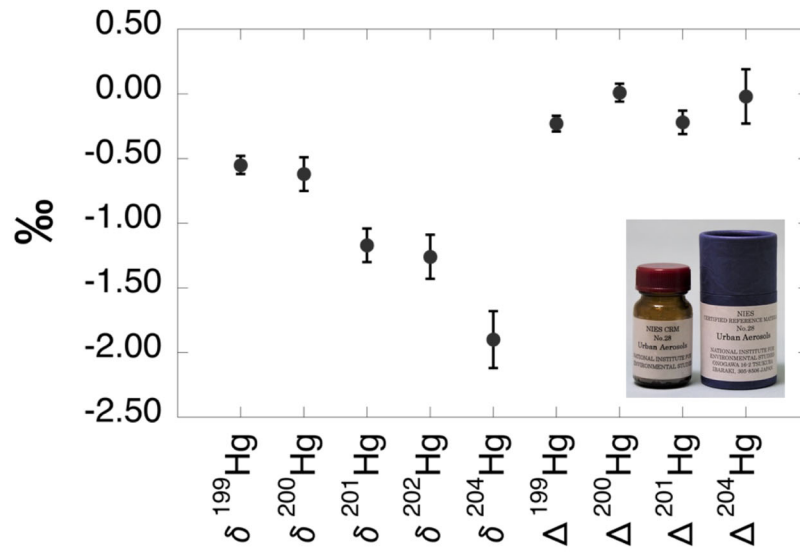
**Fig. 4** Hg isotopic composition of NIES CRM No. 28 Urban Aerosols. Isotopic compositions are reported in the delta ( $\delta$ ) notation relative to NIST SRM 3133 with  $^{198}\text{Hg}$  in the denominator:

$$\delta^{***}\text{Hg} (\text{‰}) = \left( \frac{(^{***}\text{Hg}/^{198}\text{Hg})_{\text{sample}}}{(^{***}\text{Hg}/^{198}\text{Hg})_{\text{NIST SRM 3133}}} - 1 \right) \times 1000,$$

where \*\*\* is the mass of each mercury isotope between 199 and 204 atomic mass units. Mass-independent fractionation is reported in capital delta ( $\Delta$ ) notation as the difference between the measured and the theoretical  $\delta^{***}\text{Hg}$  values:

$$\Delta^{***}\text{Hg} (\text{‰}) = \delta^{***}\text{Hg} - (\beta \times \delta^{202}\text{Hg}),$$

where  $\beta$  is the kinetic or equilibrium fractionation factor appropriate for the particular isotope ( $\delta^{199}\text{Hg}/\delta^{202}\text{Hg}=0.252$ ,  $\delta^{200}\text{Hg}/\delta^{202}\text{Hg}=0.502$ ,  $\delta^{201}\text{Hg}/\delta^{202}\text{Hg}=0.752$ ,  $\delta^{204}\text{Hg}/\delta^{202}\text{Hg}=1.492$ ).

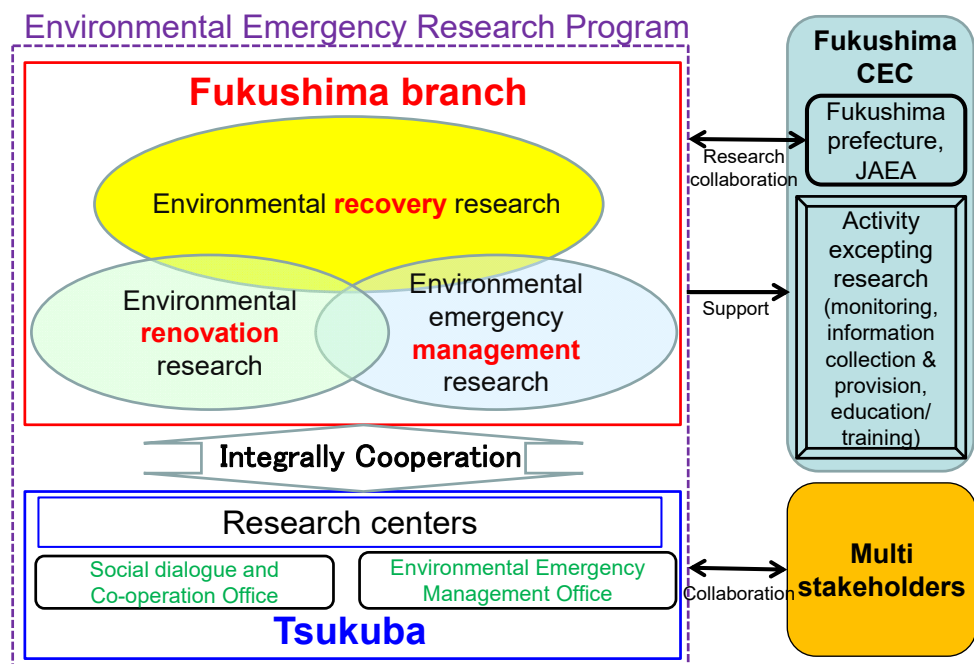




**Fukushima Branch**

In April 2016, NIES opened its Fukushima Branch in the research building of the Fukushima Prefectural Centre for Environmental Creation (Fukushima CEC), located in the town of Miharu in Fukushima Prefecture. The Institute’s objective is to promote and maintain rigorous scientific research focused on disaster-affected areas. NIES uses its Fukushima Branch as a collaboration hub to conduct environmental emergency research aimed at environmental recovery and renovation in disaster-affected areas. The collaborating partners include various relevant organizations, including the government of Fukushima Prefecture and JAEA (the Japan Atomic Energy Agency). NIES, by providing its environmental emergency research expertise, also extends support to Fukushima CEC’s efforts to collect and disseminate environmental information and to prepare educational, training, and exchange programs (Fig. 1).

**Fig. 1** Outline of environmental emergency research conducted at NIES’s Fukushima Branch. JAEA, Japan Atomic Energy Agency



In FY 2020, Fukushima Branch continued to conduct many kinds of research (laboratory work, field measurement, model simulation, and field studies) in the field of environmental emergency research, in collaboration with researchers in the research centers at Tsukuba. Research staff at Fukushima Branch also took part in the Environmental Emergency Research Program (see “Environmental Emergency Research Programs” in this report). In addition, we continued to promote climate change adaptation research and research into SDGs (Sustainable Development Goals) in collaboration with local governments, non-profit organizations, and local people in Fukushima Prefecture. In particular, collaboration with many local governments has led to research outcomes and the conveying of information to the public through public lectures, publications, and our website.

# Environmental Information Department

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## **Environmental Information Department**

The Environmental Information Department provides information technology (IT) support for research and related functions at NIES; supports public relations initiatives (including publishing NIES research reports); and performs miscellaneous other activities, including collecting and processing environmental information and disseminating it to the general public and performing tasks commissioned by the Ministry of the Environment (MOE). These tasks are described in detail below.

### **1. IT support for research and related activities at NIES**

The Department manages and operates the computers and related systems at NIES, uses IT to improve the work efficiency of NIES, and runs a library service.

#### **1.1 Management and operation of computers and related systems**

The first NIES supercomputer, an NEC SX-3, was installed in 1991 to elucidate phenomena related to global environmental change and to project such future phenomena. The NIES computer system has been updated several times, and in March 2020 computing performance and storage capacity were vastly improved by the installation of a new system consisting of the following three main elements:

- a vector-processing computer (NEC SX-Aurora TSUBASA A511-64; 256-vector engine, total 2048 CPU, peak performance 622.8 TFLOPS) (Fig. 1)
- a scalar-processing computer (HPE Apollo 2000; 28 nodes, total 1120 cores, peak performance 86.0 TFLOPS)
- a large-capacity file system (Data Direct Networks [DDN] SS9012 etc., total about 22 PB).

A local area network (LAN) called NIESNET was established at NIES in 1992. NIESNET was replaced in March 2021. We are improving convenience by expanding the wireless LAN usage area and strengthening security by introducing an authentication function.

**Fig. 1** The NEC SX-Aurora TSUBASA supercomputer



### **1.2 Use of IT to improve work efficiency at NIES**

The Department provides IT support to the administration and planning divisions of NIES with the aim of increasing work efficiency. It also provides NIES researchers with processed research data and helps them to disseminate their data through the NIES website. In FY 2020, the Department supported:

- development of an electronic application and registration system at NIES
- operation of a thin-client PC management system for the administrative section
- development of the NIES research information database
- modification and operation of a database of basic information on each staff member at the Institute.

### **1.3 Library services**

As of March 2021, the NIES library (Fig. 2) held 71,311 books, 897 journals (including electronic resources), and various other technical reports and reference materials. These materials can be searched by using OPAC (Online Public Access Catalog) and a link resolver via the Intranet. We have also introduced a web-scale discovery service, Primo (Ex Libris). It has the capacity to more easily connect researchers with the library's vast amount of information held in physical holdings, digital collections, and various repositories.

In addition to these resources, researchers at NIES can use abstracts and full-text articles through scientific and technical information databases such as Web of Science (including Essential Science Indicators and Journal Citation Reports).

Library facilities include separate rooms for reading books, journals, and reports and are equipped with two PCs for accessing electronic materials.

**Fig. 2** The NIES library



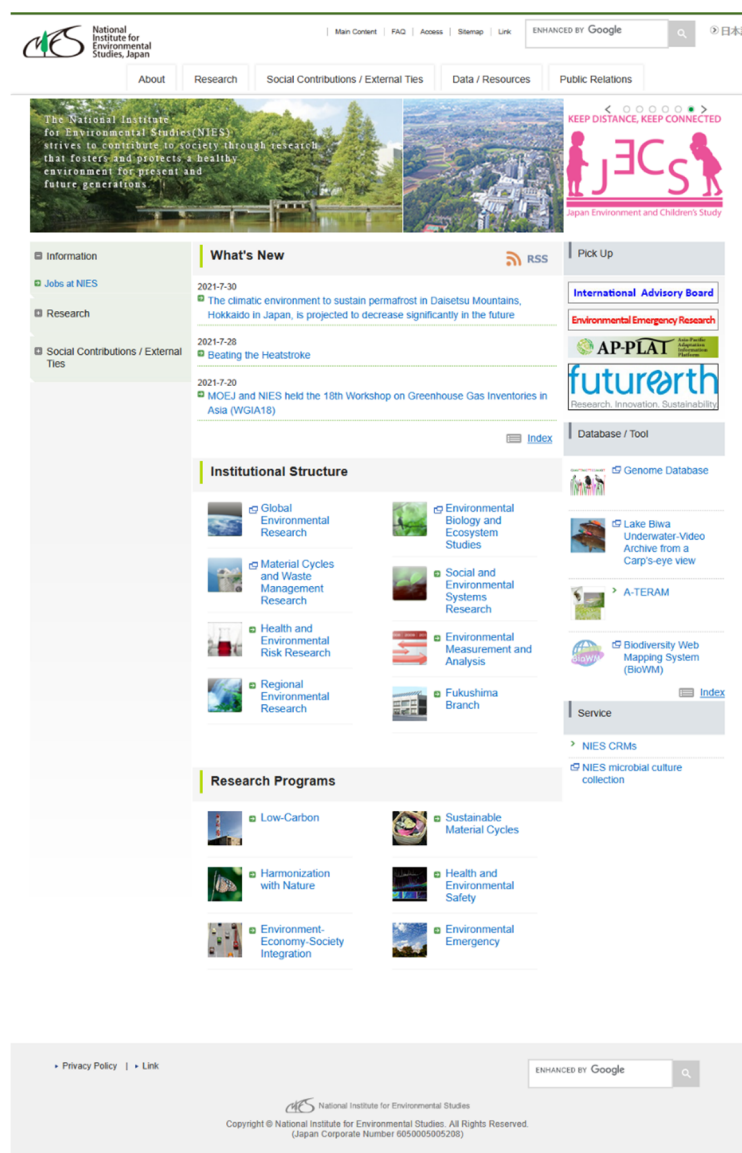
## 2. NIES public relations activities

The Department manages the NIES website. It also edits and publishes NIES reports such as research reports and this *Annual Report*.

### 2.1 Management of the NIES website

NIES began to provide publicly accessible information on its research activities and results via the Internet (<https://www.nies.go.jp/>; Fig. 3) in March 1996. In April 2001, the website was completely revamped and improved in step with the restructuring of NIES as an Independent Administrative Institution. The website was again revamped in July 2013. It also provides information on NIES initiatives related to the Great East Japan Earthquake.

**Fig. 3** The NIES website



## 2.2 Editing and publication of NIES reports

Reports on NIES research activities and outcomes, such as the *NIES Annual Report* and research reports, official newsletters (*NIES News*, in Japanese), and NIES research booklets (*Kankyo-gi*, in Japanese), are edited, published, and distributed by the Department.

## 2.3 Promoting Open Science

To facilitate the use and application of research resources, prevent the loss of research results, and assure permanent accessibility, we have started attaching digital object identifiers (DOIs) to research data. Accordingly, we have set up a system for publishing URLs (metadata) associated with DOIs on the NIES website.

In response to calls for the establishment of a system for promoting open science, we have also started exploring an archive system (an institutional repository) to be created and operated by NIES. In addition, to estimate the costs of APCs (article processing charges) each year, we have conducted a survey of open access activities at NIES. We are using the CHORUS Institution Dashboard Service to monitor publicly funded research that has been published, and we reported the case study for use it at the Japan Science and Technology Agency/CHORUS session of the Library Fair in November 2020.

## 3. Other activities

### 3.1 Collection, processing, and dissemination of environmental information

One of the major tasks at NIES is the collection, processing, and dissemination of environmental information. The Department provides various kinds of environmental information to the public through websites. It also processes and manages environmental information databases and provides environmental information via GIS (Geographic Information Systems).

#### 3.1.1 Environmental Observatory (Information Platform for Environmental Outlook)

The Environmental Observatory (Information Platform for Environmental Outlook) is a multimedia site providing integrated environmental information to promote wider involvement of the public and relevant institutions in environmental conservation. It gives users broad access to a range of systematically organized environmental information aimed at creating a sustainable society. The site offers a quick search facility to access news updates on such things as environmental issues in Japan and throughout the globe; descriptions of key environmental technologies; information on policies and laws in environmental fields; environmental



information via GIS; and other content to aid environmental learning.

### **3.1.2 Processing and management of environmental information databases**

Various environmental data are needed for research, policy decisions, and policy enforcement. We compile and process air-quality and water-quality data collected by local governments and reported to MOE. These processed data can be accessed through the database on the NIES website. Duplication and lending services are also available.

### **3.1.3 Provision of environmental information via GIS**

The Department, with the cooperation of MOE, has been using GIS to develop an environmental data provision system. By displaying data on environmental quality and other information on maps, this system helps users to understand the status of the environment easily. The system has been publicly available through the Internet since September 2002 and was revised in March 2011.

## **3.2 Tasks commissioned by the Ministry of the Environment**

In FY 2020, the Department performed the following task, as commissioned by MOE:

- conversion of hourly values of regular air-monitoring data to standard format.

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