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NIES Annual Report 2022

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National Institute for Environmental Studies
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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 unique 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 2021 (FY2021: April 2021 to March 2022) which marked the first year of our Fifth Five-Year Plan (FY2021-FY2025).

In FY2021, NIES embarked on its Fifth Five-Year Plan under plans to steadily engage in basic and fundamental work to create scientific knowledge that should serve as a source to solve environmental issues by establishing six fields (Earth System; Material Cycles; Health and Environmental Risk; Regional Environment Conservation; Biodiversity; Social Systems) as the pillars of environmental research and two fields (Environmental Emergency and Resilience; Climate Change Adaptation) aiming to systemize over the long term. In addition to promotion of *Foresight and Advanced Basic Research* based on creative and cutting-edge science exploration, we will also steadily develop *Intellectual Research Infrastructure* to support academic and policy work through *Policy-Oriented Research* for practical research responding to policy needs, and global environmental monitoring which has been ongoing for long years.

Eight Strategic Research Programs are set across research fields to solve urgent issues. These research programs are climate change and air quality, material flow innovation, comprehensive environmental risk, harmonization with nature, decarbonized and sustainable society, co-design approach for local sustainability, environmental emergency and resilience, and climate change adaptation. The programs will be conducted in a focused and comprehensive manner with awareness to achieve goals within the next five years. The climate crisis issues will be particularly promoted in an integrated manner under *Climate Crisis Research Initiative*, which coordinates four related programs.

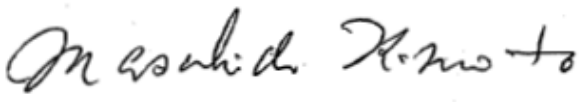
Based on national plans, NIES will continue to conduct the satellite-based global observation of greenhouse gases (GOSAT) and the nationwide birth cohort study of 1,000,000 pairs of parents and children on children's health and the environment as projects to be implemented beyond the Mid-and-Long Term Plan period. As for climate change adaptation, we will conduct research and provide technical assistance to local governments to promote adaptation.

As a core institute for environmental research in Japan, NIES must strengthen collaborations with the Ministry of the Environment and other relevant ministries and agencies, research institutes and regional

environmental research institutes, as well as fulfilling contribution to the society. With the start of our Fifth Five-Year Plan, we newly established Research Collaboration Division in the Administration Department to promote collaboration with other institutes and dialogues with the society. The Fukushima Branch is renamed to Fukushima Regional Collaborative Research Center to clearly demonstrate our intention to contribute to the regional community by collaborating with various entities.

Despite various restrictions due to the pandemic, we were able to start the first year of our Fifth Five-Year Plan without sacrificing research productivity by maintaining dialogues with the society by use of online tools, video distributions and other means. NIES will continue to enhance research activities based on our Fifth Five-Year Plan.

This Annual Report aims to inform the public of our research activities. We would appreciate any forthright opinions on our status and future activities.



Masahide KIMOTO
President
November 2022

Contents

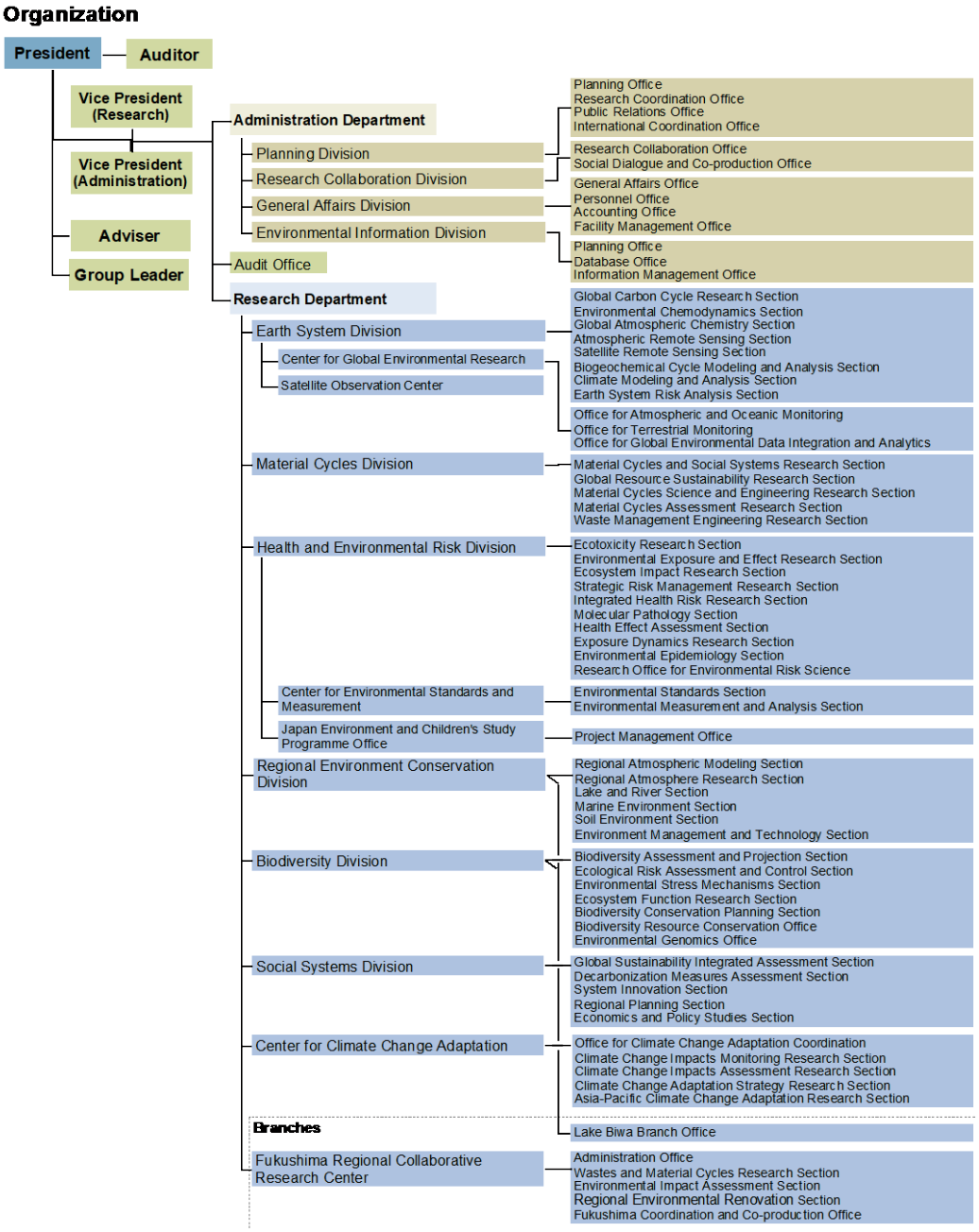
During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established in 1971 as part of the Japanese government to develop measures to counteract serious problems associated with environmental pollution, such 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. 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. In the Fourth Five-Year Plan (2016-2020), NIES established Fukushima Branch in April 2016 and Lake Biwa Branch Office in April 2017. In December 2018, we also established the Center for Climate Change Adaptation in line with the enactment and enforcement of the Climate Change Adaptation Act to research and promote adaptation to climate change.

Fig. 1 Organization



April 2021 marked the beginning of the Fifth Five-Year Plan (2021-2025). NIES established 8 Strategic Research Programs such as environmental emergency and resilience research and climate change adaptation research, and pursuing them in an integrated manner that transcends individual fields.

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 April 1, 2021, there are 300 NIES permanent staff and 664 contract staff (Table 1; Figs. 2 to 5). The total budget for FY2021 was 20,468 million yen (Table 2).

Table 1 Numbers of permanent staff

Administration Department	58
Research Department	237
Executives and Advisers	5
Total	300

(As of April 1, 2021)

Table 2 Budget for the Fifth Five-Year Plan

(Unit: million yen)

	Category	2021-2025 Budget (5 years)	Fiscal Year 2021 Budget
Revenue	Grants for Operating Costs	85,277	16,514
	Subsidies for Facilities	2,003	318
	Commissioned Work	18,428	3,636
	Total	105,708	20,468
Expenditure	Project Costs	66,315	12,649
	Facility Improvements	2,003	318
	Expenses for Commissioned Work	18,179	3,636
	Personnel Expenses	17,069	3,411
	General Administrative Expenses	2,141	455
	Total	82,162105,708	20,468

Note: The budget for each annual work plan will be requested and decided for each fiscal year, based on the Mid-and-Long Term Plan.

Administration Department	:	58	
Research Department	:	237	(6)
Executives and Advisers	:	5	
Total		300	(6)

Notes:
1. Data is as of April 1, 2021.

2. Figures in parentheses indicate number of foreign nationals.

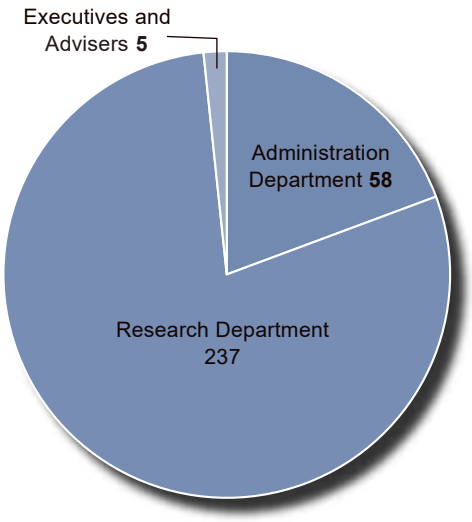


Fig. 2 Permanent staff breakdown

Basic Sciences	:	98	43.95%
Engineering	:	69	30.94%
Agricultural Sciences	:	33	14.80%
Medical Sciences	:	9	4.04%
Pharmaceutical Sciences	:	3	1.34%
Veterinary Medicine	:	1	0.45%
Social Sciences	:	10	4.48%
Total		223	

Note: Data is as of April 1, 2021.

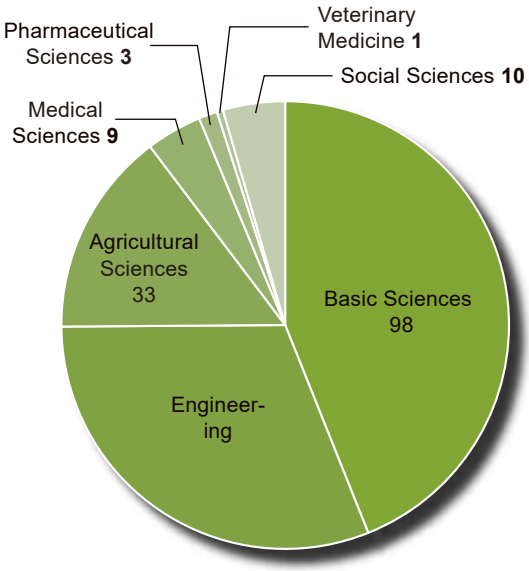


Fig. 3 Fields of expertise（Researchers holding doctorates（95.5%））

Senior Fellow	:	1	
Fellow	:	6	
Research Associate	:	89	(37)
Junior Research Associate	:	9	(3)
Research Assistant	:	28	(7)
Expert	:	239	(9)
Assistant Staff	:	277	
Senior Staff	:	4	
Senior Research Associate	:	11	
Total		664	(56)

Notes:
1. Data is as of April 1, 2021.

2. Figures in parentheses indicate number of foreign nationals.

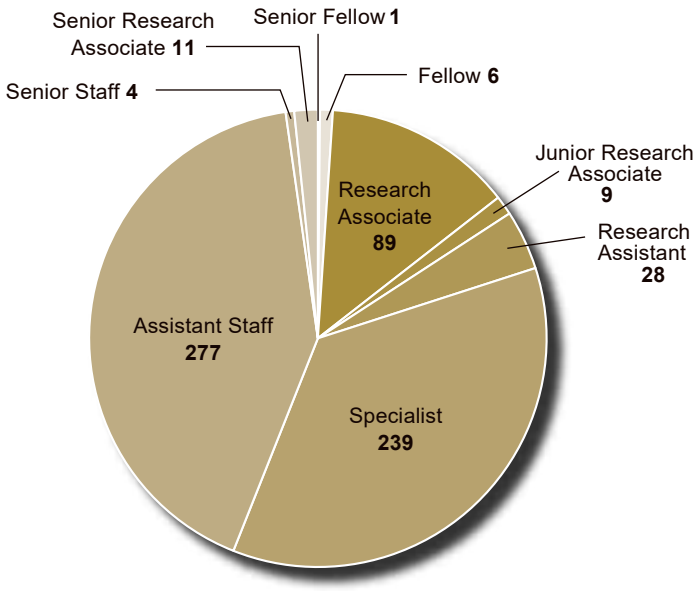


Fig. 4 Contract Staff Breakdown

Visiting Researcher	203	(15)
Collaborative Researcher	69	(9)
Research Student	39	(10)
Interns	11	(2)
Total	322	(36)

Notes:

1. Data is the total number accepted in FY2021.

2. Figures in parentheses indicate number of foreign nationals.

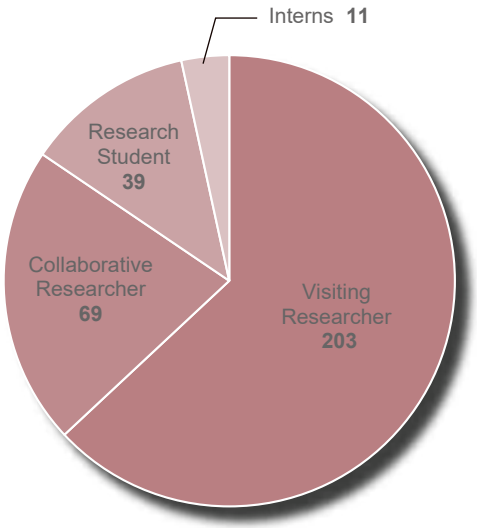


Fig. 5 Visiting and Collaborative Researchers, Research Students, and Interns

Strategic
Research Program

Climate Change and Air Quality Research Program

By making the best combined use of the Earth observation data from ground-based, ship-based, aircraft, and satellite platforms, we intend to meet the challenge to establish an operational system to estimate greenhouse gas (GHG) emissions and uptake on a global scale. We will also develop a new methodology to estimate GHG and SLCF (short-lived climate forcer) emissions on the national and city scales. In addition, by using the latest emission estimates and evaluations, we will improve the accuracy of hindcast and forecast of the changes and variability in climate and air quality. To do this, we will use state-of-the-art modeling that takes into account the latest emission estimates and the latest knowledge of the fundamental processes of microphysics and chemical reactions and of the interactions of Earth systems. Overall, we will provide the scientific basis needed to make policy decisions to achieve the long-term goal of global stabilization of climate and air quality (Fig.1).

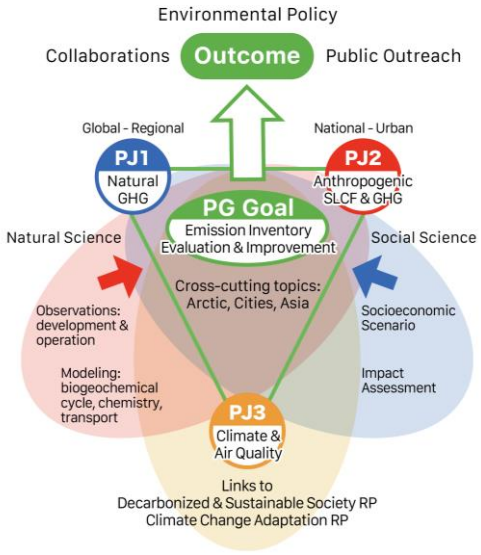


Fig.1 Conceptual schematic of the Climate Change and Air Quality Research Program

Project 1. Quantitative evaluation of natural / anthropogenic GHG sources and sinks on the global scale

This project aims to develop unified, neutral, and objective methods for estimating global GHG sources and sinks, from developed to developing countries, that are associated with different technical levels of preparation and compilation of emission inventories. To do this we are making the best use of the data obtained from ground-based, ship-based, aircraft, and satellite observations. The project comprises three sub-themes: (1) GHG exchange over land and ocean, based on highly precise observations; (2) GHG budgeting over an extensive regional scale by atmospheric observation and modeling; and (3) GHG emissions and dynamics of carbon (C) and nitrogen (N) associated with human activities.

Sub-theme 1 has been evaluating terrestrial and oceanic carbon dioxide (CO_2) budgets based on observations. Figure.2 shows the distribution of CO_2 sources and sinks in the Southeast Asian islands, where ground-based observations are sparse,

in September 2015, in the largest El Niño period this century. These values were estimated by using an inverse analysis method based on high-frequency CO_2 observations by commercial aircraft and cargo ships. The total CO_2 emission from September to October 2015 was evaluated at 273 Tg C, which was comparable to the annual CO_2 emissions from Japan (Niwa et al., Atmos. Chem. Phys., 2021)[1]. Under this sub-theme, we have also evaluated coastal CO_2 uptake in Tokyo Bay, Ise Bay, and Osaka Bay by using oceanographic data based mainly on observations taken aboard cargo ships. The results clearly indicate that these regions are among the world's largest CO_2 uptake regions in the coastal zone (Tokoro et al., J. Geophys. Res., 2021)[2].

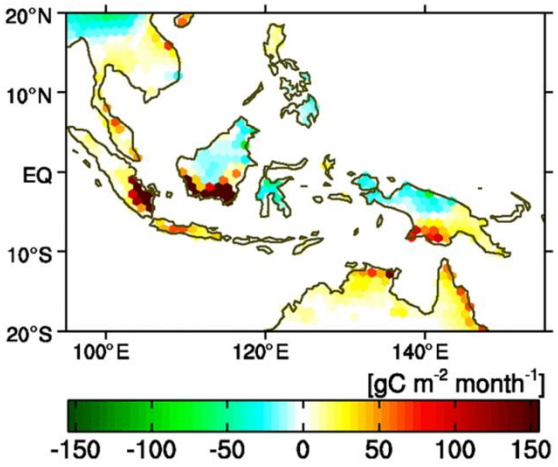


Fig.2 Distribution of CO_2 sources and sinks in the Southeast Asian islands in September 2015. Positive values indicate sources and negative values indicate sinks (Niwa et al., Atmos. Chem. Phys., 2021)[1].

Sub-theme 2 has been analyzing seasonal and interannual variations in the stable isotope ratio of CO_2 and in GHG concentrations. These data are obtained from flask-sampling observations at Nainital (NTL) in the mountainous region of North India and Comilla (CLA) in the paddy field region of Bangladesh. As control data, seasonal and interannual variations are analyzed by using observations at Mauna Loa summit (MLO) in Hawaii, USA. The results indicate that the rate of increase in CO_2 concentration observed at NTL was not affected by the El Niño Southern Oscillation, unlike at MLO, and that regional factors such as the atmospheric circulation field associated with the Indian monsoon and agricultural patterns in the Ganges River basin have a substantial impact on seasonal and interannual variability (Nomura et al., Atmos. Chem. Phys., 2021)[3]. The data are made available to the public through the Global Environment Database of NIES. In addition, in August this year, the Comprehensive Observation Network for TRace gases by AIrLiner (CONTRAIL) Project began releasing preliminary data within 1 year of observations, with DOIs (digital object identifiers) in the same database (https://www.nies.go.jp/doi/10.17595/20210827.002-e.html).

Sub-theme 3 has evaluated marine N pollution in the East China Sea by using a numerical model focusing on riverine transport, which is the major source of

pollution of coastal areas. Although N loading into the East China Sea has been increasing since the 1960s, the increase in chemical N fertilizer applicatipns in the agricultural areas of northeastern China has been suppressed, and application has slowed since the 2000s. However, N loading from rivers increases with increasing annual precipitation in the watershed, indicating that future increases in rainfall in this watershed may offset N fertilizer reduction efforts (Nishina et al., Environ. Res. Commun., 2021)[4]. The sub-theme also evaluated past uncertainty in presenting N balances in global agricultural lands by intercomparing global nitrogen databases regarding chemical fertilizers, composts, N deposition, biological N fixation, and crop N yield. It found that the most uncertain elements in the N budget differ among countries (Zhang et al, Nature Food, 2021)[5].

Reference :

1) Niwa Y., Sawa Y., Nara H., Machida T., Matsueda H., Umezawa T., Ito A., Nakaoka S.-I., Tanimoto H., Tohjima Y. (2021) Estimation of fire-induced carbon emissions from Equatorial Asia in 2015 using in situ aircraft and ship observations. *Atmospheric Chemistry and Physics*, 21, 9455–9473

2) Tokoro T., Nakaoka S., Takao S., Kuwae T., Kudo A., Endo T., Nojiri Y. (2021) Contribution of biological effects to carbonate-system variations and the air–water CO_2 flux in urbanized bays in Japan. *Journal of Geophysical Research: Oceans*, 126, e2020JC016974

3) Nomura S., Naja M., Ahmed M. K., Mukai H., Terao Y., Machida T., Sasakawa M., Patra P. K. (2021) Measurement report: Regional characteristics of seasonal and long-term variations in greenhouse gases at Nainital, India, and Comilla, Bangladesh. *Atmospheric Chemistry and Physics*, 21, 16427–16452

4) Nishina K., Ito A., Zhou F., Yan X., Hayashi S., Winiwarter W. (2021) Historical trends of riverine nitrogen loading from land to the East China Sea: a model-based evaluation. *Environmental Research Communications*, 3, 085005

5) Zhang X., Zou T., Lassaletta L., et al. (2021) Quantification of global and national nitrogen budgets for crop production. *Nature Food*, 2, 529–540

Project 2. Quantitative evaluation of anthropogenic SLCF and GHG emissions on regional, national, and city scales

This project aims to reduce the uncertainties in anthropogenic emission inventories for SLCF and GHG. These inventories are based on international assessment reports and are used by modeling studies of both climate and air quality. In FY 2021, we performed four activities: (1) expansion of the network of observations from the ground and from ships and aircraft; (2) development of new analysis and observation methods; (3) development of a method of estimating emissions at a high spatial resolution; and (4) preparation for the building of high-resolution inventories. Below are details of two topics in the activities (1) and (2).

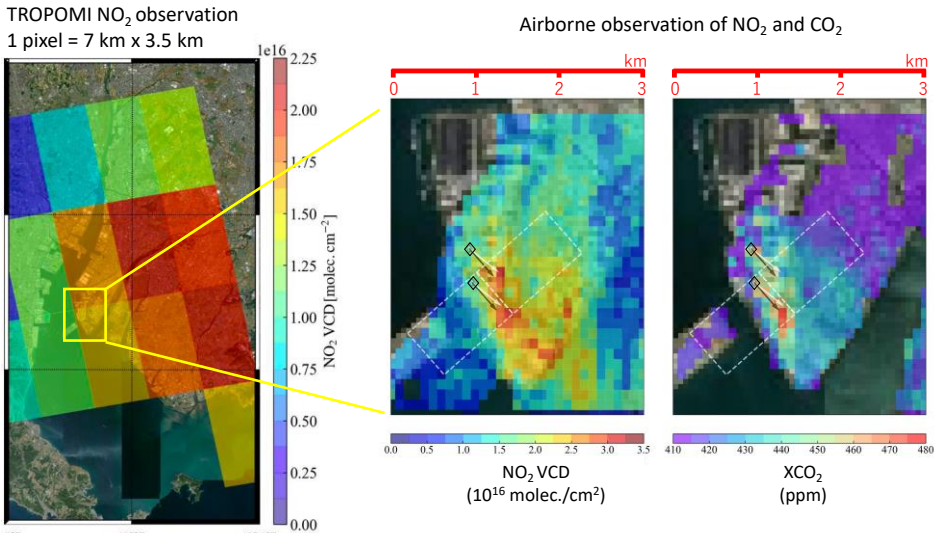


Fig.3 Distributions of NO_2 vertical column densities (VCDs) observed by the TROPOMI satellite (left panel), and mesh plots of NO_2 VCD and XCO_2 (column-averaged CO_2) data retrieved by aircraft observation (right panel) (Fujinawa et al., Geophys. Res. Lett., 2021).

The influence of the COVID-19 pandemic on urban CO_2 emissions was investigated by using atmospheric observations in a residential area (approximately 4×105 m^2) in Yoyogi, Tokyo, Japan. The measured CO_2 flux decreased by 20% ± 3% in April–May 2020 compared with the same period during the past few years. The decrease in flux was due to a decrease in liquid fuel consumption (e.g., in cars), whereas household gas fuel consumption (e.g., for cooking and heating water) was slightly increased. A human-activity analysis in the flux footprint area supported the results of the observation: car traffic decreased and household gas consumption increased (Sugawara et al., Geophys. Res. Lett., 2021)[2].

Combined nitrogen dioxide (NO_2) and CO_2 observations have the potential to constrain identification of the locations and strength of urban CO_2 emissions—in particular, at point sources such as power plants. We reported the first results of airborne spectroscopic NO_2 and CO_2 observations over an urban area of Japan in February 2018. The inverse rates of emission of CO_2 from two stacks of a coal-fired power plant showed relatively good agreement with those estimated by using a bottom-up inventory (within –7% to 40%), because the plume shapes were well identified owing to constraint by the NO_2 measurements (Fujinawa et al., Geophys. Res. Lett., 2021)[1]; see Fig.3.

Reference：
1) Fujinawa T., Kuze A., Suto H., Shiomi K., Kanaya Y., Kawashima T., Kataoka F., Mori S., Eskes H. Tanimoto H. (2021) First concurrent observations of NO_2 and CO_2 from power plant plumes by airborne remote sensing. *Geophysical Research Letters*, 48, e2021GL092685
2) Sugawara H., Ishidoya S., Terao Y., Takane Y., Kikegawa Y., Nakajima K. (2021) Anthropogenic CO_2 emissions changes in an urban area of Tokyo, Japan, due to the COVID-19 pandemic: A case study during the state of emergency in April–May 2020. *Geophysical Research Letters*, 48, e2021GL092600

Project 3. Simulation and projection of climate air quality with enhanced numerical modeling capabilities

In this project, we are studying historical and future changes in climate and air quality by numerical simulation using global climate models (GCMs) that include aerosol and chemistry modules. Output data from the numerical simulations are useful when discussing measures for mitigation of, and adaptation to, climate and air quality changes. By producing such output data, we intend to help to achieve the temperature goals in the Paris Agreement.

This fiscal year, by using a GCM, namely MIROC6, we conducted numerical experiments to examine how clouds accelerate or decelerate global warming. Projections of global mean surface temperature with multiple GCMs exhibit large uncertainty, namely inter-model spread, which causes difficulties in discussing measures for mitigation and adaptation. Such uncertainty is primarily associated with inter-model spread in cloud feedback, which accelerates or decelerates global warming through cloud sunshade or greenhouse effects, or both. A possible reason

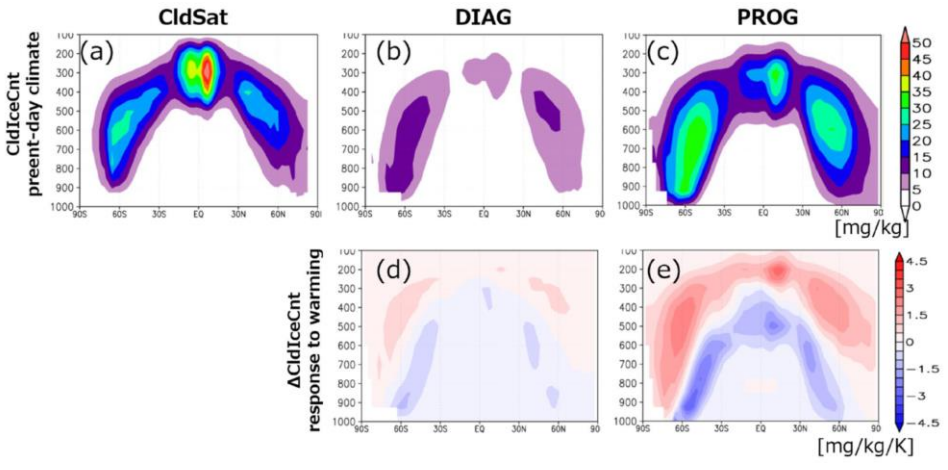


Fig.4 Atmospheric ice hydrometeors in the present-day climate and their responses to global warming. (a to c) Total ice contents in the present-day climate (mg kg^{-1}), as determined by observation ("CldSat"), DIAG, and PROG. (d, e) Responses of cloud ice contents to surface warming (mg kg^{-1} K^{-1}), as determined by DIAG and PROG (Hirota et al., Geophys. Res. Lett., 2022)[1)]

for the spread in cloud feedback is the overly simplified treatment of precipitation (hereafter DIAG) in GCMs, whereby rain and snow particles fall immediately from the atmosphere down to the surface within a single model time interval of about 10 min. Here, we introduced a more sophisticated precipitation scheme (hereafter PROG) that explicitly calculates the physical processes of the falling of rain and snow particles, thus preserving their "memory" in the atmosphere with their sunshade and greenhouse effects incorporated. As a result, the representation of clouds in MIROC6 has improved substantially (Fig.4). In addition, the cloud feedback associated with the elevated altitude of clouds in warming climates is substantially enhanced, thus accelerating global warming by the greenhouse effect. This study lends credence to greater cloud feedback and climate sensitivity if models incorporate the missing feedback processes in line with observational constraints (Hirota et al., Geophys. Res. Lett., 2022).

Reference :

Hirota N., Michibata T., Shiogama H., Ogura T., Suzuki K. (2022) Impacts of precipitation modeling on cloud feedback in MIROC6, *Geophysical Research Letters*, 49, e 2021GL096523

Overview of Material Flow Innovation Research Program

The Material Flow Innovation Research Program is focused on the assessment and enhancement of material flows over entire product life cycles to achieve the sustainable utilization of resources. We have been implementing three research projects with the goal of qualitatively and quantitatively demonstrating the future changes required in material flows (Fig.1). The projects are: Project 1, Material flows transition and social adaptation (PJ1); Project 2, Chemical management for material flows transition (PJ2); and Project 3, Material circulation and sequestration technology (PJ3).

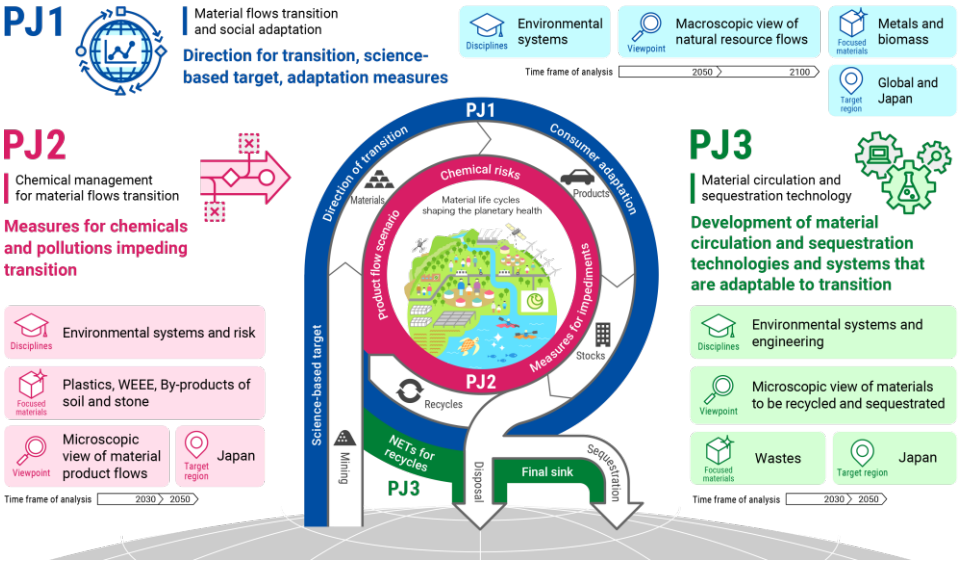


Fig. 1 Overall diagram of the project structure of the Material Flow Innovation Research Program.

In the first year (FY 2021) of the five-year research period (FY 2021–2025), the Program made solid progress according to its annual research plan. To start with, we clarified our vision among the three PJs, namely how our research outcomes should ultimately benefit society ("Theory of Change"). The Program's research team members also confirmed the target audience for disseminating research outputs, as well as the stakeholders for collaboration.

With this vision and the social contribution objective in mind, we conducted substantive information dissemination and outreach activities in FY 2021. We launched a website (https://mfi.nies.go.jp) and published three papers, with press releases. Science animation video clips on our research findings, a booklet on decarbonized lifestyle options for Japanese cities, and a related database (https://lifestyle.nies.go.jp/en) were also developed and released for general viewers. The press releases led to our discussion with producers who were deeply involved in material flows, mainly in the field of metals, as well as with consumers on the importance of material flows transition. In addition, we disseminated our research findings on decarbonized lifestyles to an even wider readership.

PJ1 proposes scenarios for material flows transition to more advanced levels, and PJ2 demonstrates methods of managing hazardous chemical substances to enable the transition. PJ3 enhances the feasibility of the scenarios through the development of more advanced waste treatment technologies for a decarbonized society and stable long-term storage technologies for waste materials that need to be isolated from the environment. More specifically, in FY 2021, PJ1 made projections of future global targets for metal recycling and stocks, and PJ2 used these targets as conditions for making scenarios for the future utilization and recycling of materials and products. Similarly, PJ2 estimated the impacts of hazardous chemicals (i.e. hindering factors) on recycling rates, and assessed the effectiveness of removing these hindering factors. PJ1 reflected these results in parameters of a model developed as part of the project. Furthermore, PJ3 developed technological options for the treatment of bio-based waste, and PJ1 utilized the PJ3 research results, namely the per-unit energy consumption data, to develop the model.

Highlighted research findings

Project 1: Material flows transition and social adaptation

The foundations of a modern society are based on metals, yet their production is currently placing considerable strain on the Earth's carrying capacity. To explore a desirable direction for material flows transition on a macroscopic scale, we developed a global-scale simulation model to quantify the flows and stocks of major metals (iron, aluminum, zinc, lead, nickel, and copper). We also formulated a long-term outlook and the "material budgets" required for the transition to a decarbonized society, as well as their effect on planetary health. (Material budgets are the maximum amounts of materials that could be available at a global level under a given set of environmental constraints.)

We showed that, for the metal sector to contribute proportionally to the emission reduction targets of the industrial sector, global in-use metal stocks would need to converge from the current level of around 4 t/capita to about 7 t/capita (see Fig.2). This would require today's high-income countries to contract their per capita stock from the current levels of about 12 t/capita to make room for growth in countries that are presently classified as middle- and low-income countries. The model also calculated the same value (about 10 t) under a variety of ambitious measures for improving resource efficiencies (e.g., transition to decarbonized power generation, enhancement of energy efficiency, and promotion of recycling); this value was again below the high-income countries' current level. These results show that keeping global metal production and consumption at the high-income countries' level will be difficult. These findings highlighted the importance of satisfying basic needs (e.g., housing, transport, and communication) with lower levels of metal production and consumption, in addition to developing decarbonized production technologies. Wealthy countries will need to use existing metal stocks more intensively, and for longer periods, to reduce stock replacement demand, whereas poor countries will need to develop long-lasting and material-efficient infrastructure to curtail stock expansion demand in the first half of the 21st century.

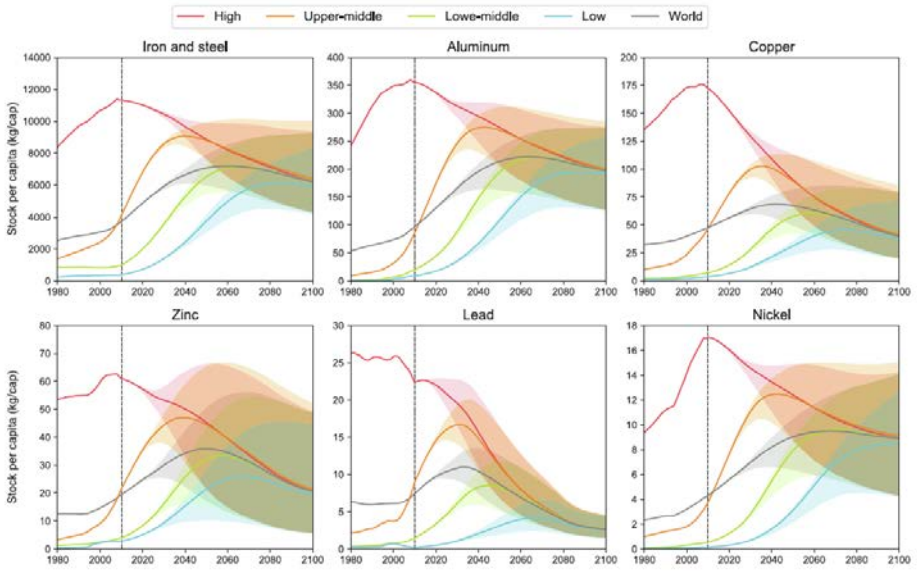


Fig.2 Per capita in-use stocks of the six major metals under the emissions budget, 1980–2100. The color band around each line reflects the uncertainties associated with advances in technology and the circular economy. Solid lines represent the means of scenarios. Vertical dashed lines mark the year in which the future projections began (2010).

Project 2: Chemical management for material flows transition

We identified and categorized hazardous chemicals that potentially hinder recycling of plastics and construction materials. For plastics, we examined overlaps between the items on a hazardous plastics additive list (consisting of approximately 400 items) published by the ECHA (European Chemicals Agency) and hazardous chemicals in plastics reported by other governmental institutions. There were 20 overlapping chemicals that potentially harm the environment and hinder recycling, including substances that are already regulated internationally or those of very high concern listed by the EU's (European Union's) REACH regulation; the Stockholm Convention on POPs (persistent organic pollutants); and the European RoHS (Restriction of Hazardous Substances) Directive. These findings led us to plan our next activities, namely to review the current state of concentrations and flows of these hazardous substances in plastic products and waste and to understand their behavior in recycling processes.

In the case of construction materials, environmental standards for soil can be a factor hindering their recycling if the standards are made tighter or if new substances are added to the current list. Soil standards are often referenced in determining the feasibility of recycling these materials. We reviewed the drinking water quality standards (DWQSs) of other countries—especially the substances they cover—because they are referenced as a basis for other environmental standards. As Japan is also likely to reference these lists when modifying domestic environmental standards, we reviewed the DWQSs and guidelines of the EU, the US, Australia, Canada, China, South Korea, and the WHO (World Health Organization), and we identified commonly regulated substances, such as antimony and barium, that Japan had not yet included in its DWQSs. If these substances are added to Japan's DWQSs, then depending on their DWQS values, the recycling of construction materials is likely to be affected. We examined the current concentrations of these chemicals in approximately 50 recycled construction

materials, and we evaluated their release to the surrounding environment by using leaching test methods that have generally been adopted in Japan. These results will enable us further to examine whether setting certain criteria levels for these substances will inhibit the use of recycled materials. Environmental standards for soil that are at levels similar to DWQSs can be too strict for determining safety of recycled construction materials. For this reason, we have confirmed a strong need to establish new risk assessment methods based on appropriate evaluation of chemical exposure and risk from the use of such materials.

Project 3: Material circulation and sequestration technology

We conducted laboratory-scale experiments to determine the thermal decomposition behavior of different biomass-derived materials and products. From the results of the experiments, we determined the temperature (T_{max}) at which their thermal decomposition rate was maximized. For example, we found the following T_{max} values: approximately 300 °C for biowaste (e.g., agricultural residue and food waste); from 285 to 400 °C for paper, diapers, and biodegradable polymers (BDPs) such as PLA (polylactic acid); and from 440 to 480 °C for biomass-based polymers (BBPs) such as biopolyethylene. The maximum difference in T_{max} between BDPs and BBPs was about 200 °C. The above results showed that, if low-temperature thermal decomposition processes are applied, the treatment temperature can be lowered to 350 to 400 °C (500 °C lower than with incineration) by switching the raw materials from petroleum-derived plastics to BDPs or paper.

We developed a mathematical simulation model to evaluate the effectiveness of long-term waste storage and disposal technologies and systems (e.g., closed-type landfills) in isolating hazardous substances from the environment and controlling the transport of the hazardous substances. Our simulation results showed that CO_2 produced from the waste can be expected to increase substantively with the aging of the storage structure (Fig.3). Exposure of floor slabs to a high concentration of CO_2 (e.g., approximately 40% after 1 year) in the facility could start to cause cracks in the slab concrete after 10 years; lead and chromium would be emitted through the cracks into the surrounding environment, regardless of whether the cracks were caused only by the exposure or by seismic motion. With a corrosion rate of 100%, the crack widths in the floor slabs were estimated at 19 to 27 mm (i.e., 38 to 54 times the permissible crack widths for commonly used reinforced concrete structures). As floor slabs are exposed to high chloride ion concentrations (up to 70 g/L), the corrosion rate after 10 years is projected to reach 100%. Therefore, we found that, to maintain high functional performance in isolating hazardous substances, effective measures such as controlling landfill gases (i.e., waste-derived CO_2) and coating concrete structures with appropriate water- and corrosion-protection materials would be necessary.

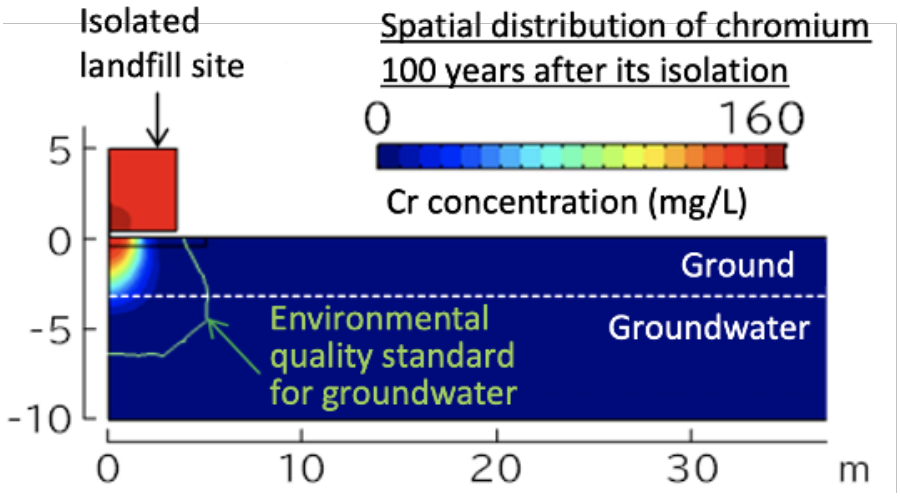


Fig.3 Example of results from a simulation of chromium distribution at a final waste disposal site designed to isolate hazardous wastes

Comprehensive Environmental Risk Research Program

In this program, we started conducting research to promote the comprehensive risk assessment and management of chemicals and other pollution factors (the pollutome, i.e., the total of all forms of pollution that can harm human and ecological health; Figure 1). To assess and manage the greater part of chemicals originating from human activities, we expanded the target chemicals to all chemicals of concern and considered vulnerable groups and life stages of humans and other organisms. In addition, we upgraded our comprehensive measurements and mathematical models to better assess those effects and risks that have been hard to quantify. As a result of these efforts, we aim to help establish comprehensive health risk indexes and ecological risk indexes. We also intend to establish and amend the control measures for chemicals and other pollution factors directed by Japanese government (mainly the Ministry of the Environment) and other organizations via risk assessment infrastructure (Fig. 1).

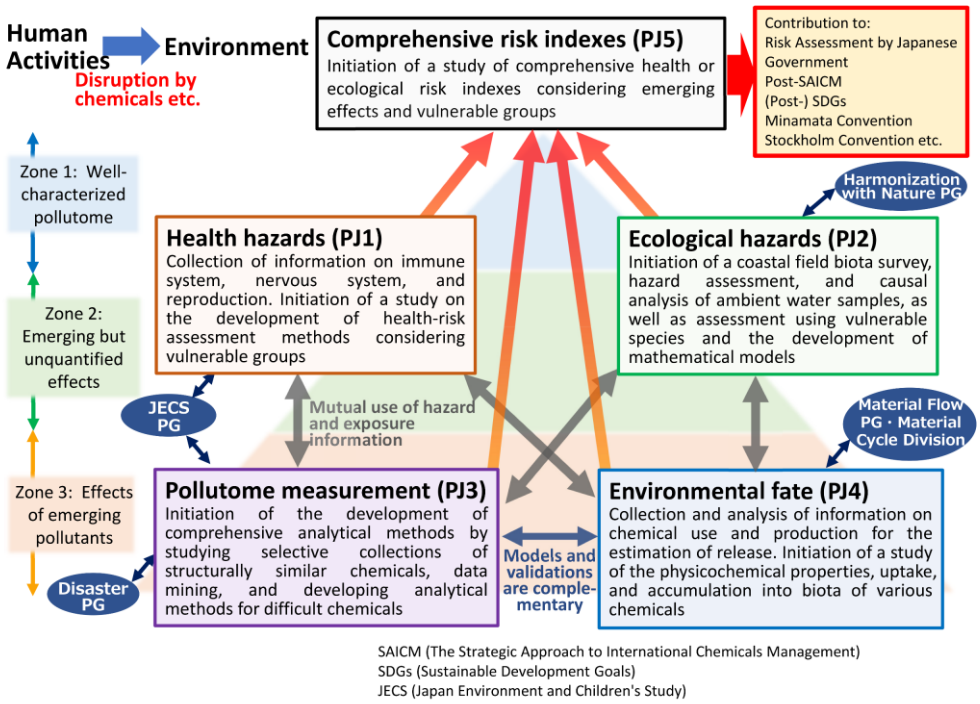


Fig. 1
The Comprehensive Environmental Risk Research Program consists of five research projects. The projects' outcomes are integrated to establish comprehensive risk indexes for international and domestic chemical management regulations. PG, program

Project 1. Health hazard assessment considering the real-life environment and vulnerabilities

To help formulate comprehensive health-risk indexes, we collected scientific knowledge on the effects of chemicals on diseases (e.g., immune diseases, neurodevelopmental disorders, metabolic diseases, and cardiovascular diseases) and reproduction. Experimental studies were also initiated to obtain basic data for health hazard assessment considering the real-life environment and vulnerabilities. Our main research outcomes this financial year (related to immunotoxicity, neurotoxicity, and cardiovascular toxicity) were as follows.

We investigated the mechanism of the adverse effects of oral exposure to the bisphenol analog bisphenol S (BPS) on allergic asthma in mice. BPS at 0.4 μg kg^{-1} day^{-1} (BPS-M, middle dose group) with ovalbumin (OVA) significantly enhanced the production of OVA-specific immunoglobulins and proinflammatory molecules such as interleukin (IL)-5 in the lungs (Fig. 2A). In addition, OVA-induced activation of mediastinal lymph node cells was promoted in BPS-M-exposed-mice with OVA sensitization. (Fig. 2B). We have also started to establish a new allergic asthmatic mouse model.

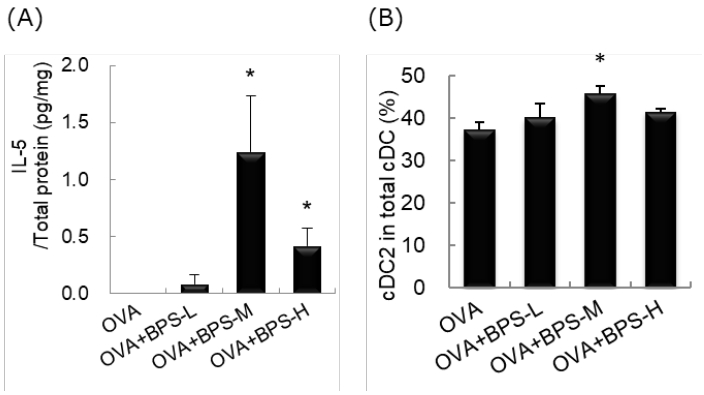


Fig. 2
Levels of interleukin (IL)-5 protein in lung tissue (A), and type 2 conventional dendritic cells (cDC2) as a percentage of total cDC cells in mediastinal lymph nodes (B). Data are shown as means ± SE; n = 6 animals/group; **P* < 0.05 vs. OVA group. BPS-L, 0.04 μg kg^{-1} day^{-1}; BPS-M, 0.4 μg kg^{-1} day^{-1}; BPS-H, 4 μg kg^{-1} day^{-1}

In vivo research showed that *l*-menthol, like psychostimulants, increased the expression of extracellular dopamine and the proto-oncogene c-Fos in the striatum of the brain and promoted ambulation in mice. Developmental exposure to tetrabromodibenzofuran, a type of brominated dioxin, can affect brain development by at least partly decreasing the hepatic expression of Tff3 (trefoil factor 3), a protein that has a protective effect against brain injury. In *in vitro* research, we used a neuronal precursor cell line, LUHMES, to assess the neurotoxicity of chemicals, and we observed the effects of rotenone on neural dendrites.

We examined the cardiovascular risks of exposure of mice to diesel exhaust particles during the fetal and neonatal period. Atherosclerosis or myocardial infarction was not observed in mice fed a high-fat diet after exposure to 100 μg/m^3 of diesel exhaust particles.

Project 2. Ecological hazards and factor analysis considering vulnerabilities

We conducted fisheries-independent bottom-trawl surveys along the coast of Fukushima, Japan, in June 2021 and January–February 2022 to study the megabenthic community structure after the 2011 earthquake, tsunami, and nuclear disaster. On the basis of all data from October 2012 onward on species richness or biodiversity and the total abundance and biomass of megabenthos (i.e., fishes, crustaceans, mollusks, and echinoderms), total population densities have shown a decreasing trend since 2013, especially in the case of crustaceans, echinoderms, and certain flounders. No substantial changes have been observed in total biomass

among years, primarily due to fishes, such as elasmobranchs and puffers. Our results suggest that there has been no recognizable recovery in the megabenthic community despite the limited activity of commercial fisheries; megabenthic species might have been experiencing reproductive or recruitment failure. In a chain of studies to elucidate this possible reproductive or recruitment failure in the megabenthic community off the coast of Fukushima, we used a plankton net (diameter, 1.3 m) to collect invertebrate larvae along nine latitudinal transects extending off the coastline in July–October 2020. Each transect was composed of three sites at different water depths (20, 50, and 80 m) along the coast. Interestingly, no, or few, larvae of Penaeoidea (i.e., the prawns *Trachysalambria curvirostris* and *Metapenaeopsis dalei*) were collected at any site during the surveys. Because relatively high adult population densities of *T. curvirostris* and *M. dalei* were observed in 2020, it is possible that failure of any one of the stages of sexual maturation, copulation, spawning, embryo development, hatching, and subsequent larval development occurred in these species in the coastal waters off Fukushima. Further research is needed to elucidate any reproductive or recruitment failure and to reveal the factors causing these phenomena in the megabenthic communities, including crustaceans, in the coastal waters off Fukushima.

We also conducted ecotoxicity tests, using daphnids and algae, on 30 river water samples collected from all over Japan. We conducted a comprehensive chemical analysis of pharmaceuticals, pesticides, and metals, as well as a multi-target analysis of five samples in which we detected relatively high impacts on the test species. Besides collecting data on the ecotoxicity of individual chemicals to daphnids and algae, we estimated the contributions of these chemicals to the overall toxicity of the river water samples. The contributions of some metals, such as zinc and nickel, were found to be above 100%. This was probably due to a lack of correction of the concentrations into bioavailable concentrations.

In research into vulnerable species, the distribution of species sensitivity to 6-PPD quinone, the product of transformation of the antioxidant 6-PPD added to tire rubber, was investigated because of this chemical's acute lethality to coho salmon (*Oncorhynchus kisutch*) off the northwestern coast of the US following the fish's exposure to urban runoff. We found that the acute toxicity of 6-PPD to Japanese medaka (*Oryzias latipes*), zebrafish (*Danio rerio*), *Daphnia magna*, and an amphipod (*Hyalella azteca*) was comparable to that to coho salmon, with a median lethal (or effect) concentration (LC_{50} or EC_{50}) in the range of 28 to 250 μg/L. However, for 6-PPD quinone, the LC_{50} or EC_{50} of 6-PPD in these four species (>34 μg/L) was far higher than that in coho salmon (0.095 μg/L) (Fig. 3 and Hiki et al., 2021).

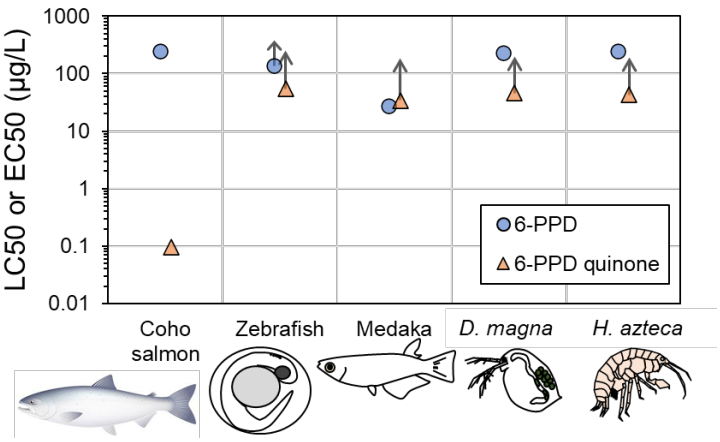


Fig. 3
Ecotoxicity of 6-PPD quinone to freshwater fishes and invertebrates

To assess the broadscale impact of anthropogenic disturbances, including the effects of chemicals, on river ecosystems in Japan, we have started to construct an extensive data set that integrates information from multiple public databases on river environments. First, we organized information, publicly provided by the Ministry of Land, Infrastructure, Transport and Tourism, on the locations and quantitative sampling surveys of benthic animals in rivers. Next, with the aim of providing comprehensive information on the aquatic environment, we organized the data, available on the Ministry of the Environment's website, on water quality measurements in public water bodies. We will continue to organize the database, and we will comprehensively evaluate the ecological effects of multiple chemical substances by using the database we have constructed.

Reference:

Hiki K., Asahina K., Kato K., Yamagishi T., Omagari R., Iwasaki Y., Watanabe H., Yamamoto H. (2021) Acute toxicity of a tire rubber-derived chemical, 6PPD quinone, to freshwater fish and crustacean species. *Environmental Science & Technology Letters*, 8(9):779–784. doi:10.1021/acs.estlett.1c00453.

Project 3. Comprehensive pollutome measurement

This project aims to develop methods to help us measure and understand exposure to all environmental chemical substances of concern. We also intend to develop new methods of analyzing chemical substances that have been hard to identify and quantify, as well as to establish a scheme that will help search for causative factors when new effects become apparent.

As part of the development of a selective method for collecting substances with a common structure, we used a molecularly imprinted polymer (MIP) mimicking the thyroid hormone receptor (hTR) to investigate a method of purifying substances that bind to the hTR. Liquid chromatography measurements were performed on a MIP-packed column by using thyroxine (T4), an hTR-binding active substance

produced *in vivo*, as the template and methanol–acetonitrile at 1/1 (v/v) as the mobile phase. The results confirmed retention selectivity based on the molecular imprinting effect (Fig. 4).

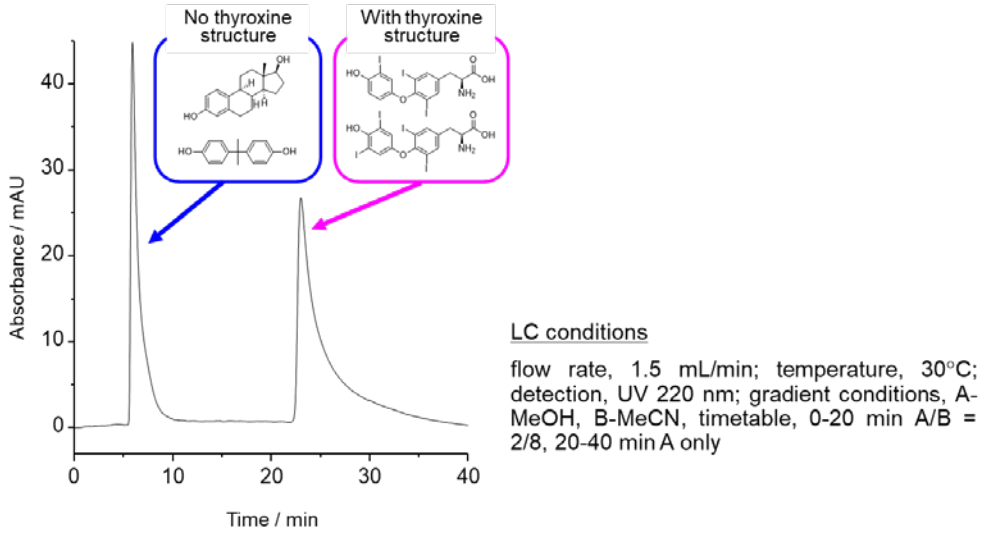


Fig. 4
Separation of substances with and without thyroxine structure by using MIP columns. LC, liquid chromatography

In studying selection methods by using gas chromatography–mass spectrometry (GC/MS) measurement data on substance groups with common structures, we attempted the comprehensive detection (data extraction) of analogous compounds from non-target and comprehensive analysis data. Specifically, we studied the extraction of comprehensive data on volatile perfluorinated compounds (VPFCs) from measurement data by using gas chromatography–atmospheric pressure ionization–time-of-flight mass spectrometry (GC/APCI/ToFMS). A program designed in-house performed the comprehensive data extraction of VPFCs from several water and oil repellents. From one of the samples, 10 VPFCs were identified and 12 unknown components were extracted as peaks. The mass spectra of the latter showed fragmentation patterns similar to those of the VPFCs used as standards, and they were therefore assumed to be VPFCs.

In proposing new analytical methods for difficult-to-measure substances, we investigated a new atmospheric-pressure chemical ionization technique for the determination of highly volatile neutral per- and poly-fluoroalkyl substances (PFASs) that are hard to measure with existing ionization techniques. We then developed a highly sensitive and selective method that uses high-resolution mass spectrometry. We also started developing a new sampling technique to collect highly volatile neutral PFASs in indoor and outdoor air samples; these substances are difficult to collect by using existing sampling techniques. We began studies to evaluate the applicability of the sampling method to atmospheric environmental monitoring. Furthermore, we developed a new solid-phase technique for extracting anionic and zwitterionic PFASs in leachate samples; these PFASs are difficult to extract by using existing extraction techniques.

Project 4. Modeling the environmental fate of the pollutome

In this project, we are developing methods to derive emission inventories, physicochemical parameters, and bioaccumulation properties to evaluate the environmental fate of all substances of concern for which we have only limited risk evaluation information. We are also improving environmental fate models to perform more reliable simulations and future predictions.

To investigate the applicability of environmental emission factors to exposure assessments, we compared emission factors that were calculated by using chemical use categories from different data sources. The first source was a domestic one, National Institute of Technology and Evaluation–Chemical Risk Information Platform (NITE-CHRIP), and the others were foreign, Substances in Preparations in Nordic Countries (SPIN) and Chemical Data Reporting (CDR), the latter being from the United States Environmental Protection Agency. There were low coefficients of determination ($r^2 < 0.1$) among the sources. In future we need to consider expanding the target substances for such assessments.

We performed simulations up to 2100 by using an integrated model that we are developing for the analysis of mercury dynamics, exposure, and impacts under various climate scenarios. The modelled total mercury content in the upper ocean was highest under a Fossil-fueled Development scenario (Shared Socioeconomic Pathway/Representative Concentration Pathway 5-8.5), but no profound impacts of climate change on human exposure to methylated mercury were found (Fig. 5). To help us understand the details of the Hg biogeochemical cycle, seawater from the western Pacific was used in a demethylation incubation experiment. The resulting gaseous Hg concentrations indicated that deep seawater has more demethylation potential than surface water.

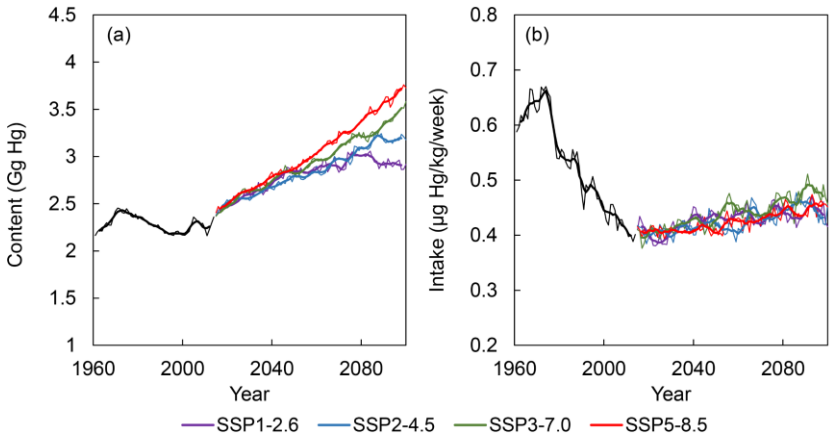


Fig. 5
Modelled (a) global contents of total mercury in the upper ocean (0 to 70 m depth) and (b) global average of methylated mercury intake via seafood consumption. SSP, Shared Socioeconomic Pathway

A passive sampling method was developed to measure the sediment sorption coefficients (K_d) of cationic surfactants. A polyacrylate-fiber passive sampler provided repeatable values of K_d for benzalkonium, the model cationic surfactant

that we used. The K_d values obtained were within the range of those in previous reports. Additionally, kinetic parameters for the bioaccumulation of a group of ionizable perfluoroalkyl acids in a polychaete sandworm were measured as part of this project. The respiratory uptake efficiency and depuration half-life values obtained, as well as their trends against alkyl-chain length, differed from those reported in other aquatic organisms. The factors accounting for these differences need to be studied further.

Project 5. Development of comprehensive health risk and ecological risk indexes

To propose and develop comprehensive indexes of health risk and ecological risk, we organized workshops comprising all the project leaders in the Comprehensive Environmental Risk Research Program. In the workshops, we started discussing the assembly and study of existing comprehensive methods of assessing the environmental risks posed by chemicals. Approaches to the comprehensive risk assessment of multiple chemicals include concepts such as the component-based approach and the whole-mixture approach. As an example of the component-based approach, one research direction would be to group chemicals on the basis of their structural similarity or their mechanism of action. Another possible research direction would be to perform rough analyses of the environmental risks posed by all chemicals of concern on the basis of their chemical or physical properties and statistical information on their production and emission amounts. The precision of risk assessments performed by using this second method is relatively low. In this project, we have decided to pursue both directions to find comprehensive environmental risk assessment methods.

In our health risk assessment in cooperation with Project 1, we started to collect health hazard information on the effects of chemicals on diseases, including immune diseases, developmental disorders, metabolic diseases, and cardiovascular diseases, as well as on reproduction. Together with Project 2, we started to develop comprehensive ecological risk assessment methods. In addition to existing assessment methods that utilize the results of toxicity testing on aquatic life at three different trophic levels, we assembled information on hazard assessment methods based on the species sensitivity distribution (SSD) model. We discussed both the component-based approach and the whole-mixture approach (see above) to comprehensive ecological risk assessment. When the component-based approach is used, hazard assessment of all chemicals of concern is not experimentally feasible. We therefore considered performing comprehensive assessments by grouping chemicals and using toxicity estimation methods such as the quantitative structure activity analysis (QSAR) and category approach. Together with Project 3, we initiated a discussion of comprehensive exposure assessment using new analytical methods for chemicals that have similar structures. In cooperation with Project 4, we started discussing comprehensive exposure assessment methods that use the chemical-group environmental concentrations predicted by environmental fate

models. To help the Japanese government to assess and manage environmental risks, we are also investigating the problems and challenges faced in scientific and regulatory environmental risk assessments. Exchange of opinions to facilitate future chemical risk assessment and management were held with volunteers from the Ministry of the Environment with the aim of minimizing the comprehensive environmental risks posed by all chemicals of concern across their life cycles.

Harmonization with Nature Research Program

The Harmonization with Nature Research Program conducts research into, and technological development of, measures for biodiversity conservation and the sustainable use of ecosystem services, which are essential for establishing a society in harmony with nature (Fig. 1). Our projects in FY 2021 were as follows:

Project1: **Sustainable ecosystem management strategies for a society with a declining population**
Project2: **Management of ecological risk causative factors that threaten biodiversity and human society**
Project3: **Biological responses, acclimations, adaptations, and resiliencies to environmental changes**
Project4: **Research on problem solving using ecosystem functions**
Project5: **Integrated research for balancing conservation and utilization of biodiversity and behavioral change**

Through these activities, we aim to mainstream biodiversity and promote transformative changes, such as behavioral change, as well as to improve natural capital by synergizing the conservation and sustainable use of biodiversity. We will also contribute to the post-2020 Global Biodiversity Framework of the Convention on Biological Diversity, the next National Biodiversity Strategy and Action Plan, and the regional circular and ecological sphere from the perspective of sustainable use of regional resources.

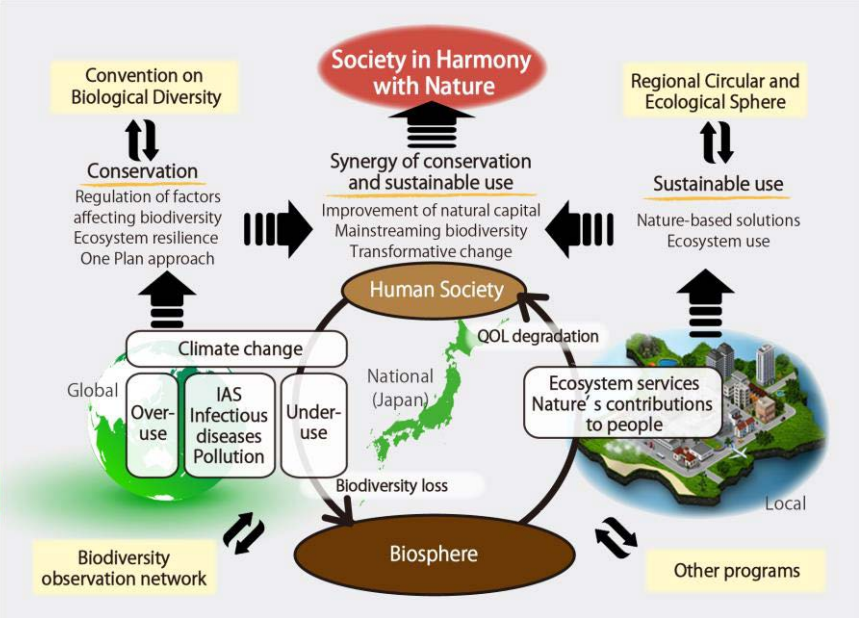


Fig. 1 Overall structure of the Harmonization with Nature Research Program.
IAS, Invasive Alien Species; QOL, quality of life;

Project 1. Sustainable ecosystem management strategies for a society with a declining population

To direct wildlife management research started by NIES in this Midterm Plan, the current status and issues of wildlife management were summarized for deer, wild boars, and bears (both black and brown). We found differences in social issues, monitorable items, and the status of monitoring system development. Therefore, there are different research needs in terms of evaluation trends and countermeasures for each species.

To evaluate deer and wild boar population trends that are comparable over a wide range of environmental conditions, we started collecting data on the numbers of deer and wild boars captured and sighted per hunter day, as reported by hunters. To date (2021), we have collected data from 33 municipalities. We created an integrated database of hunting records, designed the flow of information, and developed an automatic processing program to update the database when new data become available (Fig. 2).

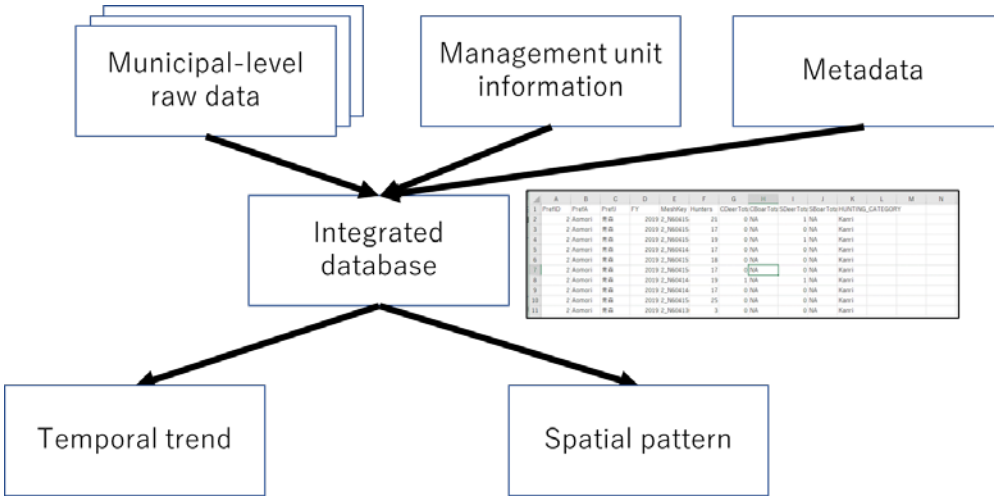


Fig. 2 Overview of the automatic data processing system. Arrows indicate flow of information.

Hunter reports for wild boars are relatively difficult to obtain. For these animals, in a collaborative study with external research institutions including the University of Hyogo and Nihon University (Higashide et al. 2021) [1], we developed an abundance index that uses signs of activity. We found that the density of digging marks was a good abundance index and was highly correlated with the independently estimated population density.

We also participated in a collaborative study with external research institutions, including the National Agriculture and Food Research Organization and the Forestry and Forest Products Research Institute. To develop an efficient control strategy for preventing crop damage caused by deer, we identified crop-foraging individuals on the basis of stable isotope ratios of bone collagen. We found that the density of crop-foraging female deer was high within 20 km of farmland, and intensifying the control effort radius should be efficient in preventing crop damage (Hata et al. 2021) [2].

The Fukushima Daiichi nuclear power plant accident resulted in the declaration of a large evacuation zone, designated as the difficult-to-return zone (DRZ). Given the cessation of activities such as farming, changes in biodiversity and ecosystem status have been anticipated, and there has been an increase in the numbers of wild boars (*Sus scrofa*) in the DRZ. The increased wild boar populations in Fukushima have caused damage to agricultural operations, and the animals require control by state-funded hunting programs. Understanding the population structure of the boars in terms of their genetic diversity in Fukushima provides important information for their management. To clarify the population dynamics of wild boars in Fukushima, we obtained 328 genetic markers from 179 wild boars by using MIG-seq (multiplexed inter-simple sequence repeats genotyping by sequencing) analysis. In a STRUCTURE analysis, we found significant genetic differences between populations of wild boars inhabiting the east and the west parts of Fukushima, divided by the Abukuma River (Saito et al. 2022) [3]. A BayesAss analysis revealed that the migration rate from the eastern population to the western population was higher than that in the reverse case (Fig. 3). Our results indicated that both the Abukuma River and anthropogenic urbanization concentrated along the river may affect the migration of wild boars. They also indicate that the population in the western area was established by migration from other neighboring prefectures rather than by migration from the eastern part of Fukushima. To clarify the connections of the western population of wild boars, we will need to extend our genetic analysis into other prefectures adjacent to western Fukushima.

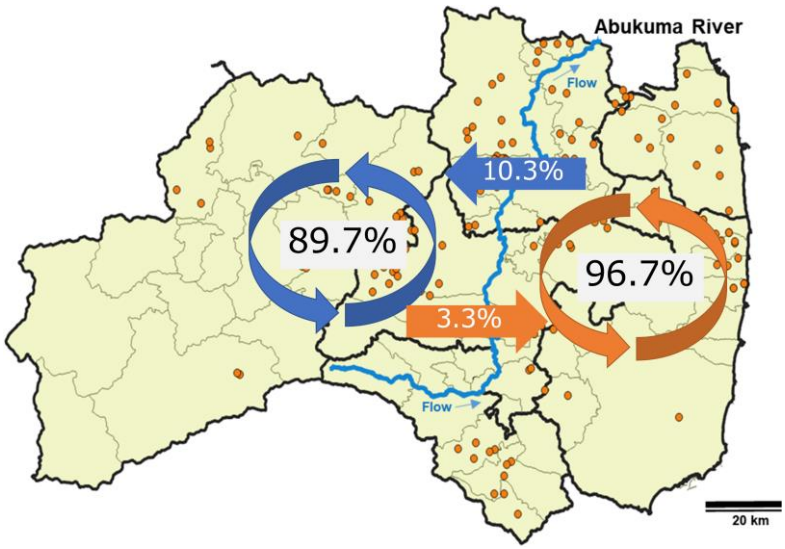


Fig. 3 Population dynamics of wild boars in Fukushima. Migration rates within the western (blue circular arrows) or eastern (orange circular arrows) sides are almost the same, whereas the migration rate from east to west exceeds that in the other direction. Sampling points of wild boars are shown as orange dots.

Reference:

1) Hata, A., Nakashita, R., Fukasawa, K., Minami, M., Fukue, Y., Higuchi, N., Uno, H., Nakajima, Y., Saeki, M., Kozakai, C., & Takada, M. B. (2021) Occurrence patterns of crop-foraging sika deer distribution in an agriculture–forest landscape revealed by nitrogen stable isotopes. *Ecology and Evolution*, 11, 15303–15311.

2) Higashide, D., Kuriyama, T., Takagi, S., Nakashima, Y., Fukasawa, K., Yajima,

G., Kasada, M. and Yokoyama, M. (2021) Effectiveness of signs of activity as relative abundance indices for wild boar. *Wildlife Biology*, 2021: wlb.00869.

3) Saito, R., Kondo, N.I., Nemoto, Y., Kumada, R., Nakajima, N., Tamaoki, M. (2022) Genetic population structure of wild boars (*Sus scrofa*) in Fukushima Prefecture. *Animals*, 12, 491.

Project 2. Management of ecological risk causative factors that threaten biodiversity and human society

Origin of the pandemic of the emerging amphibian infectious disease, chytridiomycosis

Research into the frog chytrid fungus *Batrachochytrium dendrobatidis* (*Bd*), an infectious disease that threatens amphibian diversity, continues to advance worldwide. On the basis of variations in the *Bd* ITS (internal transcribed spacer)-DNA, we hypothesized that the origin of frog chytrid fungus may have been the East Asian region, including Japan; a few cases of mass mortality caused by this fungus have been observed in wild amphibian populations in Japan. To verify our hypothesis, we collected more than 5500 swab samples from wild amphibians throughout Japan. We then investigated the amphibians' infection status by using the nested-PCR method. We sequenced the DNA samples obtained and constructed a maximum-parsimony (MP) tree including DNA sequence data from other countries to clarify the phylogenetic diversity of Bd. The MP tree showed that the diversity of *Bd* strains in Japan is much higher than those in other countries (Fig. 4). The tree structure also suggested that some strains in Japan belong to *Bd*-GPL and *Bd*-Brazil. The *Bd*-GPL strain has been reported worldwide, but *Bd*-Brazil has been found only in native amphibians in Brazil. Except in local populations of the Japanese giant salamander (*Andrias japonicus*) on Honshu Island and the sword-tail newt (*Cynops ensicauda*) on Okinawa Island, the *Bd* infection prevalence in native amphibian species was very low. The alien bullfrog *Aquarana catesbeiana* had high *Bd* infection rates in all areas where it was sampled. No *Bd* infection was detected in other native amphibians in the areas where giant salamanders, sword-tail newts, and bullfrogs were collected, suggesting that many native amphibians are resistant to *Bd* infection. The sword-tail newts on Okinawa Island had both the highest prevalence of infection and the greatest number of haplotypes. The giant salamander also had a relatively high infection prevalence, but the infected strains were limited to specific ones that are considered to be the oldest lineage in Japan. These results suggest that *Bd* likely originated in East Asia, including Japan, and that the giant salamander and sword-tail newt are refugia of diverse *Bd* lineages. From the results of our DNA phylogenetic analysis and an analysis of the infection status of amphibian specimens in the world, we surmised that *Bd*-Brazil was first introduced to Brazil in about 1900, when Japanese migration to Brazil began, and that the *Bd*-GPL strain was subsequently dispersed throughout the world in the 1970s. During the *Bd* transfer from Japan, it is likely that the vector was a bullfrog

native to North America that was transferred internationally for food.

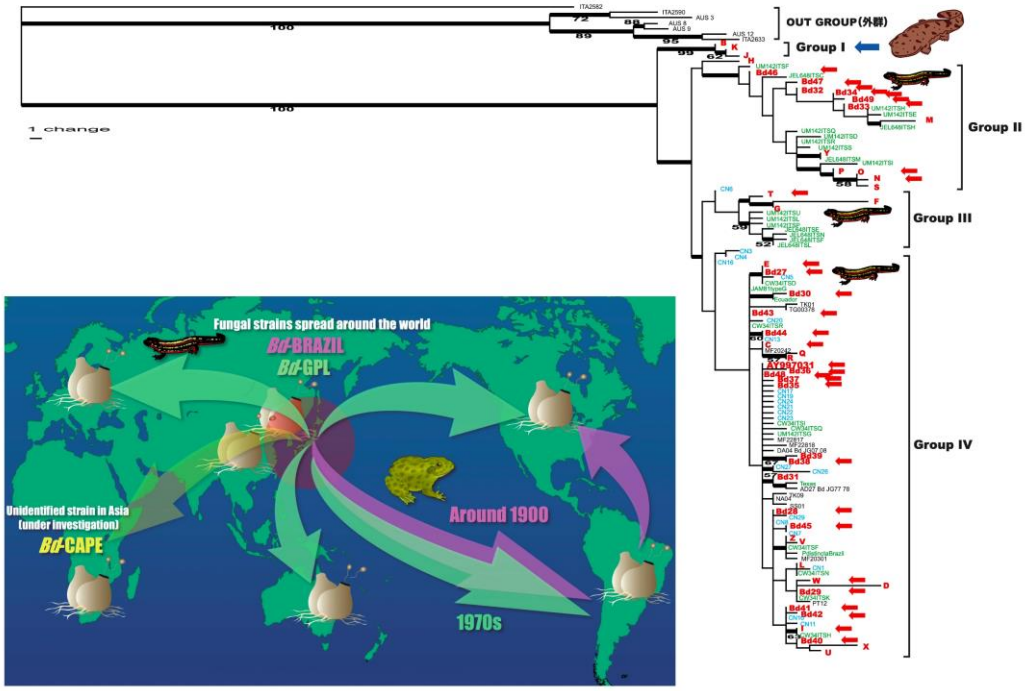


Fig. 4 Phylogenetic tree of the ITS haplotypes of *Batrachochytrium dendrobatidis*, generated by using maximum-parsimony analysis, and estimated *Bd* distribution expansion process

The numbers under the branches in Figure 4 are the parsimony bootstrap support values for values greater than 50%. The numbers above the branches represent the lengths of the branches. Red text indicates haplotypes detected in Japan (50 types); blue text indicates sequences detected in China (21 types). Green text indicates sequences detected in North and South America (31 types); black text indicates sequences detected in the USA, Ecuador, and Italy (12 types). Red arrows indicate haplotypes of *Bd* ITS-DNA on *C. ensicauda* (30 types), indicating that all group strains of *Bd* except group I have been detected on the newt. The results of the phylogenetic relationships and the specimen analysis infer a process by which the fungus expanded its global distribution via the international transfer of amphibians.

Our studies of chytridiomycosis provide the following important insights into the evolutionary ecology of infectious diseases: 1) There is diversity and regional endemism among pathogens; 2) pathogens have a history of coevolution with host animals in local environments; 3) biological transfers result in pathogen—host encounters that transcend the co-evolutionary relationship, and emerging infectious diseases emerge as a result; and 4) therefore, it is important to conserve local biodiversity, including infectious disease pathogens.

Project 3. Biological responses, acclimations, adaptations, and resiliencies to environmental changes

Highly mobile seed predators contribute to interisland seed dispersal within an oceanic archipelago

Long-distance dispersal is an essential event for species colonization and expansion in oceanic island ecosystems. Endozoochory (seed dispersal via ingestion) by birds is an important factor promoting the long-distance dispersal of plant seeds, but its contribution to interisland seed dispersal is still unclear. Here, we showed the possible seed dispersal by a seed predator pigeon, the Japanese wood-pigeon, *Columba janthina*, among oceanic islands in the Izu archipelago, Japan. Although some previous studies showed that most seeds swallowed by this pigeon are crushed, intact seeds were found in 44.5% of collected pigeon feces, indicating the contribution of these birds to seed dispersal. Seasonal movement of pigeons among islands in the Izu archipelago, as indicated by the bird's population fluctuations on each island, and the pigeons' intensive movements between neighboring islands (Hachijojima and Hachijo-kojima) could promote interisland seed dispersal at different geographic scales (Fig. 5). We found seeds from fruiting trees not located on the islands where the pigeon feces were collected; these seeds could therefore have been transported from another island. Although the fruiting phenology of many tree species overlaps with pigeon movement between the islands, the seeds of only six species were dispersed by pigeons, and most of the dispersed seeds were from species with small seeds (less than 1.5 mm in diameter). Fruit consumption by, and frequent interisland movement of, Japanese wood pigeons might homogenize the distribution of plants with small seeds among neighboring islands. In contrast, pigeons' intensive consumption of large seeds that are crushed upon consumption might disturb the recruitment of plants with large seeds, which may make the expansion of these plants to other islands difficult. Such effects of mutualistic (dispersal) and antagonistic (predation) interactions with highly mobile seed predators may modify plant distributions and gene flow in oceanic archipelagos (Ando et al. 2021, *OIKOS*, 10.1111/oik.08068).

Reference:

Ando H., Mori Y., Nishihiro M., Mizukoshi K., Akaike M., Kitamura W., J Sato N.(2021) Highly mobile seed predators contribute to interisland seed dispersal within an oceanic archipelago. OIKOS, DOI:10.1111/oik.08068

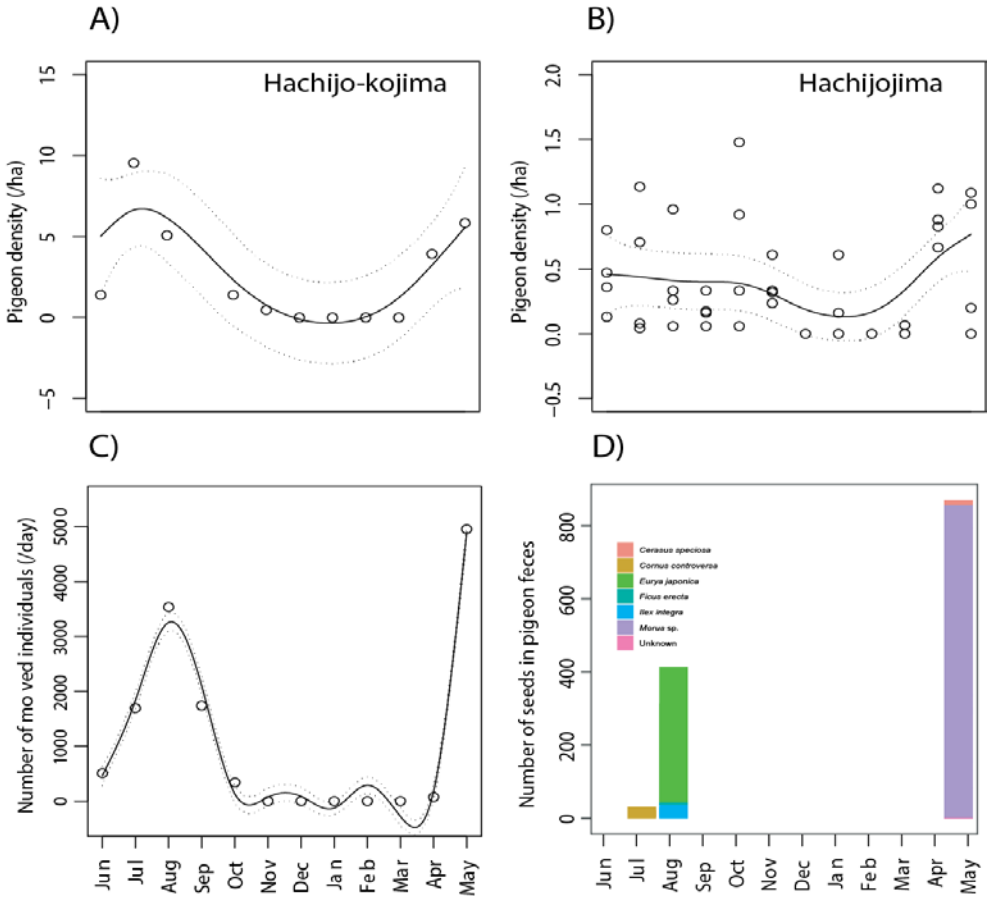


Fig. 5 Seasonal patterns of (A) pigeon density on Hachijo-kojima, (B) pigeon density on Hachijojima, (C) the number of individuals that moved between Hachijojima and Hachijo-kojima, and (D) the number of intact seeds detected in pigeon feces. Lines in (A) to (C) are mean predicted values with 95% confidence intervals from generalized additive models.

Enhanced ozone stress resilience endowed on Arabidopsis plants by a phytocyanin-encoding gene

Ozone is a phytotoxic air pollutant that causes various detrimental effects, including chlorosis and growth inhibition. By screening a collection of full-length cDNA overexpressor (FOX) lines of *Arabidopsis thaliana*, we identified a highly ozone-tolerant line overexpressing the cDNA encoding a member of the phytocyanin group, “X”, that is postulated to have plastocyanin-like and arabinogalactan-like domains in its mature form. Two representative ozone-inducible responses—chlorosis caused by cell death and stomatal closure—that were observed in wild-type plants were suppressed in the X-overexpressing line. Histological analyses of transgenic plants producing the fusion protein of X and a green-fluorescent protein, along with yeast two-hybrid analyses, suggested that X is localized in the apoplastic region of plant cells and that X suppresses ozone-induced generation or signaling of reactive oxygen species, physically interacting with such stress-related proteins as copper amine oxidase and late embryogenesis abundant protein-like protein (Fig. 6) .

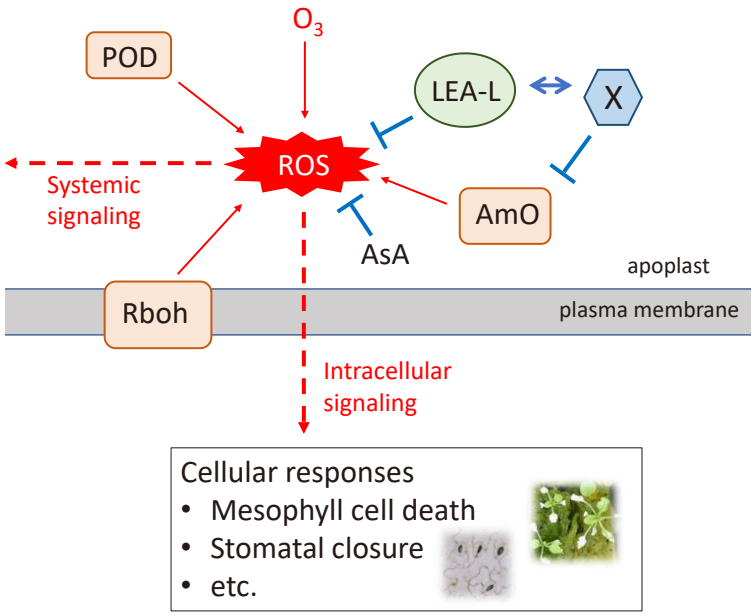


Fig. 6 Generation and signaling of reactive oxygen species and hypothetical sites of action of X in the apoplastic region of ozone-exposed leaf cells. AmO, amine oxidase; AsA, ascorbic acid; LEA-L, late embryogenesis abundant protein-like protein; O_3: ozone; POD, cell-wall peroxidase; Rboh, respiratory burst oxidase homolog; ROS, reactive oxygen species; red arrows, promotion; blue lines ending with bars, suppression; blue double arrow, interaction

Project 4. Research on problem solving using ecosystem functions

As part of this project we have been conducting three subprojects. The subproject "Promotion of ecosystem services provided by effective spatial arrangement and management in urban ecosystems" is designed to elucidate pollination systems in urban ecosystems and their impact on the surrounding ecosystems. It is also examining the use of urban greenspaces as OECMs (other effective area-based conservation measures) and issues related to OECMs. Field research revealed that an increase in the percentage of residential land has affected pollination functions by altering the abundance and diversity of pollinators and plant species in the sparse grasslands remaining throughout the urban areas of Hokuso, in Chiba Prefecture.

We also distributed a questionnaire survey of management policies for biodiversity conservation to more than 2000 public and private greenspaces (urban parks, aquariums, zoos, etc.) with administrative offices; these greenspaces were considered to include potentially protected areas and OECMs. Of the facilities that responded, at least 25% were inhabited by rare species, and more than 30% had explicit guidelines or plans for biodiversity conservation (Fig. 7). These urban greenspaces may be suitable candidates for OECMs. The results also revealed some issues to be considered, such as a lack of funds for hiring personnel for the biodiversity conservation that is critical to continuing effective conservation activities.

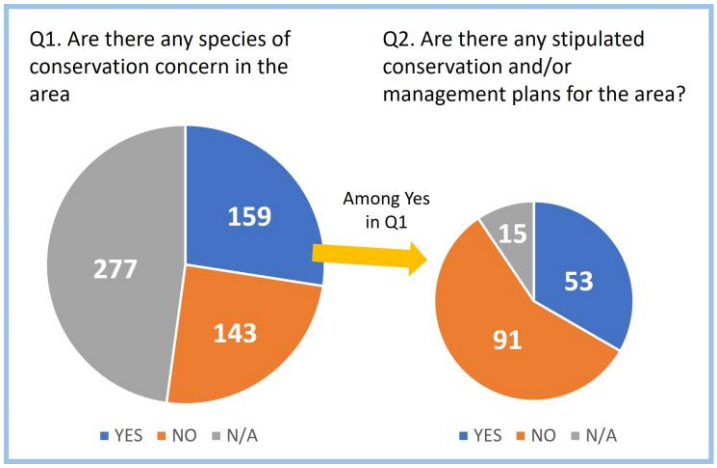


Fig.7 Results of a questionnaire survey of management policies for biodiversity conservation.

The subproject "Nature-based approaches to balancing agriculture, water quality, and biodiversity" focuses on nutrient "input" control (e.g., conversion of agricultural methods) and nutrient "output" control (e.g., water purification by wetlands) to control nutrient loads from agricultural land. To explore the potential of nutrient input control, we focused on no-fertilizer farming. We collected surface soil samples from croplands (both no-fertilizer farming sites and surrounding conventional farming sites) in Ibaraki, Chiba, and Saitama prefectures, and we examined the chemistry of the air-dried soil. Soils on the cropland with a long history of no-fertilizer farming method had significantly lower electrical conductivity, nitrate concentration, and total nitrogen content, as well as higher C/N ratios, than soils on conventional croplands. The fertilizer-free plots were expected to have less nitrogen leaching to groundwaters. As a verification experiment for output control, we restored an abandoned rice paddy field deep in "Yatsu" in Chiba Prefecture to wetland by cutting trees and weeds, repairing the banks, and increasing the water retention time. The concentration of nitrate in spring at Yatsu was very high, but it was reduced to less than half when the water was routed through the restored wetland. The results suggest that converting abandoned rice paddies into wetlands may help to improve water quality.

Satoumi refers to marine and coastal landscapes that have been formed and maintained by prolonged interaction between humans and ecosystems. The subproject "Evaluation of ecosystem services and reenergizing of people living in *satoumi* ecosystems" aims to restore the clam population as part of the restoration of nature on the vast natural tidal flats of Yamaguchi Bay in the Seto Inland Sea, as well as to reenergize local members of the public through these activities. To aid the recovery of clam populations, more than 100 juvenile clams per bag were found by using the newly introduced Ohno method of net-bag harvesting, which is expected to be used in combination with the conventional covered-net method. Although efforts to restore the enthusiasm of local members of the public through nature restoration activities on the tidal flats were severely limited by the COVID-

19 pandemic, the number of visitors to the adjacent artificial nature park in FY 2021 was about triple that in the previous year. A field demonstration test was conducted on a newly developed artificial tidal flat in the park to reimport the clam population restoration technology, which had been modified for compact urban artificial tidal flats. Environmental factors, juvenile recruitment and retention rates, and adult survival rates were examined. It became clear that the Ohno method of deploying net bags for juvenile clam collection at appropriate locations in the park would be effective in restoring the clam population.

Project 5. Integrated research for balancing conservation and utilization of biodiversity and behavioral change

Funding shortages are among the major causes of limited ability to mitigate environmental degradation. Online crowdfunding can help address the perennial financial shortfalls in environmental conservation and management. Although many online crowdfunding campaigns fail to collect any funds because they do not achieve their targets, little is known about what drives success. To address this knowledge gap, we applied a mixed methods approach to data from 473 successful and failed campaigns hosted on an online crowdfunding platform in Japan (Kubo et al. 2021). We found that fundraising performance varied by topic, with campaigns on pet animal management outperforming those focused on landscape management or sustainable use (Fig. 8).

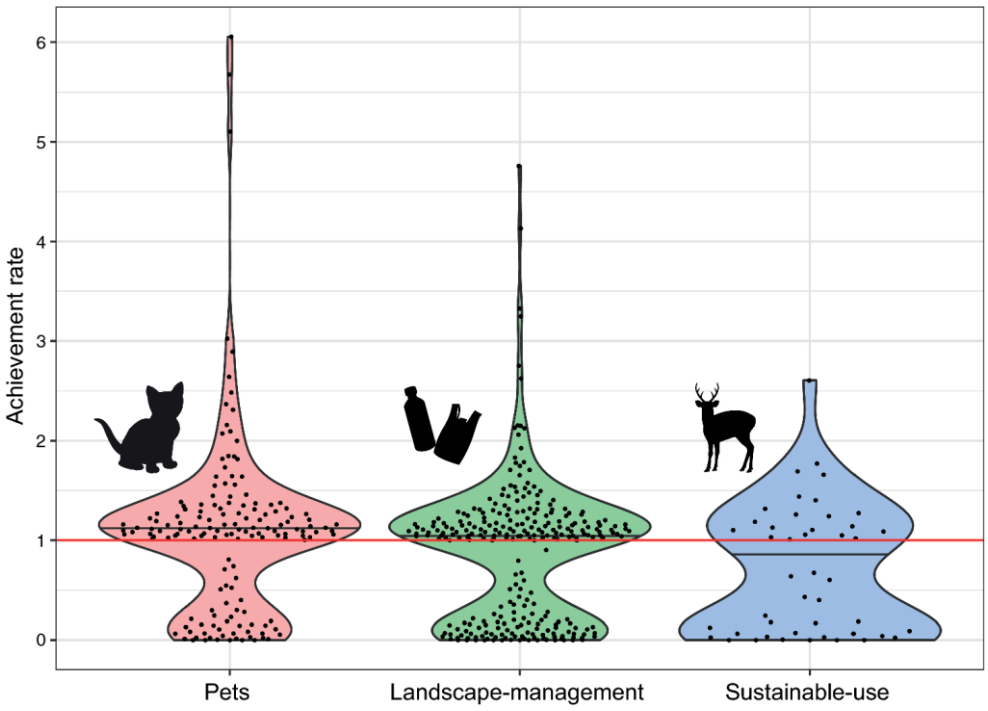


Fig. 8 Achievement rates of campaigns by cluster, namely pets, landscape management, and sustainable use. Horizontal black lines indicate the median of the achievement rates. The mean achievement rates were 1.08, 0.872, and 0.688, respectively.

We also found that marketing strategies associated with online findability and increased reach through social networks increased fundraising success. However, the existence of other environmental campaigns running simultaneously reduced

the chance of success, implying that selecting popular topics does not always increase the likelihood of success if there is increased competition. Wider application of marketing could enhance the ability of environmental crowdfunding campaigns to raise funds.

Reference:

Kubo, T., Veríssimo, D., Uryu, S., Mieno, T., & MacMillan, D. (2021) What determines the success and failure of environmental crowdfunding? *Ambio*, 50(9), 1659–1669.

Decarbonized and Sustainable Society Research Program

The goal of the Decarbonized and Sustainable Society Research Program is to present a vision and principle of a decarbonized and sustainable society at the global and national levels while ensuring intergenerational equity. To realize this goal, we will identify the long-term requirements for a decarbonized and sustainable society on a global scale. In addition to the global scale analyses, by taking into account the current national development stages, we will also identify the actions and institutions needed at the national level to develop a decarbonized and sustainable society in Asian countries, including Japan. We intend to utilize our integrated assessment model to evaluate the necessary countermeasures at the global and national levels. On the basis of these quantitative and narrative results, we will develop medium- to long-term roadmaps for achieving a decarbonized and sustainable society both globally and nationally, thereby contributing to the various efforts to achieve this goal.

This research program consists of the following three research projects:
Project 1: Simultaneous Achievement of Global Decarbonization and Sustainability
Project 2: Quantification of National Decarbonization and Sustainable Society Scenarios
Project 3: Establishing a Regime Inclusive of Future Generations in a Sustainable Society.

Project 1. Simultaneous Achievement of Global Decarbonization and Sustainability

Project 1 consists of three subthemes with different target study periods: subtheme 1 (short/medium-term: present to 2050); subtheme 2 (long-term: present to 2100); and subtheme 3 (extra-long-term: present to 2100 and beyond). With the whole Earth as the target area, each subtheme attempts to grasp the relationships between decarbonization and sustainability; examine policies, systems, and measures for the simultaneous achievement of decarbonization and sustainability; and assess these efforts through the quantification of scenarios.

Subtheme 1 is developing a group of global models to evaluate mitigation measures centered on a bottom-up technology model. It is also assessing the emission pathways of greenhouse gases (GHGs) and short-lived climate forcers (SLCFs) in the short to medium term to meet the targets of the Paris Agreement. We are quantitatively evaluating the potential of drastic reduction measures for these gases and the impacts of the spillover effects of such measures on sustainable development. We are also conducting qualitative evaluations of, for example, the progress of nationally determined contributions (NDCs) for GHG mitigation, as well as the progress of international institutions and funding mechanisms under the Paris Agreement. In FY 2021, we expanded a group of global models to cover not only the energy sector but also non-energy sectors and to analyze early and drastic mitigation pathways of GHGs and SLCFs with the aim of deep global decarbonization. We also evaluated the cobenefit and tradeoff effects of deep decarbonization in reducing air pollutant and mercury (Hg)

emissions. Figure 1 shows the characteristics of global Hg emission pathways and sectoral emission reductions, as well as sectoral Hg emission reductions and remaining emissions in the developing countries that are major Hg emission sources. Hg emissions would be significantly reduced as cobenefit effects if mitigation measures equivalent to the 2°C target were taken. However, some regional disparities can be found: for example, large cobenefit effects can be found in India and South America, whereas the cobenefit effects in China and Africa would be limited. To aim for much more drastic Hg reductions to achieve zero Hg emission, Hg-removal measures would need to be introduced, especially in not only steel and cement production processes but also fuel combustion, particularly in thermal power generation with carbon capture and storage (CCS).

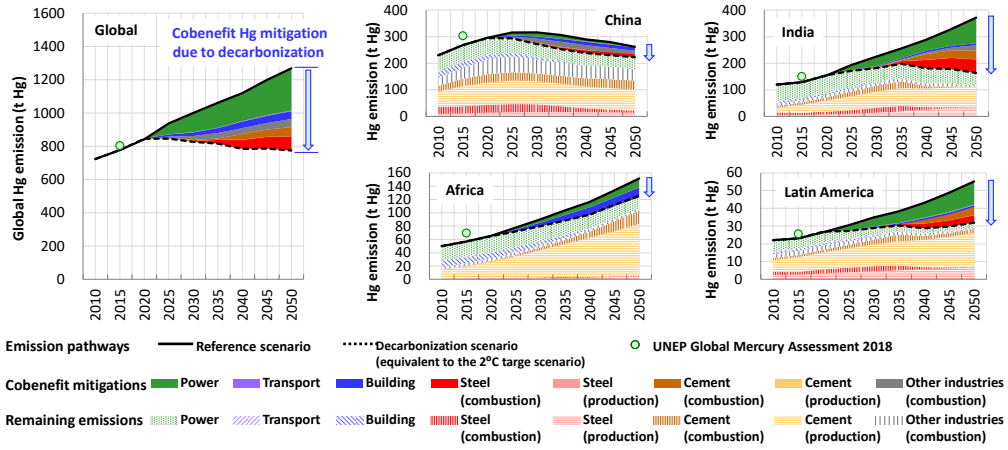


Fig. 1 Characteristics of Hg emission-reduction common benefits and country emission trends through decarbonization measures. Data were obtained by using a global technology selection model, namely AIM (Asia-Pacific Integrated Model).

Subtheme 2 is developing a global sustainability assessment model that is based on the existing computable general equilibrium model and presents GHG emission pathways consistent with the Paris Agreement. We also intend to analyze the side effects of the mitigation measures employed for the emission pathways on sustainability; clarify the remaining climate risks under the emission pathways; and assess the equity of the expected consequences. In FY 2021, as part of the expansion of our method of integrated climate impact analysis, we developed a statistical model tool (emulator) that can be used easily to perform (bio-)physical and economic assessments of climate impacts, by sector, with a short calculation time. We evaluated the reproducibility of the climate impacts projected by using the process models. In our estimation of the economic impact on a global scale, the overall trend could be reproduced even with a relatively simple statistical method (e.g., a quadratic equation with the global mean temperature as an explanatory variable). Nevertheless, to reproduce details such as differences in impact by region and sector, a statistically more advanced method will need to be used, with more detailed information (climate and socioeconomic status by region) as explanatory variables.

Subtheme 3 is developing an integrated Earth system model that links an Earth system model (ESM) and an integrated assessment model (IAM) and analyzes the

interactions between climate, the carbon cycle, and human activity. The goal is to deepen our understanding of the tipping elements of Earth's climate system and to discuss global environmental and resource constraints. In FY 2021, we analyzed future-prediction experiments by using an integrated land surface model that describes the land surface processes of the Earth and the systems developed so far. By assuming various socioeconomic scenarios, such as sustainable, moderate, and fragmented societies, we analyzed the impacts of future climate and socioeconomic changes on water resources, crops, land use, and material circulation. We also analyzed the carbon cycle in the "overshoot scenario" as a means of achieving climate stabilization once the future temperature rise exceeds the temperature target, and we clarified the importance of considering the inertia of Earth's climate systems.

Project 2. Quantification of National Decarbonization and Sustainable Society Scenarios

Project 2 consists of two subthemes with different target areas, namely Japan (subtheme 1) and Asian countries (subtheme 2). Through this project, future scenarios in Japan and other Asia countries will be quantified. We are proposing measures, policies, and systems to achieve net-zero GHG emissions, as well as to quantitatively formulate short- and medium-term sustainable decarbonization roadmaps, for Japan and some Asian countries, that are consistent with achieving the 1.5°C global warming target scenarios. We are considering the diversity of Japan and other Asian countries, together with ways of resolving the challenges facing each country, including NDC ambitions and the economic, technological, and institutional constraints on long-term strategy formulation.

In subtheme 1, for Japan, we are updating the AIM (Asia-Pacific Integrated Model) to assess the effects of innovative energy-saving technologies, power grid systems introducing huge renewable energy supplies, and social transformation reducing energy service demand to achieve net-zero GHG emissions. To analyze drastic mitigation pathways, we are also considering socioeconomic issues, including demographic impacts such as the declining birth rate and the aging population, and the impacts on energy demand of innovative technologies to promote behavior change. In FY 2021, in response to Japan's new mitigation target of achieving a decarbonized society by 2050, we analyzed the country's renewable energy supply potential, taking into account the hourly electricity supply–demand balance by using a power supply model combined with AIM/Enduse as a technology-oriented bottom-up model aimed at achieving a decarbonized society in Japan. With the model, final energy consumption was reduced by more than 40% from 2018 levels, and more than 70% of the electricity generated was from renewable energy sources (Fig. 2). The result showed that NETs (negative emission technologies) such as afforestation and bioenergy with CCS will be required to achieve both net-zero GHG emissions and social transformation.

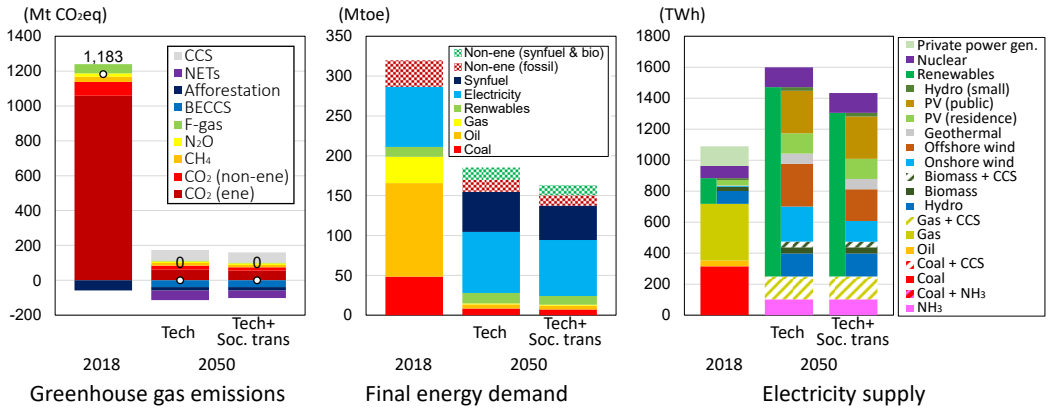


Fig. 2 Quantification of a decarbonized society in 2050 in Japan. CCS, carbon capture and storage; BECCS, bioenergy with carbon capture and storage; Tech + Soc. trans, Technology + Social transformation; PV, photovoltaic; non-ene, non-energy; Mtoe, million tonnes of oil equivalent; F-gas, fluorinated gas

In subtheme 2, for major Asian countries, we are developing the AIM to assess not only GHG mitigation measures for deep decarbonization in each Asian country but also other environmental issues specific to Asian countries, such as air quality and waste management. We are also considering Asian diversity, such as differences in economic development between developing countries and countries with economies in transition, regional disparities within the same country, differences in major emission sources, and institutional and technical issues faced by each country in formulating long-term development strategies.

In FY 2021, we developed a passenger and freight transportation model that was combined with AIM/Enduse and covered 31 provinces in China, and we evaluated electric vehicle (EV) deployment scenarios aimed at achieving carbon neutrality in 2060. In the EV scenario where the current EV subsidy rate was enhanced by up to half the initial cost, CO_2 emissions from the passenger sector would be substantially reduced by 2060, but CO_2 emissions would remain in the freight sector because of that sector's difficulty in converting to 100% EVs. There are regional disparities in cost effectiveness among the 31 provinces; for example, there are provinces where the cost of measures would be low and the reduction effect would be large, but there are other provinces where the cost of measures would be high but the reduction effect would be limited. There is a need to consider these regional disparities in any discussion of effective subsidy policies.

Project 3. Establishing a Regime Inclusive of Future Generations in a Sustainable Society

Project 3 aims to establish a regime that will help to improve intergenerational equity and enable future generations to inherit a better world. It consists of two subthemes with four elements of the regime: norm, indicator, institution, and survey. These elements are intertwined; subtheme 1 addresses mainly norm and indicator for intergenerational equity and justice, and subtheme 2 addresses institution and survey for the benefit of future generations.

In subtheme 1, we conducted a normative review to examine the incorporation of ELSI (Ethical, Legal, and Social Issues) perspectives into the evaluation of environmental policies. Then, by using energy policy as an example, we identified four major impact pathways (environmental, economic, social, and political) and four major normative evaluation criteria (economic values, quality of life/well-being, equity/rights, and intrinsic values such as culture and nature). On the basis of this review, we developed an evaluation matrix for the normative discussion.

The carbon budget is a powerful scientific concept for defining the challenge of climate change by quantifying the allowable amount of CO_2 emission that will hold global temperature levels to, for example, the 1.5°C or 2°C target. It can also be a useful communication tool for considering intergenerational distributional equity, and it has been used widely in climate justice movements because it provides a normative frame of reference for understanding the urgency of climate crisis. However, it should be recognized that by using the carbon budget we could create a narrow focus on controlling a physical limit and thereby risk ignoring the broader questions of socioeconomic inequity.

In addition, we considered the setting in which nonrenewable natural capital diffuses spatially across borders. We found that, added to the value of the change in current capital assets, the value of the natural capital projected to diffuse in the future should be adjusted to the current indicator of sustainability. The adjustments differ between national and global interests.

In subtheme 2, we reviewed the literature on the institutions considering future generations, and we also collected information about recent domestic and foreign movements that are considering future generations. We categorized the types of institutions that exist all over the world to suppress and prevent short-termism, and we started to examine the kinds of implementation problems that could occur. We tentatively summarized these institutions into categories (Table 1). During the 5 years of this project, we plan to update this table.

Finally, we surveyed time perspectives, levels of inheritance of assets between generations, and how information about future global warming affects people's willingness to act against climate change. Our study showed that the amount of the assets that 69% of respondents were willing to pass on to the next generation was smaller than what they would inherit from the previous generation; respondents with low willingness to pass on the assets had lower levels of positive time perspective, altruism, and generativity, and a higher level of future neglect. Knowing that the next generation would not be able to use a common asset affected an individual's decision to pass it on. Moreover, knowing the extent of extremely hot days in the future can help people to comprehend the severity of the worsening climate.

Table 1 Categories of institutions considering future generations

Subsystem for intervention	Category (examples of institutions)
Political system	Representation (Youth quotas, Demeny voting, longer electoral terms, second chamber)
	Legislative procedure (Posterity impact statements)
	Participation (Youth congress, future design, citizens' initiatives, referendum, and sortition)
Administration system	Administrative procedures (Future ombudsperson)
	Public finance (Ensuring primary balance, social discount rate for public investment)
Jurisdiction system	Constitutional provisions
	Courts and responsibility (Establishment of constitutional court)
Economic system	Financial market (Promotion of long-term investment, disincentives for short-term speculation (e.g., financial transaction tax))
	Avoidance of externalities (Environmental taxes)
	Long-term business management (Succession of longevity companies' management)
Cultural system	Traditional wisdom (Use and bequeath rules of local commons)
Education system	Provision of education (Education programs)

Co-design Approach for Local Sustainability Research Program

Working with local governments, local residents, and other local stakeholders as the implementing entities to create a sustainable society, we intend to construct measures to develop co-creative and sustainable local communities on the basis of human, social, and scientific knowledge. We will also examine ways to support the implementation of such measures.

This research program will address the following four issues:
Project 1: Research on sustainable society implementation through regional collaboration
Project 2: Proposal and evaluation of eco-efficient technologies and systems in collaboration with local communities
Project 3: Development of a regional diagnostic tool to simultaneously solve regional and lifestyle issues and achieve sustainability goals
Project 4: Construction of measures for creating sustainable local communities, and support for introducing such measures into local communities.

Through these efforts, we will collaborate with local governments and other local stakeholders in local communities in Japan to co-create problem-solving measures that will create sustainable local communities on the basis of scientific knowledge. We will clarify how support should be provided, with the aim of establishing these measures as feasible systems in local communities. Our aim is to promote the creation of a sustainable society in the region.

Project 1. Research on sustainable society implementation through regional collaboration

Interviews will be conducted, mainly with stakeholders in each region, to coordinate approaches to issues related to the environment. In the Okuaizu region, a model district for research centered on biomass utilization will be established and research will be initiated. In Lake Biwa, we have conducted research on the ecology and habitats of native fish, and we are promoting research on water quality and microbial production. We are also beginning to build relationships with key local stakeholders. In addition, we have conducted interviews with stakeholders in Goto, an island city in Nagasaki Prefecture, to coordinate approaches to issues and clarify the problems unique to these remote islands.

To gain an understanding of the regional issues associated with building a sustainable society in Okuaizu, at Lake Biwa and on remote islands, we exchanged opinions with stakeholders in each region. In research into the circulation of local resources (mainly biomass utilization in the Okuaizu region), we participated as an advisor to the Regional Recycling and Symbiosis Promotion Council in the town of Mishima, in Fukushima Prefecture, and we promoted the introduction of a small woody-biomass combined heat and power system and zero-carbon initiatives. We

also conducted a survey of the forestownership. In the Lake Biwa area, we exchanged opinions with the Department of Lake Biwa and the Environment, as well as with the Department of Agriculture and Fisheries of Shiga Prefecture. Shiga Prefecture divides its vision for 2030 into four perspectives: “people”, “economy”, “society”, and “environment”. In aiming to achieve a sustainable society where people can design the future according to their own perspectives, Shiga is going to be a prefecture that has a good balance of the economy, society, and the environment. Changes in the ecosystem and water environment of Lake Biwa, along with the devastation of agricultural land and forests surrounding the lake, have become environmental problems in recent years. Specific environmental problems in the lake were the decline of native fishes and shellfish stocks, the spread of alien species, a rise in surface water temperature due to climate change, and observed incomplete vertical circulation in the north basin. Lake Biwa Branch Office of NIES has begun surveying the spawning migration, and migration within the lake, of fish fauna (including non-native fishes) and water quality with the aim of helping the recovery of native fish resources and creating a sustainable local community. To gain an understanding of the issues on remote islands, we targeted the city of Goto, in Nagasaki Prefecture, and exchanged opinions with various stakeholders, including staff of the city hall and the Chamber of Commerce and Industry, to gather information on policies and other issues, as well as to clarify local issues. Similar interviews were also conducted in Iki, another island city in Nagasaki Prefecture, for comparative study.

Although there are characteristics that are regional (e.g., development history, lakes, islands), there are many common elements in environmental measures and initiatives throughout Japan, and we plan to compile a set of measures that can be applied throughout the country.

Project 2. Proposal and evaluation of eco-efficient technologies and systems in collaboration with local communities

In this project, we will examine the environmental technologies that help to solve regional issues. With a focus on heating supply and demand, technological systems for decarbonization will be presented in each industrial and residential or business area in several regions in Japan in accordance with regional characteristics. For wastewater and waste treatment and resource recycling, the project will develop a method of assessing the vulnerability of wastewater and waste treatment systems in regions with declining and aging populations. We will also conduct a preliminary technological assessment of wastewater treatment systems. For regional transportation, a future vision for an appropriate regional transportation system will be studied on the basis of a survey of current regional conditions.

Preparations were made in consultation with the relevant stakeholders to show them solutions—mainly from a technological perspective—to the issues the region faces. Such issues include social demands to improve energy efficiency and expand the

introduction of renewable energy in order to achieve carbon neutrality, and the difficulty in maintaining social infrastructure owing to the declining birth rate and aging population. We collected and organized data on regional waste and wastewater treatment through statistics and field surveys and began a needs assessment of regional transportation systems. As a means of efficiently achieving carbon neutrality in the material industries, such as plastic and paper industries, we proposed the supply of process energy (steam) to petroleum and chemical complexes by using low-grade waste that is difficult to recycle. We also established a cooperative framework with local governments and petroleum, chemical, and paper manufacturers, and we initiated a feasibility study.

In relation to the declining birth rate and waste, we conducted a study of disposable diaper use (both adult and child) as one of the impacts of population decline and aging on waste disposal, and we estimated the future generation of used disposable diapers in Mie Prefecture. The amount generated in this prefecture in 2045 will be about 17% higher than that in 2015, of which about 76% is for adult use. In the future, the percentage of the population aged 65 and over will increase in all areas of the prefecture, but in the southern part of the prefecture, the number of population aged 65 and over has been declining since 2015. The amount of used adult diapers generated has been increasing in the northern part of the prefecture and decreasing in the southern part. The decline in population is also resulting in a substantial decrease in the amount of waste generated for incineration. The share of used diapers in incinerated waste is expected to increase in all municipalities, with some municipalities in the north estimated to reach about 10% of total incinerated waste and about 15% to 20% in the south. In municipalities with small populations, used diapers are the second-largest waste item by volume after garbage (food waste) in terms of composition. We will need to start considering the collection and treatment of used diapers specifically, as well as future incineration processes.

Project 3. Development of a regional evaluation tool to simultaneously solve regional and lifestyle issues and achieve sustainability goals

By targeting two or three regions common to the Program, we will develop detailed socioeconomic, energy, environmental, and other data and analyze regional characteristics to determine the current and future state of the regions, taking into account national scenarios. In addition, the Project will study how to provide support from a scientific perspective to solve regional issues and create policies to achieve sustainability goals in collaboration with the public and other stakeholders in specific regions.

We estimated CO_2 emissions data for the residential and passenger transportation sectors for all municipalities in Japan. In addition, a new population density retention scenario was created for the 1km square mesh population of the entire country, by each prefecture's population inside and outside the zoning district of

urban planning. A methodology for designing an energy system that utilizes renewable energy resources was developed and applied to Aso County, in Kumamoto Prefecture, to quantitatively evaluate the effectiveness of energy coordination. We jointly implemented the Decarbonizing Kawasaki Citizens' Conference and developed citizen proposals that were based on scientific findings on the themes of mobility, housing, and consumption.

As a member of the executive committee of the Decarbonizing Kawasaki Citizens' Assembly, we hosted Japan's second citizens' Climate Assembly in Kawasaki. (The first was held in Sapporo in 2020.) We developed citizen proposals on the three themes of mobility, housing, and consumption through six meetings with approximately 70 randomly selected members of the public. The committee was able to identify possible policies from the perspective of the citizens of Kawasaki for 2050, when decarbonization will become a necessity. Some of the proposals for mobility-related measures included:

1. a city where public transportation is convenient and people can live without relying on private cars,
2. a city where people can move around on foot or by bicycle,
3. a city where electric vehicles are widely used, and
4. a city with a wide range of measures.

The mayor was presented with the proposals. In the future, we would like to support the holding of climate citizen meetings in different regions to create measures to form decarbonized regions by incorporating citizens' suggestions in each region, as well as to identify commonalities and uniquenesses among regions.

Project 4. Construction of measures for creating sustainable local communities, and support for introducing such measures into local communities

Through the exchange of opinions with stakeholders and others in each region, we worked with Projects 1, 2, and 3 to identify the issues facing each region, organize approaches to issues that may be obstacles to achieving a sustainable society, gain an understanding of regional characteristics, and develop a typology of issues.

In exchanging opinions with the city hall, members of Projects 1, 2, and 3 were invited to share details of the current conditions of the region and various issues. As a result of the organization of an approach to the issues, it became clear that it is difficult for members of the public to "make them their own issues" because of the gradual progression of population decline and climate change. To make them "our own issues," we started an attempt to present a realistic vision of the future society of the region when the population declines, with the cooperation of each project.

Environmental Emergency and Resilience Research Program

This new program will engage in research and technological development that will help address environmental issues associated with disasters and accidents. Specifically, regional collaborative research will be promoted to help revitalize and manage the regional environment in Fukushima Prefecture and create an environment that utilizes regional resources, in collaboration with regional stakeholders, on the basis of the results of past efforts. Moreover, the program will work to build a resilient waste treatment system and an emergency response system for chemical risk management in the event of a large-scale disaster by accumulating, utilizing, and systematizing the experience and knowledge gained from past disasters, including the Great East Japan Earthquake. Through these efforts, the program will support the construction of a sustainable local environment that meets social needs in affected areas, including the zone of Fukushima Prefecture in which the evacuation order has been lifted. The program will also use our efforts in Fukushima to help improve the environmental-disaster resilience of local communities in preparation for other large-scale disasters.

In this first year of the program, the following efforts were initiated in each project, mainly from the perspective of technological development. The goal is to implement the results of each project socially to help revitalize the environment of Fukushima and prepare for future disasters.

Project 1. Technical systems research for reconstruction and environmental recovery in areas of Fukushima where residents are returning

1) Development of technology and systems for volume reduction of removed soil and radioactively contaminated waste with the aim of final disposal

In joint research with JESCO (the Japan Energy Service Corporation), we continued to conduct full-scale soil embankment experiments for the effective utilization of the removed soil, as well as laboratory experiments on the long-term elution behavior of environmental contaminants, such as radiocesium and heavy metals, from molten slag. We confirmed that radioactive cesium was not eluted from removed soil, even if the soil had been modified by the use of Ca alkali. In addition, in the case of molten slag, although a very small amount of radioactive cesium was eluted, the level was confirmed to be no more than 1/10 of the environmental standard, even over a long period of time. In a study of technology for the volume reduction of contaminated waste for final disposal outside Fukushima Prefecture, tests of fly-ash cleaning and adsorbent performance were conducted in cooperation with JESCO. In addition, scenario setting and mass balance evaluation from volume reduction to final disposal were conducted. These studies were discussed with the audience at sessions organized by the Society for Remediation of Radioactive Contamination in the Environment and the Atomic Energy Society of Japan.

2) Development of biomass utilization technology and systems as countermeasures
We evaluated the thermal characteristics of bark and wood chips by using tools such as a thermogravimetric analyzer, with the aim of utilizing bark as a raw material in woody biomass power generation. We started to develop not only co-combustion but also co-gasification of these materials by using laboratory-scale experimental apparatuses. Preliminary investigations and combustion tests at a working plant enabled us to clarified the appropriate mixing conditions of bark and white chips for their stable co-combustion. In addition, we conducted elemental composition analysis and elution tests on co-combustion ash discharged from the plant to evaluate the safety of the ash in terms of the content and elution of toxic metals. For the efficient utilization of herbaceous plants, waste biomass, and agricultural residues, we developed a system that combined thermal conversion technology and anaerobic fermentation technology. We investigated the controllability of the concentration of inhibitory substances in the condensate generated during the gasification process, as well as the effect of adding fly ash from woody biomass combustion on the biodegradation of herbaceous plants.

Project 2. Research into environmental impacts and management in the disaster areas of Fukushima

Koshiabura (*Eleutherococcus sciadophylloides*) is a deciduous broad-leaved tree. Fresh shoots of young trees are popular edible wild food, especially in the Tohoku region. However, the radiocesium concentration of these shoots is higher than that in other edible wild plants. One hypothesis for the higher level of radiocesium in *Koshiabura* is that the tree sets roots in the surface soil, where the level of radiocesium has remained at a high level. To test this hypothesis, we investigated the rooting depth of the tree.

We used $^{87}Sr/^{86}Sr$ ratios, under the assumption that, if volcanic ash were present as a tephra layer in the soil, the vertical distribution of $^{87}Sr/^{86}Sr$ ratios in the soil might not be uniform and the $^{87}Sr/^{86}Sr$ ratio of the aboveground parts of the plant would indicate the depth of the roots taking up Sr and other base cations (e.g., Ca, Mg, Na, K, and Cs). By using this idea, we tried to estimate the rooting depth of *Koshiabura* within a forest in the Iitate village of Fukushima, where volcanic ash from Mt. Adatara ash is present as a tephra layer in the granitic soils.

The $^{87}Sr/^{86}Sr$ ratios of soil extracts were the lowest at depths of 30 to 50 cm, and increased toward the surface; this may have reflected the presence of more Adatara volcanic ash at 30 to 50 cm. The $^{87}Sr/^{86}Sr$ ratios of *Koshiabura* leaves were closest to those of soil extracts from the organic horizons and depths of 0 to 5 cm. These findings suggest that *Koshiabura* takes up radiocesium along with base cations from the organic horizons and from surface soils. Furthermore, we confirmed the presence of *Koshiabura* roots in surface soils by a root distribution survey (Fig. 1) and environmental DNA analysis.

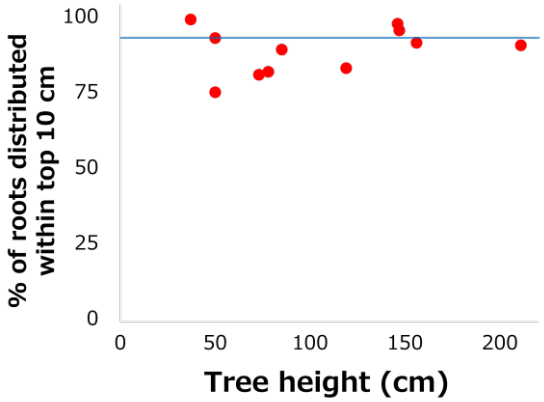


Fig. 1 Distribution of *Koshiabura* roots in soil. The percentage (by weight) of *Koshiabura* roots distributed within 10 cm of the soil surface was investigated by digging up the roots. Red dots represent the percentage of roots at 0 to 10 cm depth for each tree. The blue line indicates average percentage (90% ± 8%).

Project 3. Evaluation and analysis of regional revitalization and sustainable town reconstruction and development

We started building a database for reconstruction in the areas where evacuation orders have been lifted, and we investigated the monthly rates of return of residents, as well as the resident population in each municipality. There are interregional differences in the recovery status of the population; the distance from the nuclear power plant and the proportion of areas where evacuation orders have not yet been lifted in municipalities are factors that are likely influencing the rate of recovery. We collected information on business conditions, centered on commercial and medical facilities, and created a database. As part of the development of R2-AIM (a reboot-type regional integrated assessment model, which aimed at rebooting the local economy and achieving environmental sustainability), we developed a regional energy supply and demand module that explicitly expresses the energy supply and demand relationship inside and outside the region for each energy demand sector. By using this, we expressed and analyzed in detail the energy self-sufficiency target of zero-carbon and 100% renewable energy by 2050 in the town of Okuma. Some of the results were added to the manual “Procedure for formulating a ‘decarbonized society vision’ in the region.”

As part of the planning and evaluation method for developing a renewable energy utilization technology in the reconstruction area, we evaluated the potential for decarbonization under a scenario of diffusion of photovoltaic (PV) power generation in residential areas. Especially in the case of PV systems, the amount of

power generated fluctuates greatly depending on the weather conditions. We therefore evaluated the potential and economic efficiency of regional decarbonization, including the effect of adjusting the balance between supply and demand by using electric vehicles (EVs), which are expected to become common in the future, as storage batteries. To perform this evaluation on a block scale, we constructed a power-consumption prediction method by linking power monitoring data from houses and an air-conditioning load simulation. Next, the economic efficiency and CO_2 reduction effect were quantitatively evaluated on the basis of the time fluctuation of the power supply and demand and a scenario under which PVs and EVs were introduced. We also discussed ways to extend this study process to a variety of other renewable energies and implement it in a general-purpose evaluation system for deployment to other regions.

Project 4. Studies of the emergence of regional resources and systems in Hamadori, Fukushima, after lifting of the evacuation instruction

The main themes of PJ4 are the recovery and reconstruction of natural systems and social systems after the nuclear disaster. Subtopic (1) relates to studies from a natural science perspective of regional resources and environmental technologies, including the resource management processes required to make use of these resources. Subtopic (2) relates to quantitatively investigating the characteristics of the region and developing methods for applying the scientific findings of Subtopic (1) in society. Notable research results this fiscal year are described below.

Subtopic (1): Exploitation of forest resources in the eastern Fukushima region of Hamadori is currently difficult because of radioactive contamination. With the aim of supporting forestry management in Hamadori, we have been developing systems that combine laser measurements by unmanned aerial vehicles (drones), machine-learning technology, and forestry modeling technology to assess forest resources. This year, we developed a model for predicting the growth of individual trees and made improvements to enable the model to reproduce material cycling in the forest.

Subtopic (2): By working from a literature survey and interviews with policymakers in cities with advanced environmental and urban planning, including reconstructed cities, we identified the elements that characteristically appear in urban planning processes and described them as patterns by using a pattern language framework. From the identified patterns, we investigated the process structures and regional characteristics that are shared by advanced examples of planning. Important elements that we identified, particularly in terms of the urban planning processes of reconstructed cities, were 1) the need to promote cooperation with the private sector for community development and 2) the input of outside knowledge. We constructed a basic framework to utilize sustainable urban planning knowledge of advanced regions to Hamadori.

Project 5. Making a resilient material cycle and waste management system at the local level to tackle mega-disasters

We developed a conceptual model of disaster waste governance. In this model, social capital and other resources (e.g., knowledge and skills) are fostered through local waste governance outside times of disaster, and this contributes to approprate local waste governance when disaster strikes. To verify the model, we worked with Professor Shinya Suzuki from Fukuoka University to investigate the relationship between waste management operations in peace times and the disaster waste management capacity of Japanese municipal governments. Our questionnaire survey and statistical analysis showed that municipal governments that spend more time on developing waste management operation plans and communicating with local residents had greater disaster waste management capacity. Our findings suggested that the skills and relationships critical for disaster waste management were fostered through waste management outside times of disaster; this was consistent with our proposed conceptual model.

We also developed a prototype of an online tool that easily generates a suitable layout for a given size of temporary storage site. We discussed aspects that require improvement, including the minimization of calculation errors and the expansion of use of the tool to suit different disaster types and waste compositions.

From a technical perspective, we started gathering data and developing concepts with the aim of establishing new options and systems for recycling the concrete rubble generated after mega-disasters. Data on the material flows of soil and stone resources (including concrete rubble) in Japan outside times of disaster and during disasters were gathered. An analysis of the current and future supply–demand balance of such resources revealed that supply will exceed demand by 2030 unless a new market for recycled soil and stone resources emerges. In addition, the analysis suggested that it will be difficult to make use of recycled concrete rubble after the predicted Nankai Trough Mega Earthquake in regions where severe damage is anticipated to happen (i.e. in the Kinki and Chu-Shikoku regions).

To overcome the above challenges, we developed the concept of “A sustainable and resilient ocean circular economy (Blue Circular Economy)” through interdisciplinary discussions with experts in related fields. The idea is to use recycled concrete rubble and other industrial by-products as resources for artificial underwater mounds and the foundations of seaweed beds in an environmentally sound manner. This green infrastructure will help to increase fisheries resource production and carbon capture and to accelerate recovery from disasters.

Project 6. Strategic chemical risk management research in emergencies

This project aims to provide environmental policies with methodologies and assessment methods for rapidly and accurately determining the contamination

status and exposure effects of leaked chemicals. It will also establish a risk management infrastructure for chemicals in the anticipation of recovery from disasters and accidents. The project consists of three sub-themes. In sub-theme 1, we will examine how to strengthen our response capabilities in chemical leakage and promote the comprehensive organization of emission incidents and the generalization of practical emission scenarios. In sub-theme 2, we will generalize and improve the accuracy of automated chemical quantification systems. In addition, we will predict the disturbance effects of disasters on ecosystems. Sub-Theme 3 will establish methods for assessing the resilience process.

Notable achievements under this project include the development of a model-independent automated identification and quantification system (AIQS, for gas chromatography–mass spectrometry measurements) in a form that can be placed on the cloud and analyzed on the Web. Efforts to implement the system include briefing sessions on the use of the web-based version of AIQS; more than 40 regional environmental research institutes have started using the system. Currently, we are working on identifying problems and areas for improvement in preparation for updating the system.

Climate Crisis Research Initiative

1. About

The Climate Crisis Research Initiative (hereinafter referred to as the Initiative) is responsible for coordinating four climate change-related Strategic Research Programs (Climate Change and Air Quality Research Program, Climate Change Adaptation Research Program, Decarbonized and Sustainable Society Research Program, and Co-design Approach for Local Sustainability Research Program). It consolidates and disseminates findings that are relevant to public concerns (Fig. 1).

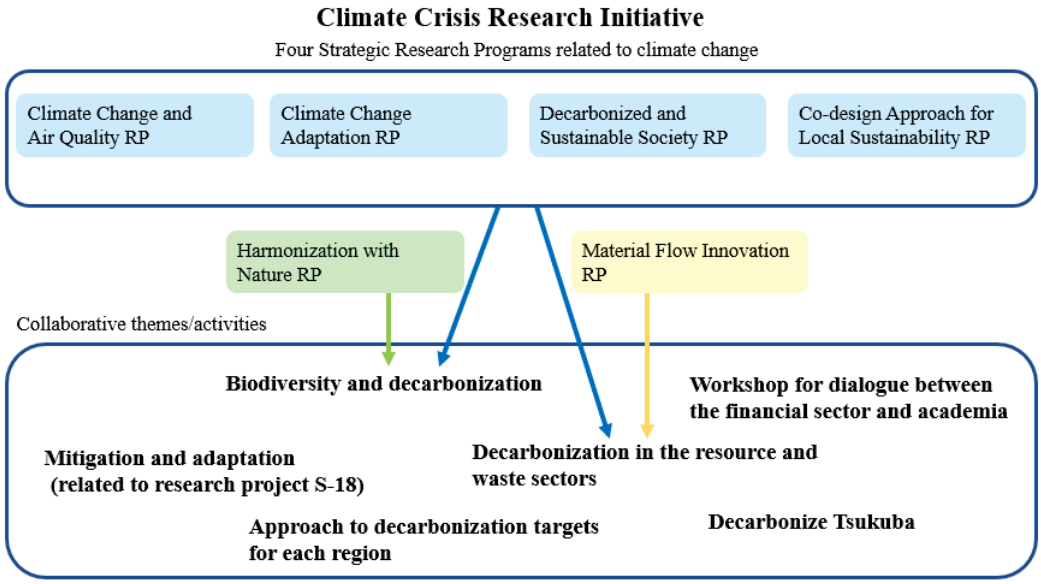


Fig. 1 Structure of the Climate Crisis Research Initiative and the four Strategic Research Programs related to climate change (Climate Change and Air Quality Research Program, Climate Change Adaptation Research Program, Decarbonized and Sustainable Society Research Program, and Co-design Approach for Local Sustainability Research Program)

2. Activities in FY 2021

2.1 Monthly meetings

The directors of the four climate change-related Strategic Research Programs, along with project leaders, directors of related research divisions (Earth System, Social System, and Center for Climate Change Adaptation), and other members, including the president of NIES, the vice-president in charge of research, and the leader of the Initiative, held monthly briefings on the progress of each Research Program and discussed shared issues for collaboration, as described in section 2.2.

2.2 Identifying themes for collaboration

During the review of which research topics were common to the aforementioned climate change-related programs, collaboration with other Strategic Research Programs was also considered. The following six themes of collaboration were identified.

2.2.1 Biodiversity and decarbonization

In recent years, there has been growing concern about the negative impacts on biodiversity caused by the development of renewable energy sources such as solar

and wind power. To address this issue, a collaboration with the Harmonization with Nature Research Program has started to survey suitable sites for renewable energy in Japan, taking biodiversity conservation into consideration.

2.2.2 Workshop for dialogue between the financial sector and academia

ESG (Environmental, Social, and Governance) investment and finance have been increasing in the financial sector in recent years, and there is a growing understanding of the importance of non-financial information on corporate value. However, although climate change is recognized as a relevant risk, the financial community's understanding of it as an important global issue is far from ideal. Therefore, with the aim of raising awareness of the issues among members of the finance community, a workshop was held in November under the leadership of the Social System Division, in cooperation with Future Earth, an international research platform. As the workshop included several themes related to climate change, the Initiative was also involved.

2.2.3 Mitigation and adaptation (related to research project S-18 of the Environment Research and Technology Development Fund)

In response to the trend of mainstreaming climate change mitigation measures (decarbonization) both domestically and internationally, discussions on linking mitigation and adaptation are under way in the Environment Research and Technology Development Fund's S-18 project, "Comprehensive Research on Projection of Climate Change Impacts and Evaluation of Adaptation." As the Initiative has both mitigation and adaptation research programs and is in a good position to study how they can be connected, this theme will be discussed in the Initiative following the report of the S-18 discussion.

2.2.4 Decarbonization in the resource and waste sectors

In the Central Environment Council's "Study Group for the Realization of a Carbon-Neutral, Decarbonized Society in 2050 in the Waste and Resource Circulation Sector," scenarios were developed focusing mainly on emissions in the resource and waste sectors. However, a need for broader study of decarbonization, which should include resource recycling in the energy and industrial process sectors, international resource recycling, lifestyles and consumer behavior, and the circular economy, was recognized. The Initiative will address this issue in collaboration with the Material Flow Innovation Research Program.

2.2.5 Approach to decarbonization targets for each region

In response to the government's 2050 decarbonization and 2030 GHG emission reduction targets, goals and action plans are being developed by local governments. Our goal is to clarify the concept of appropriate reduction targets according to the

circumstances of each municipality. An internal meeting was convened in October 2021, and issues such as understanding the emission inventories of different municipalities, and problems with the power system in the case of inter-regional flexibility, were raised.

2.2.6 Decarbonize Tsukuba

In a decarbonizing society, NIES, as an institute located in Tsukuba Science City, needs to be more involved in the decarbonization of its own municipality. With this in mind, "Decarbonize Tsukuba," a working group of 15 people, including members of the Initiative, was created. Meetings were held about once a month to discuss decarbonization in NIES and in Tsukuba generally. The working group had several opportunities to exchange opinions with non-NIES personnel, including the Mayor of Tsukuba, who visited NIES in March.

2.3 Public webinar

In relation to the collaborative theme of "Biodiversity and decarbonization (2.2.1)," a public webinar, "Biodiversity and Climate Change: Science for Simultaneous Solutions," was held in July (Fig. 2). Following the publication of the report of the IPBES-IPCC Co-Sponsored Workshop, which was held in December 2020, Professor Kazuhito Ichii of Chiba University was invited to give a briefing on the workshop. The efforts within NIES, including the results of the Initiative's domestic renewable energy construction site analysis mentioned above, were introduced and discussed with the participants. The webinar was attended by about 200 people and has subsequently been viewed more than 28,000 times, confirming a high level of public interest in this topic.

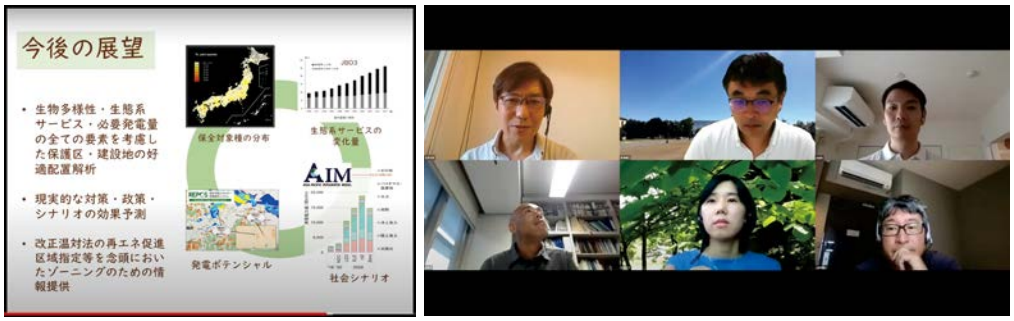


Fig. 2 Webinar on "Biodiversity and Climate Change: Science for Simultaneous Solutions"

2.4 Linkage mapping with external research funding projects

In order to distinguish between issues that are currently being addressed and areas not receiving enough attention, a linkage chart has been devised which shows external research funding projects and how they relate to the four Strategic Research Programs. It also provides an overview of what new themes need to be tackled.

Research Domain

Earth System Domain

The surface of the Earth is covered with the atmosphere, oceans, and land, and preserving this surface environment is indispensable for creating a sustainable human society. However, human activity has caused changes in the climate, including not only rising average temperatures but also an increase in extreme weather events, rising sea levels, and damage to ecosystems and food production. Countries and regions are required to take further measures to reduce greenhouse gas (GHG) emissions under the Paris Agreement, an international framework for climate change countermeasures. There is growing concern about the climate crisis in the world, and Japan has pledged to achieve net-zero GHG emissions by 2050.

Researchers in NIES's Earth System Domain will, in collaboration with scientists in Japan and overseas, work on a variety of research issues, such as prediction of future changes in the global environment, assessment of risks, and development of the advanced measurement technologies and models necessary for their research. The intellectual research infrastructure (e.g., long-term monitoring and databases) will continue to be maintained by the CGER (Center for Global Environmental Research) established in 1990. We will also work closely with the Satellite Observation Center, which is responsible for the "IBUKI" (GOSAT) series of GHG observation satellites. We will disseminate our research results more quickly and widely than has been possible before. Scientific knowledge and data will be actively transmitted to international frameworks such as the UNFCCC (United Nations Framework Convention on Climate Change) and the IPCC (Intergovernmental Panel on Climate Change). We hope that, through the above activities, we can help to achieve a sustainable global environment and society.

1. Foresight and Advanced Basic Research

Evaluation of cloud microphysical characteristics and vertical flow by composite analysis of a satellite equipped with next-generation active sensors

To improve the model reproducibility of cloud physics and convection, a state-of-the-art combined ground-based lidar and cloud radar observation system that simulates current and future satellite-borne active sensors was developed in collaboration with Kyushu University and the National Institute of Information and Communications Technology. As a result, the distribution of clouds and aerosols can be measured with higher resolution and accuracy than ever before. The system has also achieved time-continuous estimation of aerosol and cloud optical properties through its steady-state operation (Fig. 1a, b). Microphysical properties of aerosols and clouds and vertical flow were extracted by using data from this observation system, and a database is being compiled. We also used the data to improve algorithms for satellite data analysis and to validate satellite observations. The aerosol and cloud products of the Doppler wind lidar onboard the ADM-Aeolus

Earth observation satellite launched in 2018 by the European Space Agency were evaluated by using data from this observation system (Fig. 1c, d). The backscatter and extinction coefficients from the satellite observations were validated, and it was pointed out that the satellite-observed backscatter coefficients are overestimated.

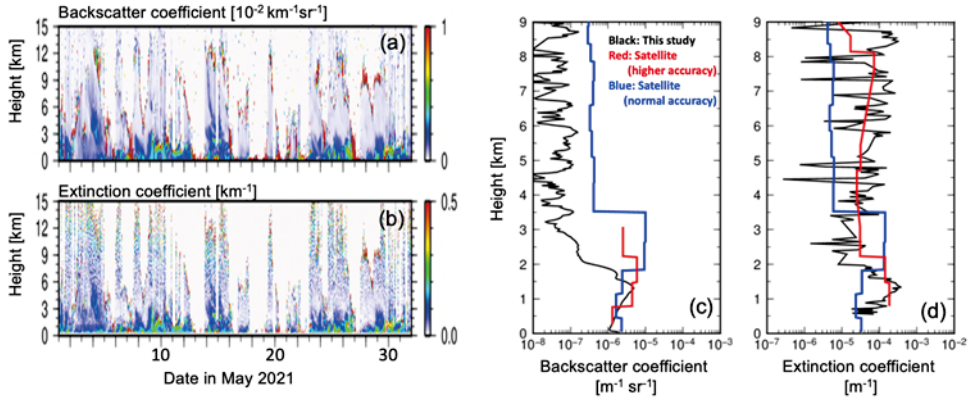


Fig. 1 Backscatter (a) and extinction (b) coefficients measured in May 2021, and ground validation of the ADM-Aeolus onboard lidar by using the measured backscatter (c) and extinction (d) coefficients.

Further reading:

Jin Y., Nishizawa T., Sugimoto N., Ishii S., Aoki M., Sato K., Okamoto H. (2020) Development of a 355-nm high-spectral-resolution lidar using a scanning Michelson interferometer for aerosol profile measurement. *Optics Express*, 28(16), 23209–23222
https://doi.org/10.1364/OE.390987

Jin Y., Nishizawa T., Sugimoto N., Takakura S., Aoki M., Ishii S., Yamazaki A., Kudo R., Yumimoto K., Sato K., Okamoto H. (2022) Demonstration of aerosol profile measurement with a dual-wavelength high-spectral-resolution lidar using a scanning interferometer. *Applied Optics*, 61(13), 3523–3532
https://doi.org/10.1364/AO.451707

2. Policy-Oriented Research

The Arctic region is the area most affected by global warming, and early detection of the progress of global warming and its impacts in Arctic nature and society is important in the effort to support Japan's science and technology diplomacy. As part of the research collaboration under a Memorandum of Cooperation between NIES and the Finnish Environment Institute (SYKE), in April 2022, we held an online seminar comparing the national inventories of black carbon (BC) and Short-Lived Climate Forcers (SLCFs). Methods of calculating BC/SLCF emissions from stationary and mobile sources, as well as spatial gridding methods in Japan and Finland, were presented. In addition to information on national emissions from anthropogenic sources, studies on future scenarios and emissions from wildfires were introduced.

3. Intellectual Research Infrastructure Development

Long-term trends in atmospheric methane concentrations observed at Cape Ochiichi and Hateruma Island

NIES has continued to observe atmospheric methane (CH_4) concentrations at Hateruma Island (Okinawa) and Cape Ochiishi (Hokkaido) with high precision and temporal resolution. The rate of increase in CH_4 concentrations remained low until about 2007, after which time the rate rose again, reaching 20 ppb/year in 2020 at Cape Ochiishi (Fig. 2). This long-term trend is consistent with that observed in other parts of the world, and the results support the possibility that certain processes in the high latitudes of the Northern Hemisphere are responsible for this increase.

The datasets are provided to the WDCGG (World Data Centre for Greenhouse Gases) and have been published in the Global Methane Budget 2020 compiled by the Global Carbon Project, as well as in the IPCC's Sixth Assessment Working Group 1 Report. Research is under way in the Climate Change and Air Quality Research Program in NIES to determine the cause of the changes in the rate of increase. The datasets are expected to play an important role in verifying the effectiveness of CH_4 emission-reduction measures, which are among the global decarbonization initiatives.

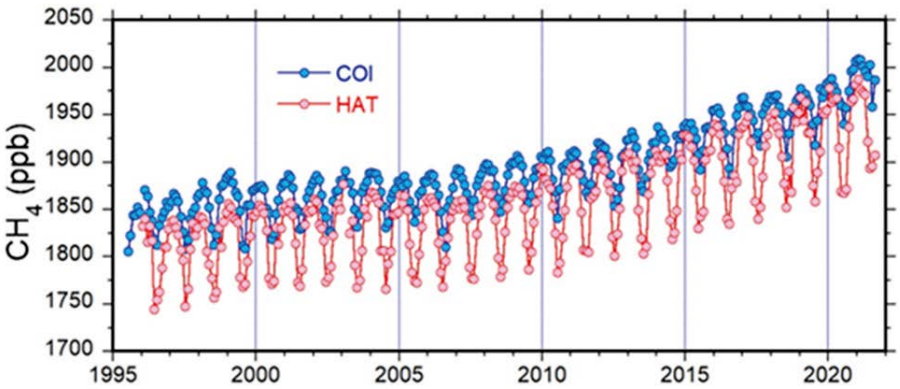


Fig. 2
Atmospheric methane (CH_4) concentrations observed at Hateruma Island (HAT) and Cape Ochiishi (COI)

Database:

Tohjima et al. (2016) Continuous Observational Data of Atmospheric CH_4 Mixing Ratios on Hateruma Island.
https://www.nies.go.jp/doi/10.17595/20160901.003.html

Tohjima et al. (2016) Continuous Observational Data of Atmospheric CH_4 Mixing Ratios at Cape Ochiishi.
https://www.nies.go.jp/doi/10.17595/20160901.004.html

Material Cycles Domain

As part of our foresight and advanced basic research, we are conducting two main research activities. One is sustainability assessment and design of a future vision of resource utilization. The other is the development of leading basic technologies to support sustainable resource recycling.

As part of our policy-oriented research, we have been conducting three main research activities. The first is the analysis of social systems and policies in the field of resource recycling. The second is the measurement, testing, and evaluation of hazardous substances in the resource-recycling process. The third is adaptation and improvement of waste treatment and disposal technologies.

In addition to the main research activities mentioned above, to strengthen international joint research we launched an international project under joint research with overseas academic institutions. As participants in several technical committees of the International Organization for Standardization (ISO), we also helped issue standard documents and scientific findings.

As part of the ongoing development of intellectual research infrastructure, we have begun to graph Japanese municipal waste data and improve the user interface. As part of this year's topic, we surveyed and accumulated data relevant to municipal waste generation during the coronavirus pandemic.

Details of the abovementioned research activities are given below.

1. Foresight and Advanced Basic Research

1.1 Sustainability assessment and design of a future vision for resource utilization

As part of our sustainability assessment and research into a future vision for resource utilization, we intend to examine a model structure and perform case studies on the optimization of supply chains under supply constraints. By targeting the future predicted Nankai Trough earthquake, we intend to confirm that the carbon emissions induced by restoration demand could be offset by selectively introducing low-carbon technologies to low-disaster-risk areas and restructuring supply chains to shorten the transport distance of restoration materials. This research should help us to formulate robust mitigation and adaptation measures under the assumption that the occurrence of natural disasters caused by climate change will increase.

In a case study of supply chain optimization under supply constraints during a disaster, we identified paths to both disaster recovery and decarbonization in the

case of a projected major Nankai Trough earthquake. As the frequency of disasters caused by climate change increases, the development of recovery plans consistent with decarbonization is becoming an urgent issue as the international trend toward decarbonization accelerates. In this study, we developed a model to identify the supply chains that would enable recovery from a huge disaster under carbon constraints. To do this, we performed optimization calculations of an inoperability multiregional input-output model by using quadratic programming under production and carbon constraints. Recovery based on pre-disaster supply chains would generate as much as 344 Mt-CO2 eq. of greenhouse gas (GHG), equivalent to 32% of pre-disaster total domestic emissions, as a result of demand for restoration in the disaster-affected areas. However, it has become clear that this increase in emissions from restoration demand can be offset by the supply of electricity from low-intensity regions (regions with low carbon emission factors), as well as by short-distance transport of commodities by the selection of production areas (Fig. 1). By locating the materials and energy needed for restoration in the most appropriate areas, the power and transportation sectors would have GHG emission reduction potentials of 68 Mt-CO2 eq. and 225 Mt-CO2 eq., respectively. These results enabled us to develop a low-carbon recovery plan through the selective introduction of low-carbon technologies to low-disaster-risk areas and the reduction of transport distances through the optimal production and placement of restoration materials. These results should help to develop recovery plans that incorporate a decarbonization perspective and also to develop climate-change mitigation and adaptation measures that anticipate the impacts of disasters in advance.

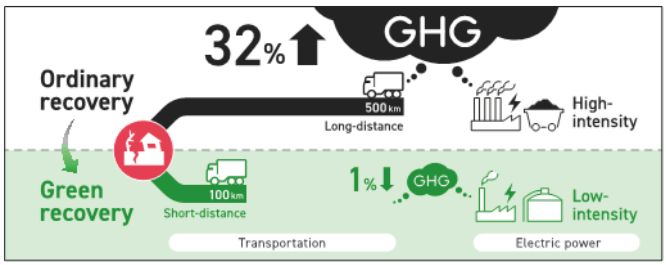


Fig. 1 Visualization of a low-carbon plan for recovery from major disasters under carbon constraints

1.2 Advanced science and engineering for material cycles

Although there has been increased attention on the fate and behavior of nanoplastics in the environment and their toxicity, only a limited number of standard nanoplastics particles are available for quantitative analysis. For the quantification of microplastics, on the contrary, standard materials are not required. However, we have no information on the mechanism of microplastics generation from plastic litter, namely by the fragmentation of plastics into microplastics. Therefore, we conducted two studies on two different sizes of plastics, nanoplastics and microplastics, as described below.

In a study on the fate and behavior of nanoplastics, for six major polymers (low-density polyethylene, high-density polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polyethylene terephthalate), we developed a method of preparing spherical nanoscale particles of nanoplastics (Fig. 2). The particles obtained by this method are made of pure polymer without surfactants or any other additives, and their polymer molecular weight, crystallinity, melting point, and glass transition temperature are equivalent to those of various common plastic products. Because these results are highly novel, they have been published in Small, a well-known academic journal (impact factor = 13.3), and a patent application has been filed. The results are expected to help in the development of quantitative analysis methods and, eventually, to our understanding of the abundance of nanoplastics in the environment. In addition, although toxicity tests of nanoplastics were conducted using only polystyrene particles in earlier works, this method makes it possible to conduct toxicity tests on other polymer particles.

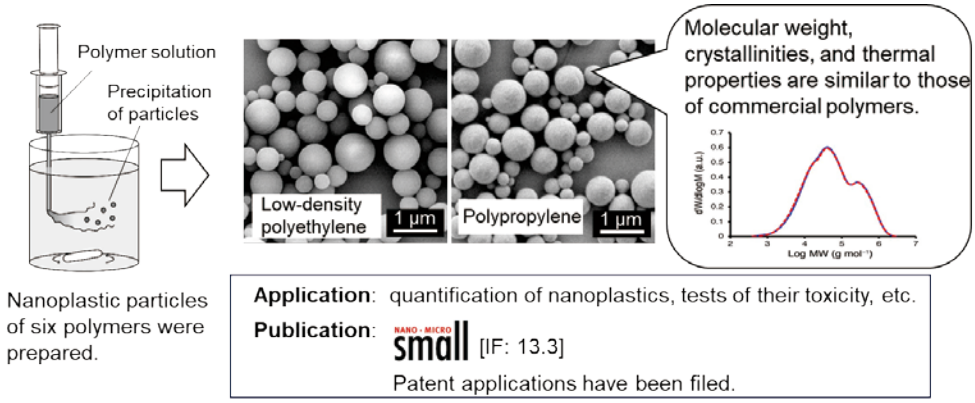


Fig. 2 Synthesis of standard nanoplastics particles

In research on the fragmentation process of plastics, preparation of plastic test pieces is in progress using pellets of general-purpose plastics supplied by domestic resin industry groups. At the same time, to evaluate fragmentation behavior, we prepared an outdoor exposure test and started preliminary tests on the test pieces by simulating different climate conditions. Furthermore, we developed an accelerated degradation test apparatus capable of irradiating ultraviolet rays more intensively than outdoor exposure before the test. The test results are expected to be used to predict the environmental emissions of microplastics and will be provided to bodies such as ISO technical committees.

2. Policy-Oriented Research

2.1 Research on social systems in material cycles and waste management

This fiscal year, we further developed our municipal waste flow model and facility aggregation algorithm and published the results as scientific papers. With respect to municipal waste flow model, we began to examine a number of policies that substantially improve material flow indicators targeting plastics and food waste. In

the study, we paid attention to consistency with medium- and long-term scenarios that aim for zero GHG emissions in 2050 in the field of waste and resource recycling and reflected the condition municipality by municipality, which is a strength of the municipal waste flow model. In addition, we held a seminar with Ministry of the Environment officials and engineers from waste treatment plant manufacturers (i.e. participants working in the field of resource recycling) to discuss the challenges of the Ministry's medium- and long-term scenarios and the technological challenges facing resource-recycling systems. From the findings of the seminar, the establishment of appropriate system boundaries and of policy priorities, as well as of more in-depth policy proposals (including expansion of demand for recyclables, securing of feedstock of bio-based plastics, measures against factors hindering circularity, integration of municipal waste treatment with industrial waste treatment, and consideration of the impact of renewable energy expansion) were proposed as research issues related to scenario analysis.

In a feasibility study on the use of statistics and administrative information related to waste and chemical substances, we verified the consistency of the reporting facilities in the Pollutant Release and Transfer Register (PRTR) system and the industrial waste manifest system. More than 90% of PRTR-reporting facilities were matched with the reporting facilities in the manifest data. We therefore considered that connection of the two sets of data could be used to estimate the flows of chemical substances in waste treatment.

We analyzed the data from a questionnaire survey of purchasers of upcycled marine plastic accessories and presented the findings at a research conference. In addition, for a study of low-carbon lifestyles, we initiated to develop questionnaires on home organization and consumption behavior.

The results of a survey on the management of waste collection points, which started in 2018, were compiled and published in April 2021 as "Case Studies on the Management of Waste Collection Points in Response to the Aging and Weakening of Local Communities." With respect to support for the elderly to clean up and discharge waste in the event of a disaster, we initiated an interview survey in the flood-disaster-affected area to gain an understanding of the types of support entities and the state of cooperation among them.

2.2 Impact assessment of hazardous substances in material cycles

We used an artificial-intelligence-based model (AI model) to study a technique for detecting asbestos fibers in phase-contrast microscope images of simulated air filter samples. As an AI model, we chose an instance segmentation model (Mask-RCNN) capable of detecting objects and recognizing shapes simultaneously. We trained the model by using 30 images obtained by skilled analysts, and we validated detection accuracy by using 10 images. We achieved detection of fibers

within about 10 s per image. The recall rate of the model was 57% and the precision rate was 46%.

To determine whether microplastics emitted during waste recycling and treatment processes are a potential source of persistent organic pollutants (POPs) in the atmospheric environment, we investigated the current discharge status of microplastics and polybrominated diphenyl ethers (PBDEs) to the atmosphere at two waste treatment facilities. The concentrations of microplastics in indoor air samples in the vicinity of the waste shredders were about 10 times those at the property boundaries. The atmospheric microplastics fluxes were comparable to those in urban environments. The PBDE concentrations in the vicinity of the shredders were similar to those in previous studies at an electronic waste recycling facility.

As part of the development of analytical methods for per- and polyfluoroalkyl substances (PFASs), we first developed a novel screening method for characterizing fluoropolymers in water and oil repellents and their treated products. By adding 1 N sodium hydroxide to the sample, hydrolyzing the sample under basic conditions at 50 °C for 24 h, and using gas chromatography–mass spectrometry to measure neutral PFAS decomposed from the side-chain fluorinated polymers (SFP), we successfully indirectly characterized SFPs in the water and oil repellents and their treated products; these had previously been difficult to measure directly. An investigation of 54 water and oil repellent samples that used the new method revealed that 25 of the samples contained SFPs with the potential to generate perfluorooctanoic acid (PFOA)-related compounds designated as POPs under the Stockholm Convention.

We conducted an annual composition fluctuation survey of incineration bottom ash and grate sifting ash, and we clarified the resource-recovery efficiency by separation discharge. In addition to conducting a questionnaire survey on the amount of ash generated and the factors influencing the amount, we collected bottom ash and fly ash from about 30 facilities and analyzed their compositions. In building a model of the mechanism of neutralization of alkaline solutions, we considered the dissolution and diffusion of carbon dioxide in water, and we extended the model to make it a two-dimensional seawater model. As part of the development of methods for determining the natural or anthropogenic origin of hazardous substances in soils, we optimized the concentration of reagents to improve the accuracy of the test method for lead; we then performed an accuracy evaluation and initiated the application of the method to fluorine and boron.

In evaluating the application of slag to green infrastructure in brackish water and marine areas, we selected steel slag, steel slag hydrated matrix, and slag artificial stone, and prepared test specimens (flat and granular). We interviewed local fishermen and consultants to select a field test site, and we devised four test methods for hanging flat plates in the marine area. We then initiated field tests to evaluate the elution and biofouling characteristics of the test specimens.

2.3 Advancement and implementation of waste management technologies for society

We have been conducting a multifaceted evaluation of final waste disposal sites in Japan; developing appropriate waste treatment and resource-recovery technologies based an assessment of waste characteristics in Asian cities; and studying the establishment of a Johkasou management technology system to adapt decentralized wastewater treatment technology to Southeast Asia.

We effectively used the long-term time-dependent leachate concentrations previously monitored by local managers for waste disposal sites and started to develop a new methodology to predict the post-closure care period of landfills by using a combined physics and statistics approach.

We conducted a groundwater investigation around an inappropriate final disposal site. The results showed that leakage from the disposal site could be estimated by evaluating the existence pattern of ion species and the transfer status of persistent organic substances.

We proposed the adhesiveness of wastes as an indicator of the difficulty of recycling and disposing of domestic wastes in Asian cities. The loss tangent (loss stiffness ratio or rigidity ratio) and adhesiveness obtained from peeling tests were shown to be representative indicators. We developed a DEM (discrete element method) model that can evaluate the impact of the mechanical separation performance of waste, with a focus on adhesiveness.

By taking the demolition of construction waste in Hanoi as a case study, we showed that the implementation of selective dismantling should increase incomes from the sale of recyclable materials and reduce expenditure on disposal fees (Fig. X3). It will also lead to an increase in income from the whole of the demolition work, even considering the increase in labor cost and the lease and loss costs of heavy machinery.

To promote the adaptation of domestic wastewater treatment technology to Southeast Asia, we conducted laboratory tests of a Johkasou system (treatment capacity 1 m3/day) under tropical conditions. The suspended solids content of the treated water was very low because the scum stayed thick, and the BOD (biochemical oxygen demand) removal rate exceeded 90%. However, in Southeast Asia, because the frequency of sludge withdrawal is not clearly defined, we need to consider the effect of sludge accumulation on treatment performance.

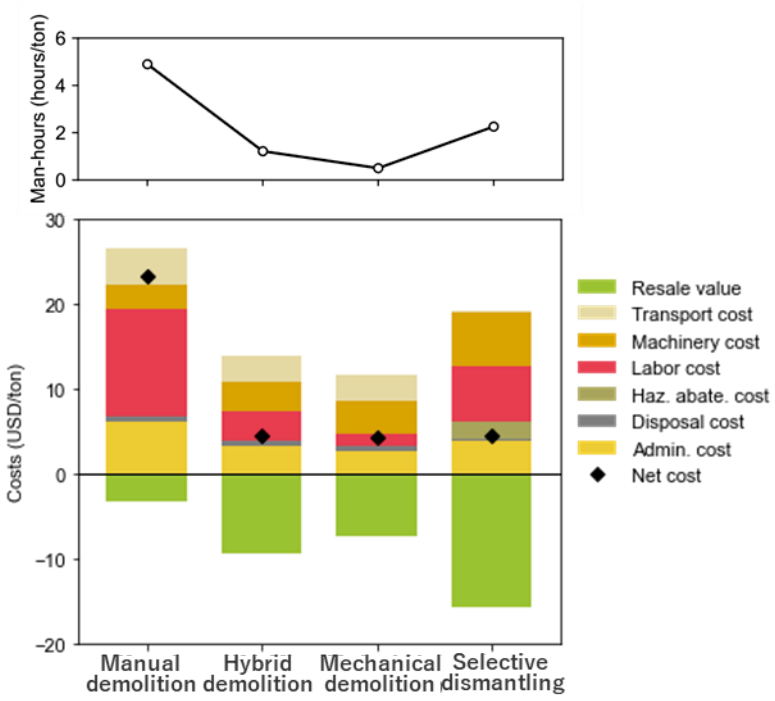


Fig. 3 Cost breakdown and person-hours of demolition/deconstruction works

2.4 International Waste Management Research Administration Office

We intend to support the proposal and implementation of international joint research by integrating research interests in multiple fields with the resource-recycling field as the core. We will promote efficient social implementation of research results and policy recommendations by promoting cooperation with academic institutions and local governments overseas and by quickly identifying needs. In addition, we will support the return of research results through international organizations and international activities.

In FY 2021, we enhanced the dissemination and diffusion of research results by issuing international guidelines, databases, and policy recommendations on technical information, and by sponsoring and supporting workshops and seminars. To strengthen the international joint research system, we applied and were selected for the International Science and Technology Network Enhancement Project implemented by Thailand's National Higher Education, Science, Research and Innovation Policy Council. In relation to this, we signed a memorandum of understanding for joint research with academic institutions. We issued press releases and gave interviews from overseas (via the Ministry of Science and Technology of Vietnam) on the publication of papers in the area of resource recycling, leading to the dissemination of this information internationally. A seminar on international mutual tests for the analysis of plastics containing POPs was held in December to disseminate the results of the international joint research. We contributed to the ISO Technical Committee on Solid Recycling Materials in issuing standards documents and provided research insights to the ISO Technical Committee on Waste Management. As part of information sharing

and human resource development in the field, we are planning and conducting events on topics such as the promotion of social implementation of results through participation in international standardization activities; the cross-sectoral exchange of foreign researchers, and the efficient dissemination of results.

3. Intellectual Research Infrastructure Development

We have been improving the databases on municipal solid waste in Japan and in the Asia-Pacific Region so that they can be widely viewed and used. In addition, we have investigated trends in municipal solid waste generation during the COVID-19 pandemic.

Although the data file for Japan's municipal solid waste database, and its viewing system, are now open to the public, there remained issues regarding the wider viewing and utilization of the database. In FY 2021, with the aim of promoting information provision from the user's perspective and needs, we focused on the main data stored in the municipal solid waste database and started to create graphs and images of the data by prefecture. Next fiscal year, a report summarizing the trends and insights that can be obtained from the visual information will be prepared and published on the website. We have started a basic analysis of the data on the total amount of waste discharged and the amount finally disposed of. We have also initiated a review aimed at improving the user interface to further enhance data usage and accessibility.

To clarify changes that occurred during the COVID-19 pandemic, we surveyed municipal solid waste generation by major cities in Japan by month in FY 2019 (before the pandemic) and in FY 2020 (during the pandemic). We received responses from 42 out of 55 cities (response rate, 76%). The survey found that most cities saw an increase in household waste generation in May and June 2020 compared with the same months in 2019, but there was a trend back to the same levels in subsequent months (Fig. 4). In contrast, for business waste, FY 2020 saw a decrease in every month compared with FY 2019.

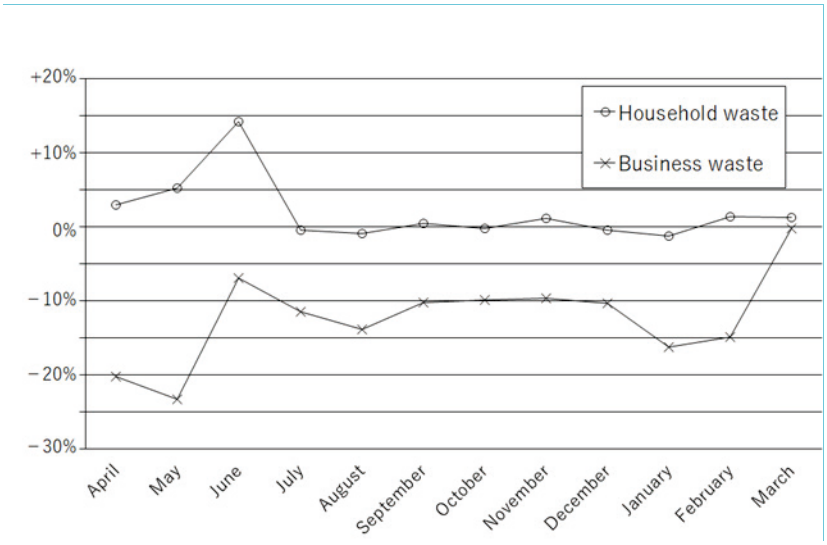


Fig. 4 Changes in monthly municipal solid waste generation in FY 2020 compared with FY 2019 in major cities in Japan

Health and Environmental Risk Domain

In the field of health and environmental risk, we aim to promote foresight and advanced basic research and policy-oriented research to help protect human health and preserve ecosystems from environmental harms such as chemical substances.

Our foresight and advanced basic research includes: (1) evaluation of the toxic effects of a variety of chemicals on organisms in the environment from the molecular level to the individual and population levels; (2) studies of exposure to chemicals via the environment, and advancement of methods for understanding and predicting actual states of exposure; (3) development of new methods to assess the impacts of ecosystem disturbance factors by using surveys, experiments, and model analysis; (4) systematization of chemical risk management and assessment of chemical kinetics and exposure; (5) development of methods for evaluating the health effects of microplastics and environmental pollutants such as PM2.5, and elucidation of the effect mechanisms; (6) new health impact assessment and mechanism elucidation considering multiple environmental factors, multiple diseases, and next-generation effects; (7) evaluation of biological effects on the cranial nervous system and elucidation of mechanisms; (8) development of a biomarker-based method for measuring lifetime exposure; and (9) elucidation of the health effects of environmental pollutants and environmental factors by using epidemiological methods and statistical analysis methods for epidemiological studies as a basis for the Japan Environment and Children's Study (JECS).

In our policy-oriented research, we intend to promote regulatory science research that is based on the latest scientific findings, including the results of our foresight and advanced basic research and our comprehensive environmental risk research program. We will contribute to environmental policy through these results and will promote our efforts as a reference laboratory.

Below are brief accounts of some of the important results of our research in FY 2021.

1. Foresight and Advanced Basic Research

1.1 Environmental properties of new POPs: Measuring and predicting the saturated vapor pressure of chlorinated paraffin congeners

Chlorinated paraffins (CPs) are highly complex mixtures of polychlorinated *n*-alkanes and have long been used in a variety of materials such as lubricants and plasticizers. Some CPs are considered persistent, bioaccumulative, and toxic and are listed as persistent organic pollutants (POPs) under the Stockholm Convention. CPs are made up of thousands of congeners with different molecular structures, and this makes it difficult to comprehend their environmental fate properties. In this

study, the saturated vapor pressure (P^*) of 35 congener groups ($C_{10–16}Cl_{4–11}$) of CPs was directly measured by using a gas saturation method (Fig. 1a). To our knowledge, these are the first ever experimental data on congener-group-specific values of P^*. Moreover, P^* values for CP congener groups were predicted by using the newly developed COSMO-RS (conductor-like screening model for real solvents)-trained fragment contribution method (FCM) (Endo and Hammer 2020; Endo 2021)[2),3)]. The predictions made by the COSMO-RS-trained FCM agreed well with the measured values (Fig. 1b). As the COSMO-RS-trained FCM can predict other partition properties, such as the octanol/water partition coefficient and Henry's law constant, without any additional calibration with experimental data, it can be useful to fill knowledge gaps regarding the environmental fate properties of CPs.

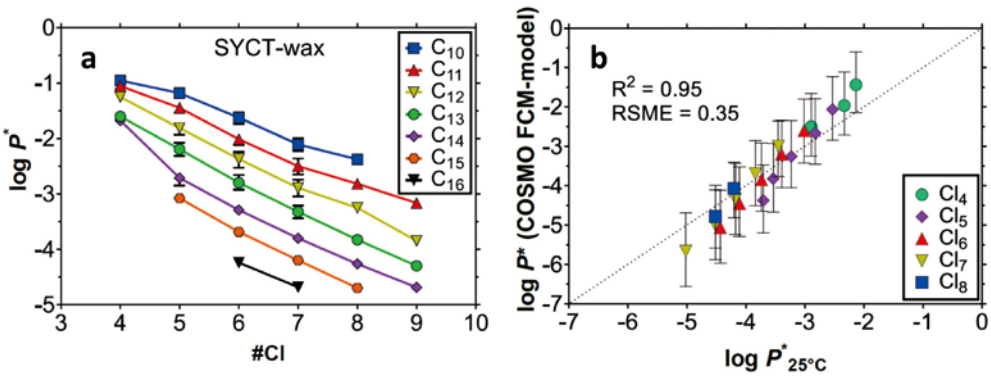


Fig. 1
Saturated vapor pressure (P^*), directly measured at 50 °C, of chlorinated paraffin congener groups (a), and comparison of measured P^* (25 °C) vs. values predicted from the COSMO-RS-trained FCM by Endo (2021) (b). (adapted from Hammer et al. 2021[1)], licensed under CC BY 4.0)

1.2 Development of sediment risk assessments for hydrophobic organic chemicals

Spiked-sediment toxicity tests (SSTTs) are used widely to assess the ecological risks of chemicals present in sediment. The sediment–water interface of SSTTs is a complex exposure system in which multiple uptake pathways by benthic organisms exist. We revealed that the test system was far from an equilibrium state: overlying water concentrations of hydrophobic organic chemicals (HOCs) changed over time, and a vertical concentration gradient existed at the sediment–water interface (Fig. 2 and Hiki et al. 2021)[4)]. Also, by using a passive sampling method, we found that there was a large gap between the freely dissolved (C_{free}) and total dissolved concentrations in pore water (i.e., the water phase in sediment), by a factor of up to 220, and that C_{free} in pore water was the most representative indicator of the toxicity of chlorpyrifos, as a model HOC, to the freshwater amphipod *Hyalella azteca*. These findings suggest that C_{free} measurements, which are rarely performed in SSTTs, can help us to interpret the results of SSTTs and thus refine sediment risk assessments.

In addition, we compared the existing data on SSTTs with water-only toxicity test data by applying the equilibrium partitioning theory, which uses C_{free} in pore water as the representative indicator of toxicity to benthic organisms. We found that the

species sensitivity distributions were not significantly different between two types of tests (Hiki et al. 2022)[5], indicating that C_{free} in pore water could be useful in sediment risk assessments in multiple taxa with a wide range of chemical sensitivities.

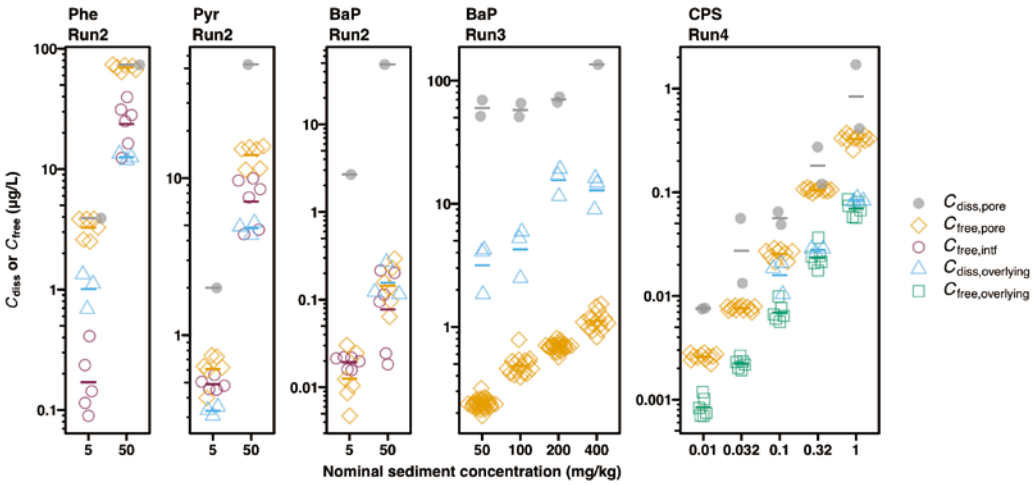


Fig. 2
Spatial concentration profile of phenanthrene (Phe), pyrene (Pyr), benzo[a]pyrene (BaP), and chlorpyrifos (CPS) as model hydrophobic organic chemicals in a spiked-sediment toxicity test. Different symbols represent different sampling positions and states (freely dissolved and total dissolved).
(Hiki et al. 2021, licensed under CC BY-NC-ND 4.0)

1.3 Effects of exposure to low-dose environmental chemicals in allergic diseases

We are using experimental animals to study the effects of exposure to low-dose environmental chemicals in allergic diseases. The use of organophosphorus flame retardants (OPFRs) as substitutes for brominated FRs has been increasing widely. Tris(1,3-dichloro-2-propyl)phosphate (TDCIPP) is a major additive OPFR and is therefore frequently detected in environmental media. TDCIPP can adversely affect human health; however, its impact on immune and allergic responses remains largely uncharacterized. We investigated the effects of dietary exposure to TDCIPP in allergic asthmatic mice. Male C3H/HeJSlc mice were fed a chow diet containing TDCIPP equivalent to 0.02 μg/kg/day (low, L), 0.2 μg/kg/day (medium, M), or 2 μg/kg/day (high, H) and were intratracheally administered ovalbumin (OVA, 1 μg/animal) every 2 weeks from 5 to 11 weeks of age. In OVA-treated mice, TDCIPP-H exposure tended to enhance pulmonary inflammation compared with vehicle exposure. In particular, lymphocyte accumulation in the lungs was more marked in the OVA+TDCIPP-H group than in the OVA and Vehicle groups (Fig. 3a). TDCIPP dose-dependently decreased the mRNA level of the G-protein-coupled estrogen receptor (*Gper*) in the lungs in the presence or absence of OVA (Fig. 3b). In the mediastinal lymph nodes, OVA+TDCIPP-H tended to increase the total cell number and promoted $CD4^+$ cell activation compared with OVA alone. In splenocytes, an increase in the fraction of regulatory B cells to total B cells and an increase in IL-5 in cell culture supernatants following OVA restimulation were observed in OVA+TDCIPP-H-treated mice compared with OVA-treated mice. These results suggested that dietary exposure to TDCIPP at a dose equivalent to the

tolerable daily intake level (2 μg/kg/day) slightly enhances allergic asthma via downregulation of the G-protein-coupled estrogen receptor at inflamed sites and by secondary lymphoid tissue alterations (Yanagisawa et al. 2021)[6]. We thank Taylor & Francis (https://www.tandfonline.com/) for granting us permission to use our article.

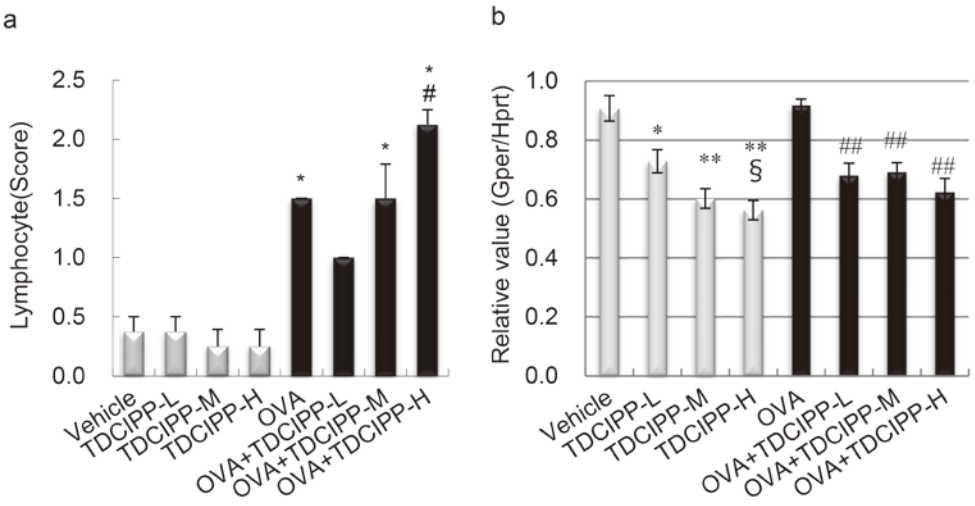


Fig. 3
Degree of accumulation of lymphocytes in the airways (a). Gene expression of G-protein-coupled estrogen receptor (*Gper*) in the lungs (b). Data are shown as means ± SE, n = 4 animals/group for (a) and n = 5 or 6 animals/group for (b). **P* < 0.05 vs. Vehicle group; ** *P* < 0.01 vs. Vehicle group; # *P* < 0.05 vs. OVA group; ## *P* < 0.01 vs. OVA group; § *P* < 0.05 vs. TDCIPP-L group. TDCIPP-L, 0.02 μg kg^{-1} day^{-1}; TDCIPP-M, 0.2 μg kg^{-1} day^{-1}; TDCIPP-H, 2 μg kg^{-1} day^{-1} (Yanagisawa et al. 2021; Figures are cited from the original)

1.4 Heatstroke prediction by machine learning

As average temperatures rise, so too does the chance of experiencing extremely hot days. Among the main hazards of high temperature and humidity is heatstroke, which can lead to central nervous system damage or even death. Although some previous studies have used weather information to develop prediction models for heat-related illnesses, they have not considered the degree of severity. A team of scientists led by the National Cerebral and Cardiovascular Center Research Institute, Kansai University, and NIES were able to predict the incidence of heatstroke in Japanese cities by using only publicly available information, such as demographics, weather forecasts, and time of year (Ogata et al. 2021)[7]. By using a hybrid machine-learning method that combined the best-performing generalized additive model (GAM) and an extreme-gradient-boosting decision tree (XGBoost), they were able to achieve a high level of accuracy (Fig. 4). The model can be used by public health officials to help plan for the risk of heatstroke cases, hospitalizations, and deaths. The team used machine-learning methods to predict the total number of heatstroke cases, hospital admissions, and deaths over a 12-h period in each of 16 Japanese cities. The team employed a hybrid model that combined the GAM curve-fitting and XGBoost decision-tree methods trained on historical data. The XGBoost method is a way of combining many weak predictions into a strong one. Here, the output of many decision trees—a kind of simple flow

chart—are grouped to make one highly accurate forecast. The other method, GAM, uses smooth spline functions to fit nonlinear data, such as the occurrence of heatstroke over the course of the year. The team also found that high temperature, a small change in maximum temperature between consecutive hot days, high solar radiation, and having a large population of people aged 65 years and older were associated with greater risk.

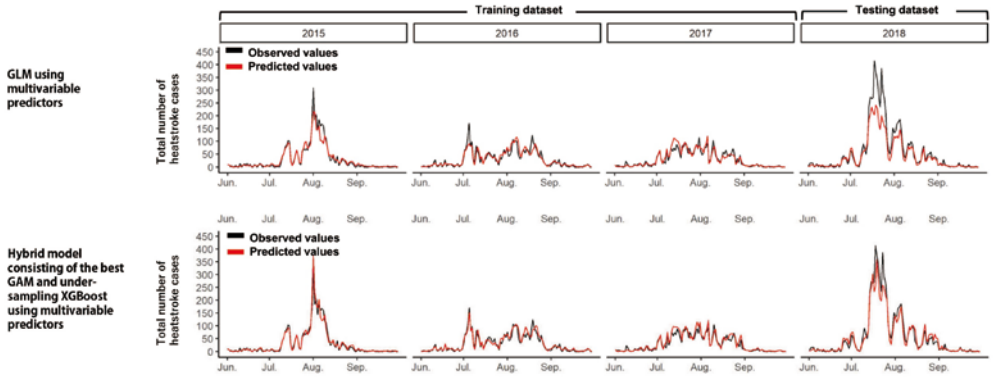


Fig. 4
Comparison between observed and predicted numbers of heatstroke cases from June to September in 2015, 2016 and 2017 (i.e., training dataset) and in 2018 (i.e., testing dataset) by using GLM and a hybrid model consisting of the best GAM and an under-sampling XGBoost. Black lines indicate the observed total number of heatstroke cases per day in 16 Japanese cities, and the red lines indicate the predicted total number of heat stroke cases per day in the 16 cities. (Ogata et al. 2021, licensed under CC BY 4.0; this figure is a partial modification of the original)

Reference:

1) Hammer J., Matsukami H., Kuramochi H., Endo S. (2021) Direct measurements and modeling of congener group specific vapor pressure for chlorinated paraffins. *Chemosphere*, 281, 130909; licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/)

2) Endo S., Hammer J., (2020) Predicting Partition Coefficients of Short-Chain Chlorinated Paraffin Congeners by COSMO-RS-Trained Fragment Contribution Models. *Environmental Science & Technology*, 54, 15162-15169.

3) Endo S. (2021) Refinement and extension of COSMO-RS-trained fragment contribution models for predicting the partition properties of C10-20 chlorinated paraffin congeners. *Environmental Science: Processes & Impacts*, 23, 831-843.

4) Hiki K., Fischer F., Nishimori T., Watanabe H., Yamamoto H., Endo S. (2021) Spatiotemporal distribution of hydrophobic organic contaminants in spiked-sediment toxicity tests: Measuring total and freely dissolved concentrations in porewater and overlying water. *Environmental Toxicology and Chemistry*, 40(11):3148–3158. doi:10.1002/etc.5199; licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc-nd/4.0/)

5) Hiki K., Iwasaki Y., Watanabe H., Yamamoto H. (2022) Comparison of species sensitivity distributions for sediment-associated nonionic organic chemicals

through equilibrium partitioning theory and spiked-sediment toxicity tests with invertebrates. *Environmental Toxicology and Chemistry* 41(2):462-473. doi:10.1002/etc.5199; licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc-nd/4.0/)

6) Yanagisawa R., Koike E., Tin-Tin-Win-Shwe, Kawaguchi M., Takano H. (2021) Impact of dietary exposure to low-dose tris(1,3-dichloro-2-propyl)phosphate in allergic asthmatic mice. *Immunopharmacology and Immunotoxicology*, 13, 1–12. doi:10.1080/08923973.2021.1959609.

7) Ogata S., Takegami M., Ozaki T., Nakashima T., Onozuka D., Murata S., Nakaoku Y., Suzuki K., Hagihara A., Noguchi T., Iihara K., Kitazume K., Morioka T., Yamazaki S., Yoshida T., Yamagata Y., Nishimura K. (2021) Heatstroke predictions by machine learning, weather information, and an all-population registry for 12-hour heatstroke alerts. *Nature Communications*, 12(1):4575. doi:10.1038/s41467-021-24823-0. PMID: 34321480; PMCID: PMC8319225; licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/)

2. Policy-Oriented Research

2.1 Severity classification of clinical signs and defining the moribund state as an experimental endpoint for acute toxicity testing in Japanese medaka, *Oryzias latipes*

Test guideline 203 (TG203) of the Organisation for Economic Co-operation and Development (OECD) is one of the most commonly used test methods for assessing the acute toxicity of chemicals in fish. However, this approach likely causes unnecessary suffering of the fish in the time before death. In recent years, it has been concluded that, although fishes' experience of pain is not similar to that of humans, they do experience noxious stimuli that have a detrimental effect on their behavior, physiology, and wellbeing; therefore, it has been proposed that fish should be treated in a humane manner when used as laboratory animals. The moribund state typically implies a severely debilitated state that precedes imminent death. However, use of the moribund state as an endpoint for acute toxicity testing in fish is complicated by a lack of consensus about the sublethal signs that define the state. To establish a criterion for defining the moribund state in Japanese medaka, we determined the death to clinical-sign ratio (D/C ratio), defined as the proportion of fish with each clinical sign that transitioned to imminent death, for 13 clinical signs in individually housed fish (Yamagishi et al. 2021). Also, the time from onset of each clinical sign to transition to imminent death was determined by continuous monitoring. Three of the observed clinical signs—immobility, lethargy, and immobility at the surface—were found to be indicators of the moribund state, with each of these signs having a D/C ratio of 1.0 (Fig. 5). Evaluation of the survival time after onset of the other 10 signs enabled us to determine whether timely

euthanasia would be appropriate, thereby providing a means of reducing the suffering of laboratory fish in the period before death (Fig. 5).

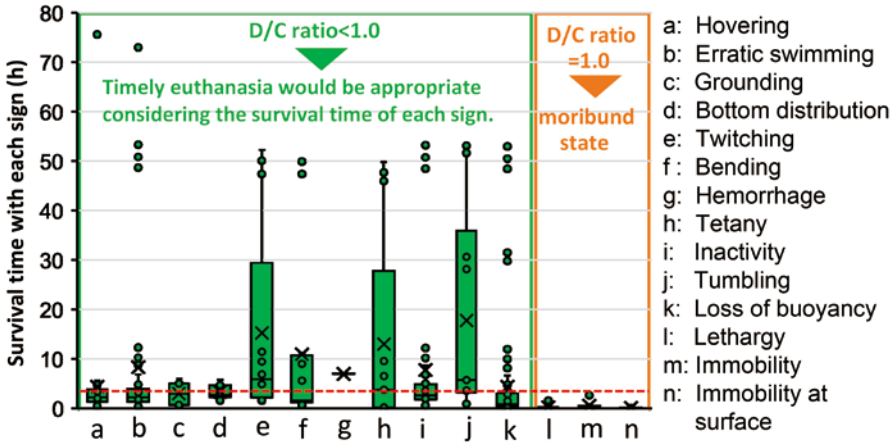


Fig. 5
Box plots showing the survival time after onset of each clinical sign. Boxes indicate the interquartile range; whiskers indicate the minimum and maximum survival times. Open circles and crosses indicate data points and mean values, respectively. Dashed line indicates a survival time of 3 h.

Reference:

Yamagishi T., Kawano M., Watanabe H., Yagi A., Shintaku Y., Ohno K., Yamamoto H. (2021) Severity-classification of clinical signs and defining the moribund state as an experimental endpoint for acute toxicity testing using Japanese medaka *Oryzias latipes*. *Environmental Toxicology and Chemistry*, 41, 1089–1095.

Regional Environment Conservation Domain

Human activities have a substantial impact on both human life and ecosystems through environmental media such as the atmosphere, water, and soil. To minimize the environmental impacts of human activities, the Regional Environment Conservation Division has been studying the dynamics and effects of substances in each medium; developing new measurement and analysis methods; and investigating environmental restoration, regeneration, and conservation technologies at various spatial scales, from cities to Asia-wide. Furthermore, in cooperation with local environmental research institutes, we are promoting research on environmental management technologies suitable for each region. Our aim is to achieve comprehensive regional environment conservation.

This Division consists of six sections (Regional Atmospheric Modeling, Regional Atmosphere Research, Lake and River, Marine Environment, Soil Environment, and Environmental Management and Technology) and has one PrincipalResearcher.

In FY 2021, we implemented many research projects covering a wide range of regional environmental issues. Most of the projects are collaborations with other NIES divisions. Our main research projects in **Foresight and Advanced Basic Research** were as follows:

- Development of a methodology to forecast global air pollution by assimilating high-resolution spatiotemporal measurements
- Restoration of coastal habitats in a brackish lagoon by using local knowledge in a case study in the Kugushi-ko lagoon (Fukui Prefecture, western Japan)

We have also developed an air-pollution-simulation support system and measured oxygen consumption in the bottom layer of Lake Biwa as part of **Policy-Oriented Research**. Additionally, there are two long-term monitoring programs as part of **Intellectual Research Infrastructure Development**, namely the Regional Atmospheric Monitoring Program, which monitors the air quality in East Asia at Okinawa and Nagasaki, and the Global Environment Monitoring System (GEMS)/Water Program in Lake Kasumigaura, which is a collaboration with the Biodiversity Division. In the following section, we briefly describe some of the important results in FY 2021.

1. Foresight and Advanced Basic Research

1.1 Development of a methodology to forecast global air pollution by assimilating high-resolution spatiotemporal measurements

To forecast the spatiotemporal distribution of air pollution more accurately at global to regional scales, we have developed an air-pollution-transport model, NICAM-Chem. This year, we ran the NICAM-Chem model to simulate short-lived gases and

aerosols with a high-resolution (56 km) grid spacing on a global scale. The horizontal resolution is the world's finest among global air-pollution-transport models. We validated the global NICAM-Chem simulation by comparing the simulated surface total oxidant (Ox) and aerosol optical thickness (AOT) with in-situ measurements of the Global Atmosphere Watch (GAW)/World Meteorological Organization (WMO), the Acid Deposition Monitoring Network in East Asia (EANET), the European Monitoring and Evaluation Programme (EMEP), and the Aerosol Robotic Network (AERONET) (Fig. 1). We found that the NICAM-Chem simulated Ox and AOT values were generally closer to the observations and other global numerical models, but the slight overestimation of Ox at the surface needs improvement. We also validated the global NICAM-Chem simulation by comparing the simulated NO_2 in column loading with the results retrieved from TROPOMI (TROPOspheric Monitoring Instrument). We found that the simulated NO_2 was overestimated in urban areas and underestimated over oceans compared with the TROPOMI results. These findings are helping us to further develop the NICAM-Chem model.

In parallel, we have developed a Localized Ensemble Transform Kalman Filter (LETKF) coupled to an aerosol module in NICAM-Chem to reproduce realistically the spatiotemporal distribution of air pollution. This year, to further improve the assimilated results, we used the AOT product retrieved as version 2 from the Global Change Observation Mission–Climate change observations satellite (GCOM-C)/Second-generation Global Imager (SGLI), which was launched in December 2017. We compared the extinction coefficients of the assimilated aerosol with the results measured by the Asian dust and aerosol lidar observation network (AD-net) , which is operated mainly by NIES. We found that the assimilated results with two-dimensional aerosol products (i.e., AOT) retrieved from the satellite were generally close to the observed results with three-dimensional aerosol products measured by the AD-net. These results were published in a paper (Cheng et al. 2021) [1].

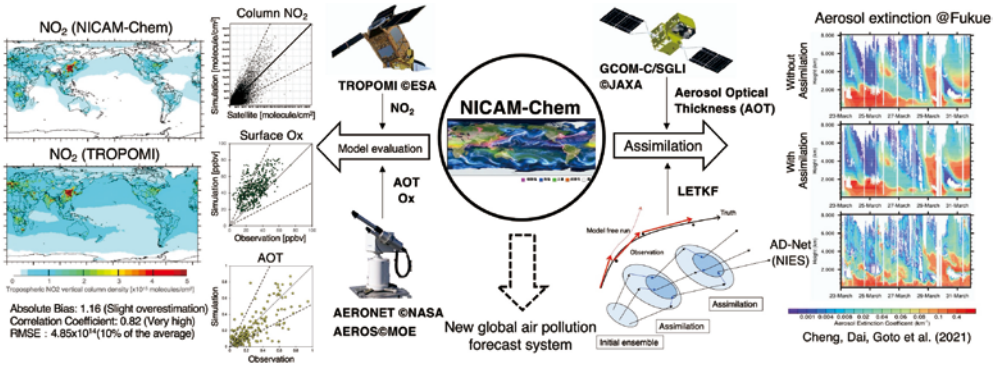


Fig. 1 Summary of model evaluation and application of data assimilation using an air-pollution-transport model (NICAM-Chem)

1.2 Restoration of coastal habitats in a brackish lagoon by using local knowledge: a case study in the Kugushi-ko lagoon (Fukui Prefecture, western Japan)

The coastal shallows in the Kugushi-ko lagoon (Fukui Prefecture, western Japan), were restored in the late 2000s to mitigate the reclaimed coastal habitats. Two different methods were used: sand nourishment (SN, at stations SN1 and SN2), which is commonly used worldwide, and natural deposition (ND, at station ND), which facilitates the deposition of river-derived sediments through the installation of jetties in accordance with local knowledge in the region. In this study, about 10 years after the restoration, we compared the habitat characteristics and benthic community structure among the three stations as habitats for benthic animals, including the commercial Shijimi clam, *Corbicula japonica*.

At the ND site, the macrozoobenthic community was dominated by Shijimi clams and reed-associated snails, including *Assiminea japonica*, linked to a significantly higher total macrozoobenthos density than at the SN sites (Fig. 2). The ND site was characterized by the remarkable recovery of reedy vegetation and the deposition of finer-grained sediment in front of the reed marsh, resulting in the formation of wide areas of shallow sandy flat near the river mouth.

These results suggest that use of the ND method likely restored the reed-vegetated shallow habitats characterizing the macrozoobenthic community structure, and that local-knowledge-based habitat restoration practices may offer new options for restoration programs in estuarine and coastal seas.

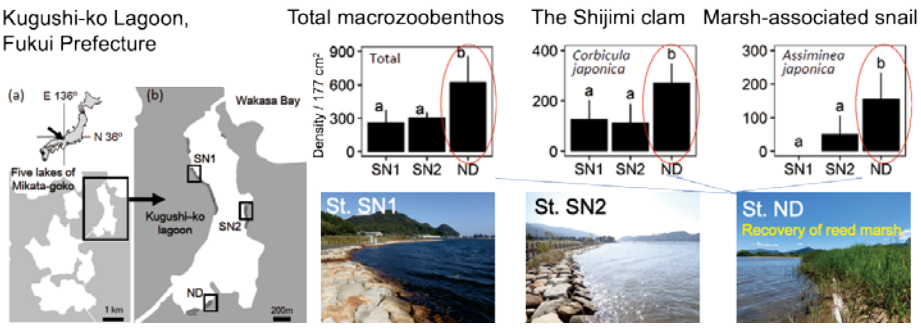


Fig. 2 Habitat restoration conducted in the Kugushi-ko lagoon (Fukui Prefecture, western Japan) (a, b) by using sand nourishment (SN) and traditional natural deposition (ND) methods. Densities of total macrozoobenthos, the Shijimi clam, *Corbicula japonica*, and the marsh-associated snail *Assiminea japonica* at the stations are shown. Bars indicate SD (n = 6). Different letters indicate significant differences among sites ($P < 0.05$, Tukey-Kramer test). Data are from Miyamoto et al. (2022) [2]. St, station

2. Intellectual Research Infrastructure Development

2.1 Long-term monitoring of the atmospheric environment in the east Asian region

Long-term monitoring of atmospheric pollutants, including aerosols and gaseous species, has been conducted by our Division 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.

A long-term trend in the aerosol optical depth (AOD) of spherical particles was confirmed by the continuous lidar observation at Fukuejima. Figure 3 (left panel) indicates that the AOD decreased gradually from 2007 to 2017. Other apparent changes were found in the chemical components of aerosols detected at Fukuejima in spring (Fig. 3, right panel). Between 2016 and 2019 the concentration of sulfate decreased and that of nitrate increased. However, different characteristics of chemical balance (low nitrate) were found in 2020 and 2021; dramatic changes in emissions were expected in the region upwind of the monitoring station, including in China, as a result of the COVID-19 pandemic.

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 transboundary 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 (https://www.nies.go.jp/asia/hedomisaki/home-e.html).

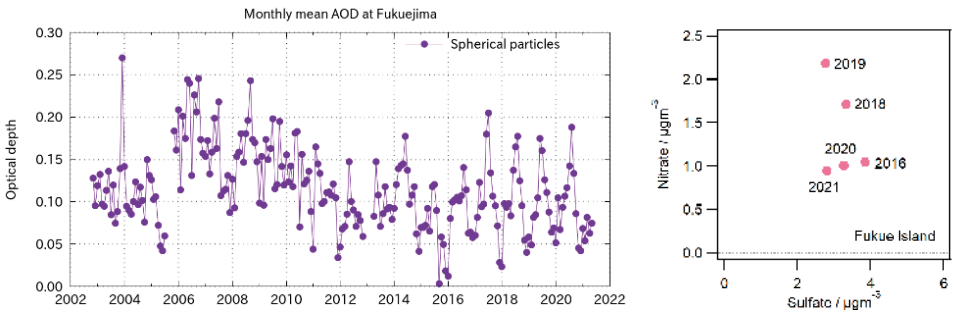


Fig. 3 (left) Monthly mean optical depth of spherical particles detected by Mie-scattering lidar at Fukuejima. (right) Seasonal mean mass concentrations of sulfate and nitrate in spring at Fukuejima.

Reference:

1) Cheng Y., Dai T., Goto D., Murakami H., Yoshida M., Shi G.Y., Nakajima T. (2021) Enhanced simulation of an Asian dust storm by assimilating GCOM-C observations. *Remote Sensing*, 13 (15), 3020

2) Miyamoto Y, Kanaya G, Taru M, Yoshida T (2022) Spatial changes in a macrozoobenthic community depend on restoration methods in historically squeezed coasts in a brackish lagoon. *Ecological Research*, 37: 115–126

Biodiversity Domain

We intend to conduct surveys and research on the structure, functions, and relationships of ecosystems, which consist of diverse organisms on the Earth and their surrounding environment, and on the benefits that humans receive from ecosystems. We will also clarify and evaluate the impacts and risks that human activities impose on biodiversity and ecosystems at various spatial and temporal scales.

In our **Foresight and Advanced Basic Research**, we will promote research aimed at developing new technologies with future development potential and proactive responses to possible future problems. In our **Policy-Oriented Research**, we will contribute to the Convention on Biological Diversity and the policies of national and local governments through biodiversity assessment and indexing, and by proposing conservation methods. In our **Intellectual Research Infrastructure Development**, the Division will contribute to the conservation and sustainable use of biodiversity both within and outside the Institute by building and maintaining internal and external research infrastructure, including preserving biological samples, monitoring, analysis support, and database development.

1. Foresight and Advanced Basic Research

The current extinction crisis demands worldwide commitment to conservation across all sectors of society. By transcending the traditional disciplinary boundaries, conservationists can reach new audiences to communicate pro-conservation knowledge, education, and awareness messages. There are approximately 2.7 billion video-gamers worldwide, with millions more joining as a result of global lockdowns. In March 2020, Animal Crossing: New Horizons was released by Nintendo and fast became the second-best-selling video game ever in Japan, selling over 26.4 million units worldwide. Unlike many popular video games, it has a unique premise that involves players creating an island, growing vegetation, catching wildlife, and donating fossils and species to a museum. The game has been praised for its positivity, escapism, and measurable benefits to mental well-being. We explored how different features of the game, including the islands, their biodiversity, and their inhabitants, encourage players to exhibit pro-conservation behaviors and attitudes (e.g., recycling litter or planting a diversity of flowers). They also improve players' knowledge about the diversity of relatively little known taxa (marine and freshwater fishes and invertebrates; see Fig. 1). We also highlighted where pitfalls in the game exist (e.g. encouraging the collection of threatened species). We principally framed these discussions in the context of Japan's cultural relationship with the natural world, including its history of insect-collecting and its management of green spaces. We concluded by outlining some recommendations about potential improvements to future releases, or for similar games, that could further promote conservation messaging.

This perspective sheds light on the avenues through which Animal Crossing: New Horizons encourages the pro-conservation knowledge, attitudes, and behaviors of its international players, with potential for these experiences to be translated into real-world conservation actions. During a critical time in humanity's history, video-gaming could provide a huge opportunity for communicating conservation messages to billions of people worldwide.

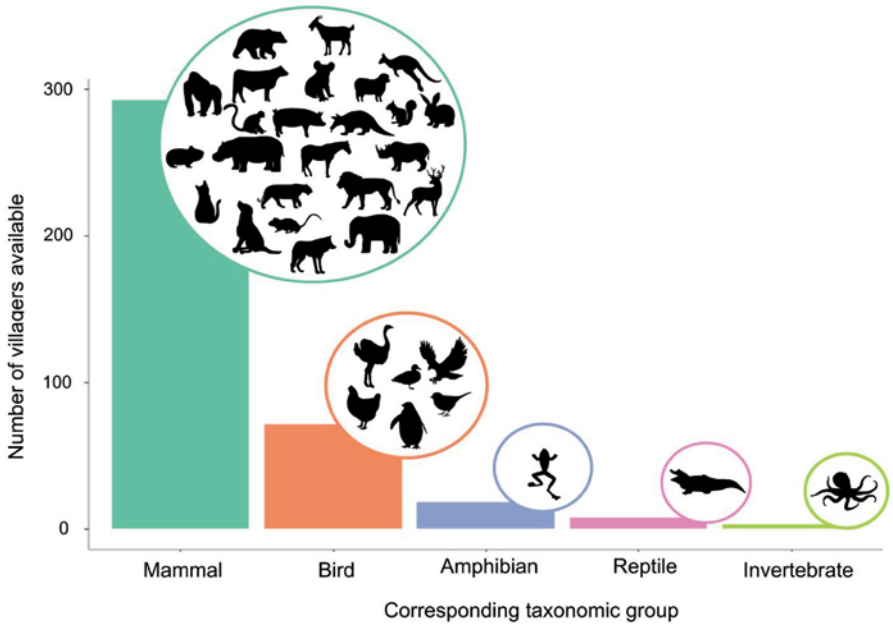


Fig. 1 Overall numbers of villagers available in Animal Crossing: New Horizons, by taxa. The variety within each taxonomic group is demonstrated by the corresponding silhouettes, for example, all amphibian villagers in the game are frogs.

2. Policy-Oriented Research

Environmental DNA (eDNA) metabarcoding has become widely applied to the gauging of biodiversity in a non-invasive and cost-efficient manner. The detection of species by using eDNA metabarcoding is, however, imperfect owing to various factors that can cause false negatives in the inherent multistage workflow. To remedy this issue, we developed a novel statistical model for eDNA metabarcoding studies that account for false-negative errors in species detection. The model allows us to analyze the sources of variation in the detectability of species throughout the different stages of the workflow. It also enables us to study species distribution and diversity in an error-tolerant manner and to optimize study designs (Fig. 2). Application of the proposed model to freshwater fish communities in the Lake Kasumigaura watershed highlighted a marked inhomogeneity in the detectability of species, indicating a potential risk of the biased detection of specific species in eDNA metabarcoding. Our findings also suggested that, to achieve better species detection, ensuring multiple within-site replications of the environmental samples is preferable. The proposed method was used in a project of the Biodiversity Center of Japan to standardize eDNA technology and helped in the revision of their manual on eDNA surveys for ecosystem investigators.

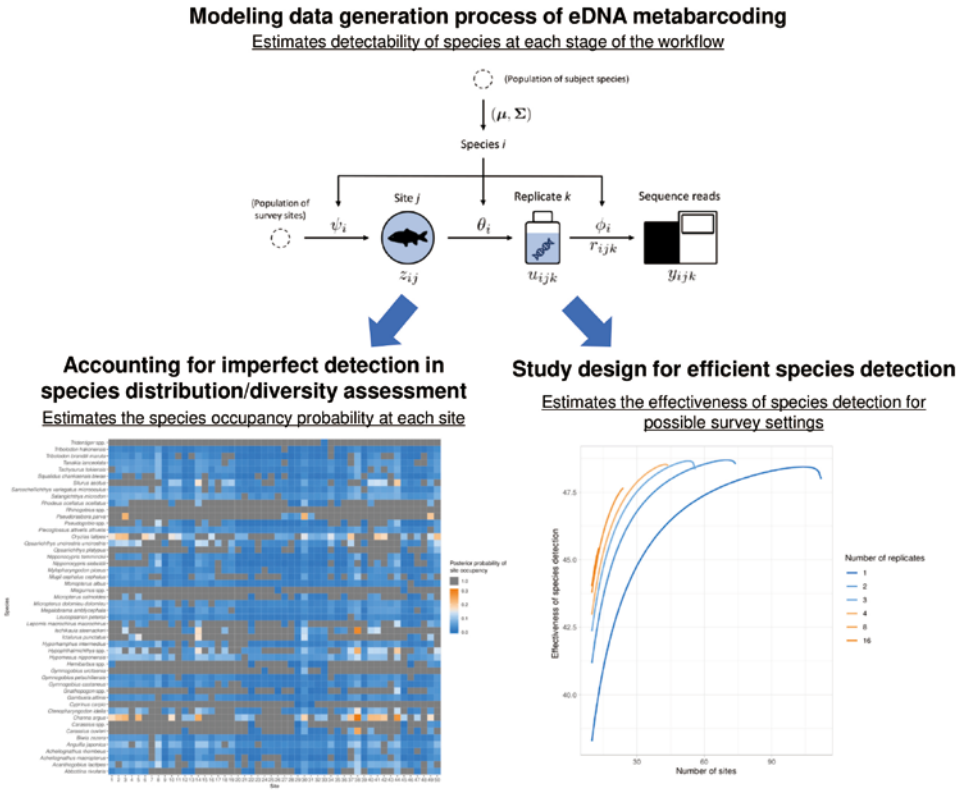


Fig. 2 Overview of the proposed method of accounting for false negative errors in species detection in eDNA metabarcoding

3. Intellectual Research Infrastructure Development

To help us understand the current status of lead contamination in raptors, 74 raptor liver samples were collected from all over Japan. These liver samples included those cryopreserved at NIES, as well as samples collected with the cooperation of the Institute for Raptor Biomedicine Japan, Hokkaido University, Tottori University, and Ehime University. Lead concentrations exceeding 0.6 mg/kg dry weight were detected in three peregrine falcons, two black kites, and one northern goshawk (Fig. 3), indicating that lead contamination occurs in raptors distributed in Honshu. In light of these results, the Ministry of the Environment announced that lead bullets will be progressively regulated in Honshu starting in 2025.

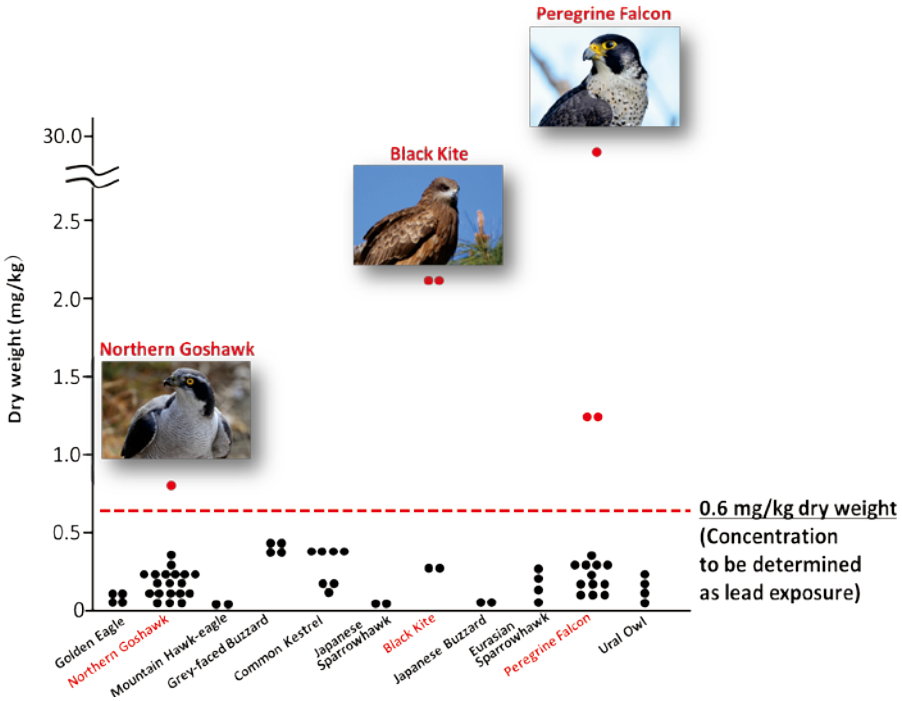


Fig. 3 Lead accumulation in the livers of raptors

Social Systems Domain

The Social Systems Division addresses the challenges of social systems to achieve the future vision that human socioeconomic activities—the root cause of our environmental problems—will be sustainable for both the environment and human society. We are conducting research to support the transition to sustainable social systems, including developing theories and methodologies such as those related to mathematical models, as well as social surveys that take an integrated approach to examining the relationship between socioeconomic human activities and various environmental issues. We are also developing scenarios and roadmaps to achieve a vision for a sustainable society that harmonizes the environment and the economy, and we are proposing specific measures and policies in collaboration with stakeholders.

The Social Systems Division consists of the following five research sections:
Global Sustainability Integrated Assessment Section: Develops integrated models to assess various comprehensive issues on a global scale to achieve global sustainability for society and the environment.
Decarbonization Measures Assessment Section: Develops models and databases for assessing decarbonization initiatives to tackle climate change problems.
System Innovation Section: Studies the sustainable use of energy and resources, including the development of measures for substantially improving their utilization efficiencies.
Regional Planning Section: Studies lifestyle and regional planning to balance the environment and quality of life in urban and rural communities.
Economics and Policy Studies Section: Performs environmental policy assessments and theoretical research on environmental evaluation and methodological developments in the field of economics.

Researchers in the Social Systems Division are engaged mainly in the Decarbonized and Sustainable Society Research Program and the Co-design Approach for Local Sustainability Research Program.

1. Foresight and Advanced Basic Research

In FY 2021, the Social Systems Division conducted the following research activities as Foresight and Advanced Basic Research to improve the relationship between socioeconomic activities and the environment from the global scale to the local scale.

1.1 Transitions of food type and nutrition disparity in global regions

Food is one of the core elements of human activities and affects many areas, such as land-use change, the economy, and greenhouse gas (GHG) emissions. To assess

future food transitions, first it is important to understand food transitions from the past to the present. We constructed a food and socioeconomic database for the period from 1961 to 2013 and analyzed food transitions, focusing on 71 major food commodities out of 103 as indicators of caloric and protein supply, for 203 countries listed in FAOSTAT (the Food and Agriculture Organization Corporate Statistical Database). To analyze the characteristics of food transitions in different climate zones and in areas with cultural and socioeconomic differences, we selected 36 major countries covering five continents of the world. Next, we evaluated the relationship between per capita protein supply, calorie supply, and gross domestic product (GDP) in those countries. Figure 1 shows the relationship among GDP per capita, protein supply per capita, and the shares of food types as indicators of food commodity transitions and percentages. The characteristics of the main food items of protein and calorie supply tended to vary by country. In particular, the trend of the meat diet differed according to differences in living standards, as indicated by GDP per capita. Protein supply from fish products and rice was major in the Asian region, whereas protein supply from meat was major in Europe, North America, and South America. China, Korea, and some other countries are westernizing their diets (becoming meat-eaters) as their economic wealth per capita increases.

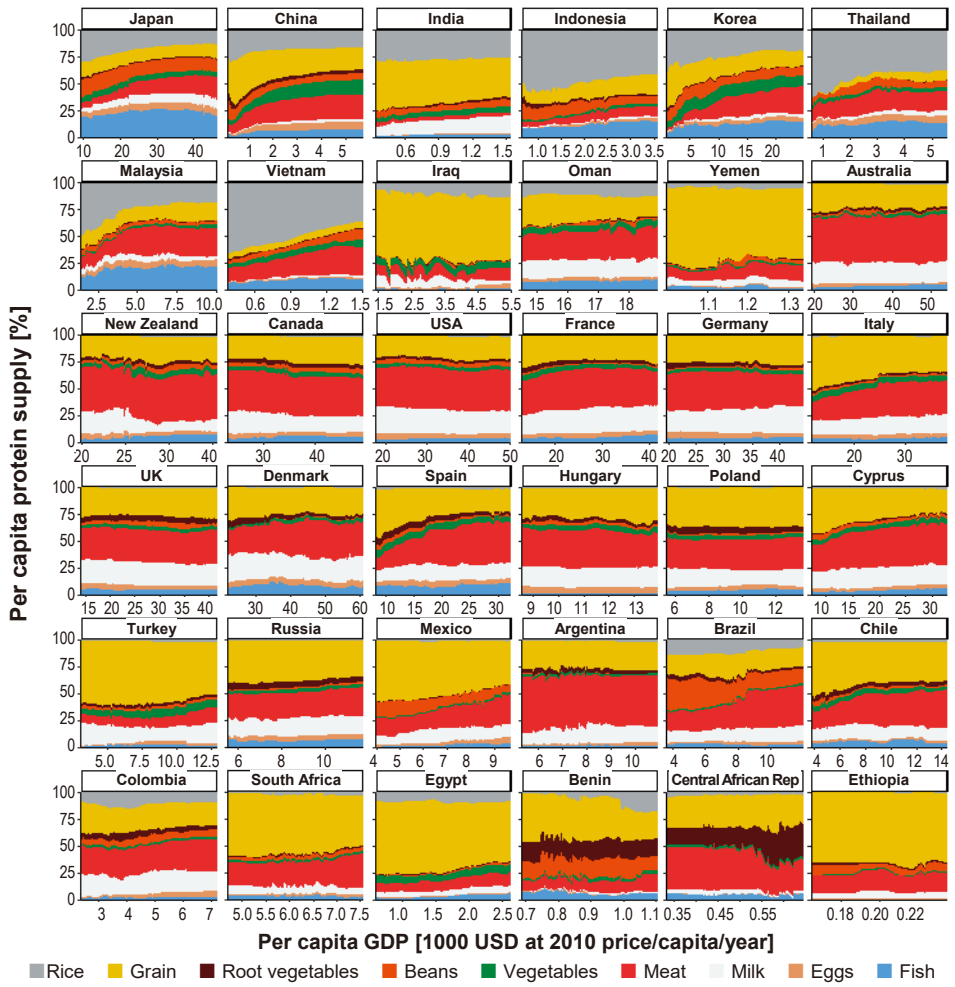


Fig. 1 Relationships among GDP per capita, protein supply per capita, and the share of food types

1.2 Is "urban to rural migration" key to a sustainable society?

The world pandemic of COVID-19 has enhanced urban to rural migration in both developed and developing countries. Through 6 years of participant observations of "community-reactivating" activities and dialogues with stakeholders as informants around the town of Tatsuno, in Nagano Prefecture, we formulated a diagram of community reactivation (Fig. 2) and studied differences in "thoughts and attitudes" between the original local residents and stakeholders (e.g. typical active newcomers) who frequently broadcast information about their activities through the Internet media. The businesses run by these newcomers are mostly small-scale merchandising, cafes, and accommodation enterprises. However, they are too dependent on remote customers in metropolitan areas and are often divorced from local needs. The newcomers' daily exchanges are almost exclusively among themselves, and the activities that they disseminate are not well known to the original residents. Whereas the original local residents tend to want "improvement of convenience," the newcomers from the big cities tend to seek "happiness despite inconvenience" and identities that they build by themselves as opposed to those created in a community. The latter therefore have a different perspective on achieving their independent dreams. Not only the enhancement of migration itself, but also increasing the "relationship population" (defined as the "third population located between the exchange population and the settled population"), may bring economic effects, additional migration, and start-ups in the future. However, such polarization and segmentation will complicate the local autonomy. During this field survey, NIES provided some environmental data for local stakeholders.

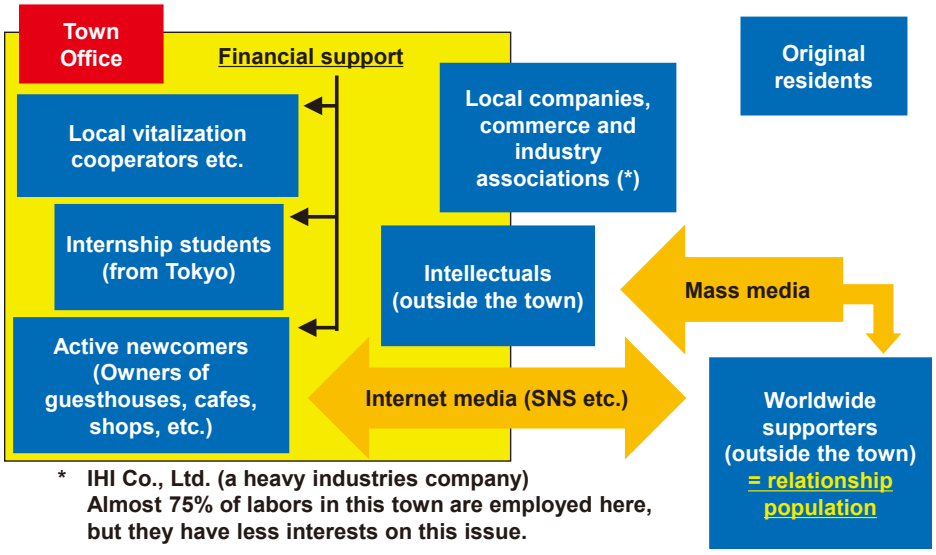


Fig. 2 Diagram of "Community-Reactivation" from the perspective of financial policy. SNS, social networking service

1.3 Analysis of electricity consumption patterns in NIES

To achieve decarbonization by 2050, NIES will lead our society through its research outcomes, as well as by taking the lead in energy-saving actions in its own activities. As a first step toward a decarbonized NIES, we collected about 450 points of

hourly-basis electricity consumption data on the Tsukuba Headquarters of NIES (Fig. 3), and we analyzed characteristics of the data for both the entire headquarters and each research building. We also investigated possible options for the decarbonization of NIES; energy saving actions such as replacement of facilities with efficient ones and decentralization of the energy supply are crucial. Installation of photovoltaics in open areas at headquarters and on its surrounding agricultural land will be an important measure to reduce GHG emissions from energy use at NIES.

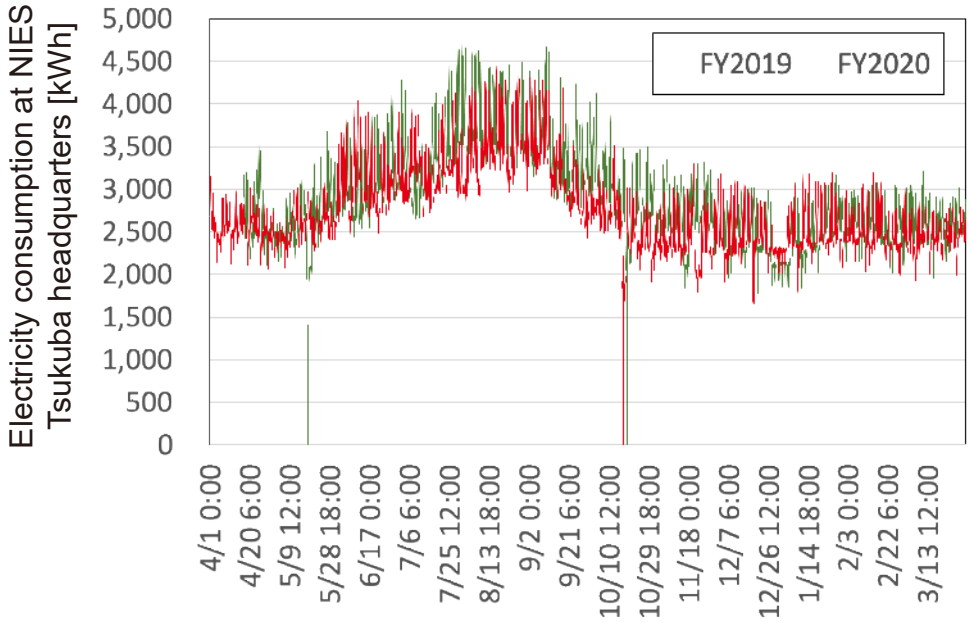


Fig. 3 Electricity consumption patterns for the whole of the NIES Tsukuba headquarters

1.4 Research on the media and public opinion

The mass media is a powerful communication tool and is known as an agenda-setting feature. It tells people "what to think about" and "how to think," and it amplifies or attenuates important social facts, with a gatekeeping function in which the media "select" events to be known by the public. We analyzed the changes in the numbers of articles in the major newspapers in Japan, as well as the effects of these changes in raising public awareness (Fig. 4). We had two types of data. One was the monthly newspaper coverage data extracted by using the keywords "climate change," "global warming," and "greenhouse effect" from the three newspapers with the highest circulation rates in Japan. We joined the international project MeCCO (Media and Climate Change Observatory) for this part. MeCCO monitors 120 sources (across newspapers, radio, and TV) in 54 countries in seven different regions around the world. Joining this project enabled us to compare Japanese mass media coverage with that of other countries or regions. The second type of data was public opinion data. A monthly poll of a population of 1500 randomly selected adults in Japan (with 900 to 1200 respondents per poll) addressed two questionnaires, namely "What is the most important issue in Japan?" and "What is

the most important issue in the world?" The questions were open-ended and after-coded by the NIES researcher who is in charge of this theme. We concluded that the mass media seems to affect the public's perception of the importance of climate change issues, especially in regard to what to think about, although we need to further look at the "how to think" and "gatekeeping" roles of the mass media.

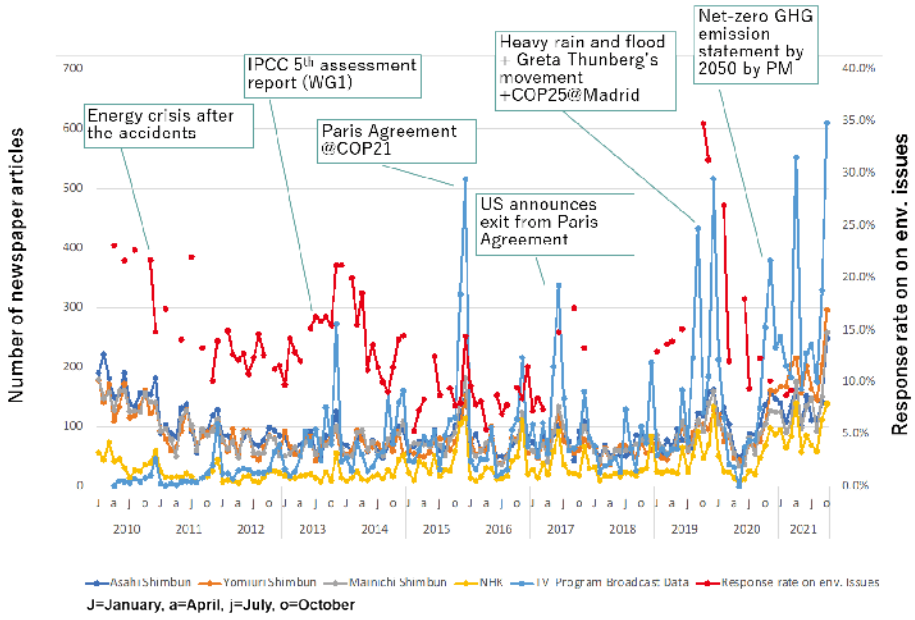


Fig. 4 Monthly media coverage of "Global warming," "climate change," and "greenhouse effect," and response rates regarding environmental issues, from 2010 to 2021. PM, Prime Minister; WG, Working Group; COP, Conference of the Parties

1.5 Evaluation of environmental consciousness and subjective well-being

We are also studying the principles behind environmental conservation, such as individual values and behavior change, consideration for future generations, and the relationship between economic efficiency and social fairness. For example, with regards to subjective well-being (SWB), we investigated the relationship between consumption and SWB in urban and rural areas in a developing-country context. We applied generalized additive models, which allow a non-linear functional form, to original data collected from Vietnam. Our results showed that any further increase in material consumption will not further increase SWB in urban areas, whereas there might be a negative relationship between material consumption and SWB in rural areas.

To enhance our understanding of the values associated with environmental issues, we also started an investigation of the environmental consciousness of Japanese people over time, by using a questionnaire based on academic theory. Although the NEP (New Environmental Paradigm; Dunlap and Van Liere, J Environ Educ 1978, 9:10–19) framework for measuring people's environmental consciousness on multiple scales is well known from those authors' leading study on environmental consciousness, it does not include new perspectives such as transitions, the Anthropocene, and intergenerational equilibrium. In FY 2021, by adding these new

perspectives, we constructed a new framework for considering environmental issues after the 2020s, and we created a questionnaire based on the framework. We are preparing to perform a survey aimed at measuring environmental consciousness.

2. Policy-Oriented Research

As Policy-Oriented Research, on 3 and 4 October 2021, the Social Systems Division organized a training workshop on 1) Climate Policy and Models, 2) AIM (Asia-Pacific Integrated Model) as a tool to assess climate change mitigation policy, and 3) Various tools for climate change impact and adaptation assessment, in collaboration with LoCARNet (Low-Carbon Asia Research Network) and the CCCA (Center for Climate Change Adaptation) of NIES. Eighty-eight participants attended from Asian and Oceanian Island countries.

For capacity development related to development of the AIM, the workshop usually takes 1 to 2 weeks per model, but because of the limited time and the need to communicate online owing to Covid-19, the content was not focused on computer programming for established researchers but instead it was a general discussion on the model for policy-makers and young researchers. The lectures covered the role of models for assessing climate mitigation policies and the input/output information required for ExSS (Extended Snapshot Tool), AIM/Enduse (technology selection model), and AIM/CGE (computable general equilibrium model; an economic model). In addition, various tools (AP-PLAT, ClimoCast, Climate Impact Viewer, and H08 Water Risk Tool) developed at the CCCA were introduced.

In FY 2021, Indonesia and Thailand submitted their long-term strategies to the UNFCCC (United Nations Framework Convention on Climate Change). At the time the strategies were prepared, the researchers in these countries provided the results of simulations performed by using the AIM. Such contributions are the goal of Policy-Oriented Research in this Division.

3. Intellectual Research Infrastructure Development

As Intellectual Research Infrastructure Development, we updated the Tsukuba Science City Landscape Photograph Archives. In the past, landscape photos taken at 70 locations in Tsukuba Science City in 1980, 1991, and 2006 were provided as an archive to record changes in the city. In 2021—15 years after the last photograph was taken—additional landscape photographs were taken at the same 70 points. These were republished as foundational information to document the changes over the 41 years (Fig. 5). The changes that can be seen include the formation of shade by the growth of trees, the restoration of views by the cutting-down of rows of trees, and the redevelopment of buildings and roads. It is hoped that this information will contribute to our understanding of landscapes lost in the past and landscapes expected to be preserved in the future, as well as to the study of landscapes that should be protected in the present.

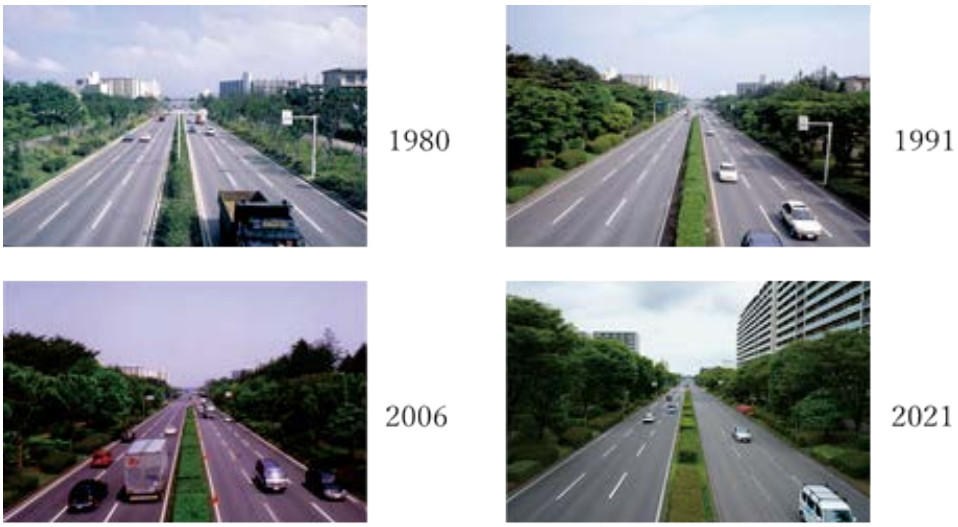


Fig. 5 Example of landscape change (Photo #16, Takezono South Pedestrian Bridge, Takezono 2-chome).
Trees on the main street have grown taller. A high-rise apartment building has been built on the right.

Environmental Emergency and Resilience Research Domain

Much empirical knowledge has been obtained from large-scale disasters such as the Great East Japan Earthquake, including the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant (FDNPP). Studying environmental emergency and resilience studies, we intend to use this knowledge to promote research and surveys to understand and evaluate the actual medium- and long-term environmental impacts in the disaster area. We will also conduct practical research for post-disaster environmental reconstruction in collaboration with the local community, as well as other research that will build strong and sustainable communities in preparation for future large-scale disasters. Specifically, as a continuing issue from NIES's Fourth Five-Year Plan, we aim to solve technical issues such as disaster waste disposal and establish a technical support framework to further improve disaster environmental management capabilities. Similarly, we will further investigate and gain an understanding of the process of environmental recovery from nuclear disasters, and we will conduct strategic monitoring research that will resolve the issues that have become obstacles to revitalization. As a new initiative of the Fifth Five-Year Plan, we intend to establish a comprehensive environmental management approach to prepare for future nuclear disasters from certain environmental perspectives. Similarly, we aim to support local governments in Fukushima Prefecture in formulating environmental policies. Furthermore, we will build a system to promote regional cooperation that contributes to environmental revitalization and sustainable regional development in Fukushima.

1. Foresight and Advanced Basic Research

1.1 Development of environment management methods in a river catchment in the early stages of a nuclear disaster

As part of the development of a model of radioactive cesium (^{137}Cs) dynamics in forest ecosystems, we performed an intercomparison by using six different models, including NIES's ForRothCs, jointly with multiple institutions in Japan and abroad. The results of the calculation of ^{137}Cs concentrations at each cedar forest site for each model were used to make weighted ensemble-averaged future projections using Bayesian model averaging (BMA). We confirmed that the initial concentration in leaves was highly reproducible, but the point at which the concentration equilibrium was reached differed greatly among the models. The results also showed that the differences between the models were large in terms of both the future trend and peak-out timing of the concentration transition in the trunk. The BMA-based predictions also revealed large uncertainties.

2. Policy-Oriented Research

2.1. A survey of municipal environmental plans and environmental policies in Fukushima Prefecture

Data on policy infrastructure, environmental measures formulated by municipalities, and local community stakeholders concerned with environmental policies will be collected, organized, and analyzed to help with environmental recovery in the disaster-stricken areas of Fukushima Prefecture. The normal environmental policies promoted by the municipalities in this area are also being assessed. These analyses will be used to make recommendations for formulating municipal environmental plans and environmental policies.

Basic research into the relationship between reconstruction policies or base development projects and the decarbonization policies of 15 municipalities, such as the Hamadori area in Fukushima Prefecture, which was damaged by the Fukushima nuclear accident, was planned and started. In this research, we will organize the reconstruction and comprehensive plans of each municipality, as well as organize sectoral plans and reconstruction and maintenance plans. In particular, the goal is to visualize and organize the relevance of these plans, and decarbonization-related policies, in collaboration with the departments in charge, so that we can conduct a fact-finding survey of the stakeholders involved in the reconstruction base development project.

Analysis of the policy needs and policy networks of the organizations involved in this project has already begun, with a focus on the Fukushima Innovation Coast Framework, which aims to build an industrial infrastructure in 15 municipalities, including the Hamadori area. In 2021, a list of organizations involved in the framework, such as corporations and civic groups, was created from administrative materials and newspaper articles. In the future, the plan is to conduct questionnaire and interview surveys with each organization. This will enable us to identify the structure of the policy network related to the framework. It will also help us to identify the issues faced in forming networks to promote the framework through wide-area cooperation among organizations.

2.2 Study of major technical aspects of the development of local disaster waste management policies

Three topics were covered in this study. The first examined a method of estimating the amount of disaster wastes. We collected past records of disaster waste management cases in Japan and started developing a new statistical model. Here, the amount of disaster waste was the objective variable, and 24-h maximum rainfall, population density, total floor area, annual average rainfall, total number of houses damaged, and number of houses completely destroyed were candidate explanatory variables. We extracted 80 cases with no missing values from various official

records and databases. We compared three models: one linear model assuming a Gaussian distribution, one generalized linear model assuming a gamma distribution, and one hierarchical Bayesian model assuming a gamma distribution. The results showed that the hierarchical Bayesian model assuming a gamma distribution with two explanatory variables (total number of houses damaged and number of houses completely destroyed) had the highest prediction power.

The second topic was the disaster-waste cleanup behavior of disaster victims and its time-series variation. For this study we started collecting data from past disaster cases.

The third topic was hand-sorting of disaster waste. We performed laboratory ergonomic experiments to clarify the impact of two types of factors on sorting work efficiency, namely factors associated with the objects being separated (color, size, shape, waste category, texture) and factors associated with the sorting environment (number of sorting targets, brightness of working environment, height of sorting table, size of the area for sorting table). This year, we integrated the findings from our previous experiments and conducted a statistical analysis to clarify the relationship between sorting work efficiency and the factors listed above. We also collected information on the working environment and the visual line movement of workers at real waste-sorting facilities to confirm the consistency of these factors with the work specifications we developed from our laboratory experiments and statistical analysis.

2.3 Environmental Emergency Management Office

This office is tasked with the mission of supporting the recovery and reconstruction of disaster-stricken areas in terms of disaster waste and chemical substance (including asbestos) management. To this end, we are also engaged in efforts to support local governments and other organizations to help improve their disaster-response capabilities, even in times outside disaster.

In FY 2021, we accumulated, organized, and disseminated performance data on disaster waste management from previous years' case studies. We also supported policy-making by participating in national and local government committees. In addition, in collaboration with related organizations, we discussed supporting measures and advance preparations for emergency monitoring. In the event of a disaster, we will provide help, mainly from a technical standpoint, in coordination with affected local governments and the national government, while gathering necessary information for future research. The main results of this year's activities were as follows.

First, administrative materials such as disaster waste-management planning documents and articles contributed on experience with treatment projects in past disasters were posted on the web pages of the Disaster Waste Information Platform, which is managed and operated by our office. In addition, "Sai-hai," a disaster waste management support

tool developed under NIES's Environmental Emergency and Resilience Research Program, was made available to the public. A database of existing disaster waste management plans was constructed, and a Disaster Waste Management Plan Search System was developed and made available to the public so that users can search for the content of the plans they seek.

In addition, we exchanged opinions on mutual collaboration with four organizations affiliated with the Disaster Waste Management Support Network (D.Waste-Net) of the Ministry of the Environment. In addition, discussions were held on information sharing during normal times and on cooperation policies in times of disaster.

3. Intellectual Research Infrastructure Development

3.1 Estimated amount of radioactive cesium recovered by environmental restoration projects

The accident at the FDNPP in March 2011 resulted in the contamination of soil and waste over a wide area by radioactive Cs released into the environment. We attempted a simple calculation of how much of the total amount of radioactive Cs released at the time of the accident has been recovered by the environmental restoration project.

By using data published by the Ministry of the Environment and aircraft monitoring data from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), we calculated the ratio of the amount of radioactive Cs recovered from soil and waste to the total amount of radioactive Cs deposited on the ground of Japan. The total amount of deposited on the ground was assumed to be 20% (= 6600 TBq) of the total amount released to the atmosphere (33 PBq). However, as the radioactivity deposited on the ground was estimated to be 4900 TBq according to the MEXT aircraft monitoring data, the total amount of radioactive Cs deposited on the ground was assumed to be between 4900 and 6600 TBq. In this study, specific wastes under the Law Concerning Special Measures (designated wastes exceeding 8000 Bq/kg and wastes in the area subject to countermeasures) and soil removed as a result of decontamination were targeted and these concentration of radioactivity at the time of the accident was calculated in accordance with the half-lives of radioactive Cs (^{134}Cs: 2.0652 years; ^{137}Cs: 30.167 years).

The amount of radioactive Cs recovered that could be ascertained at this point was estimated at 421 TBq. This is 6.4% to 8.6% of the total amount of 4900 to 6600 TBq deposited on the ground. In Fukushima Prefecture, the total amount recovered in intermediate storage facility and specific waste landfill disposal facility was 421 TBq; this was 54% of the 773 TBq deposited in Fukushima Prefecture, excluding undecontaminated areas and forests not subject to decontamination.

3. 2 Monitoring of radioactive Cs behavior in a multi-media environment

In the area affected by the FDNPP accident, ^{137}Cs concentrations in some river fish continue to be higher than the standard limit for general foods in Japan (100 Bq/kg), despite the fact that monitoring by the Japanese government has reported that ^{137}Cs is undetectable in the waters of all rivers across Japan. Therefore, to propose an efficient monitoring method to predict future ^{137}Cs concentrations in fish, we measured the concentrations of dissolved ^{137}Cs (a highly bioavailable form) in the waters of major rivers located within a 200-km radius of the FDNPP in eastern Japan, and we analyzed the factors controlling these concentrations.

Dissolved ^{137}Cs concentrations in river water (0.4 to 120 Bq m^{-3}) were significantly positively correlated ($r^2 = 0.48$) with the averaged ^{137}Cs deposition in the catchment area at each water sampling point. The standardized dissolved ^{137}Cs concentration, obtained by dividing the dissolved ^{137}Cs concentration by the average ^{137}Cs deposition in the catchment (4.7×10^3 to 1.7×10^6 Bq m^2), was 4.5×10^{-6} to 2.2×10^{-3} m^{-1}. The standardized dissolved ^{137}Cs concentration was negatively correlated ($r = -0.63$) with the land-use ratio of forest in the catchment and positively correlated ($r = 0.82$) with the land-use ratio of buildings. The standardized dissolved ^{137}Cs concentration was also correlated with water temperature, electrical conductivity, K^+ concentration, and concentration of dissolved organic carbon.

To analyze the main factors that determine the concentration of dissolved ^{137}Cs, multiple regression equations were identified by using the standardized dissolved ^{137}Cs concentration as the objective variable, GIS data (land use, topography, and soil composition) as the explanatory variable, and water quality items as the explanatory variable. In the best model using GIS data ($R^2 = 0.61$), the land-use ratio of buildings was selected as the variable with the most explanatory power. On the other hand, in the best model using water quality data ($R^2 = 0.54$), electrical conductivity had the most explanatory power, but the model calculations underestimated the dissolved ^{137}Cs concentrations in the urban area. Therefore, the dissolved ^{137}Cs concentration cannot be explained solely by the influence of coexisting dissolved materials, suggesting that sources of dissolved ^{137}Cs specific to urban areas contribute to this value.

3.3 Biodiversity and ecosystem monitoring for regional collaboration

The FDNPP accident in 2011 created a large evacuation zone. In this zone, anthropogenic activities such as farming have been restricted, and there is concern about the impacts of under-use on the regional biodiversity and ecosystems maintained by anthropogenic disturbance. Although the evacuation order covering a large part of the area (except for the “difficult-to-return” zone) was lifted in 2017, the status of ecosystems in the newly accessible areas and the difficult-to-return zone remains to be determined. To reveal this status and share the information broadly, following on from the previous year, biodiversity and ecosystem monitoring inside and outside the evacuation zone was conducted. Mammals were

surveyed by using 46 camera traps set in forest areas. Birds, frogs, and insects were surveyed in 54 locations in the yards of schools or community centers. Integrated circuit recorders with a timer function were used to record the calls of birds and frogs, and flight intercept traps and Malaise traps were used to capture insects.

As a result, we obtained movie files from 45 locations, sound files from 47 locations, and insect samples from 54 locations. The files and insect samples were sorted and identified to obtain distribution data sets. Furthermore, a data set of birds for 2018–2020 was compiled and published through updating of a data paper and registration with GBIF (the Global Diversity Information Facility; https://www.gbif.org/), one of the largest international databases of species distribution data sets. This meant that the NIES data set contributed overwhelmingly to the open information on bird distribution data surrounding the evacuation zone (Fig. 1).

In addition, continuing on from the previous year, marine organisms and environmental status were surveyed at nine locations to evaluate the impacts of fisheries limitations around the FDNPP. The samples are being analyzed biologically and chemically.

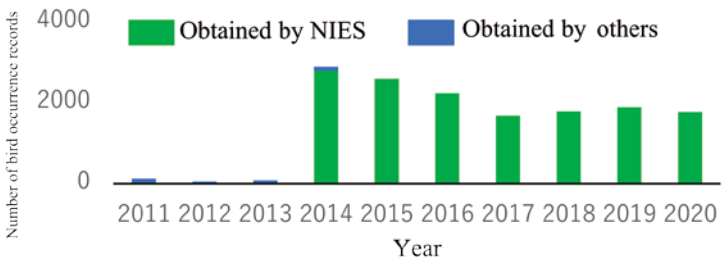


Fig. 1 Numbers of occurrence records of birds surrounding the evacuation zone after the FDNPP accident, as registered with GBIF as open data (accessed January 2022)

3.4 Promotion of regional collaboration

To further promote research in collaboration with the local community, we conducted public relations activities, dialogues with the local community, and research in collaboration with the local community in an integrated manner. As specific initiatives, in terms of content planning and production, the "FRECC+" website, featuring a web magazine designed to stimulate thought about the future of the Fukushima region and its environment, was created and released, and the first and second issues of "FRECC+ Essence," a booklet re-edited from the web magazine, was published (Fig. 2). For the purpose of learning and educating, and fostering the next generation of local human resources, we established "Environmental Cafe Fukushima," a year-round dialogue forum, with eight members of the chemistry club at Fukushima Prefectural Asaka Reimei High School. We held a debriefing session on their activities at the end of the year. We also held on-site lectures at several high schools in Fukushima Prefecture on the themes of environmental restoration in Fukushima and the United Nations Sustainable Development Goals. In addition, as part of efforts to support environmental policy-making by local governments, we supported holding a workshop for formulating a

comprehensive plan for the city of Tamura. We participated on the executive committee of the Council for the Promotion of Regional Recycling and Symbiosis in the Fukushima town of Mishima, and we conducted a review of the conclusion of a Koriyama-area-wide cooperation agreement.

Fig. 2 The first and second issues of "FRECC+ Essence," a booklet re-edited from the web magazine and designed to stimulate thought about the future of the Fukushima region and its environment

Environmental Measurement Research and Affairs

Environmental measurement research and affairs are managed by the Center for Environmental Standards and Measurement. In this center, two laboratories, namely the Environmental Standards Section and the Environmental Measurement and Analysis Section, are responsible for fundamental measurement work in a cross-disciplinary manner, as well as for advanced measurement research in cooperation with other research domains. In addition to performing analyses on request by using chemical measuring instruments, the center also prepares and provides environmental reference materials that meet international standards in response to social needs. We also add certified values and reference values to existing environmental reference materials in order to increase their usefulness. In addition, to improve our understanding of the status of chemicals in the environment, we are promoting a long-term preservation project for environmental samples, including the collection, long-term preservation, and analysis of bivalve mollusks from the coast of Japan.

Below are brief accounts of some of the important results of our research in FY 2021.

1. Foresight and Advanced Basic Research

1.1 Volatile and non-volatile nanoparticles emitted from aircraft

Characterization of the ultrafine particle emissions from jet aircraft equipped with turbofan engines, which are commonly used in civil aviation, is an important issue in assessments of the impacts of aviation on climate and human health. We conducted field observations of aerosols and carbon dioxide (CO_2) near a runway at Narita International Airport, Japan, in February 2018. We used a scanning mobility particle sizer (SMPS) with unheated and 350-°C heated modes and an engine exhaust particle sizer (EEPS) with unheated mode to measure particle number size distributions. Spiked increases in the particle number concentrations and CO_2 mixing ratios were observed to be associated with changes in the direction of wind from the runway, which in turn were attributable to diluted aircraft exhaust plumes. More than half the particle number emission indices were in the size range smaller than 10 nm for both total (volatile and non-volatile particles) and non-volatile particles in most of the cases analyzed in our study (Fig. 1). Large contributions of the sub-10 nm size ranges of total particles in the diluted plumes was qualitatively consistent with that of previous studies, but that for the non-volatile particles was shown for the first time.

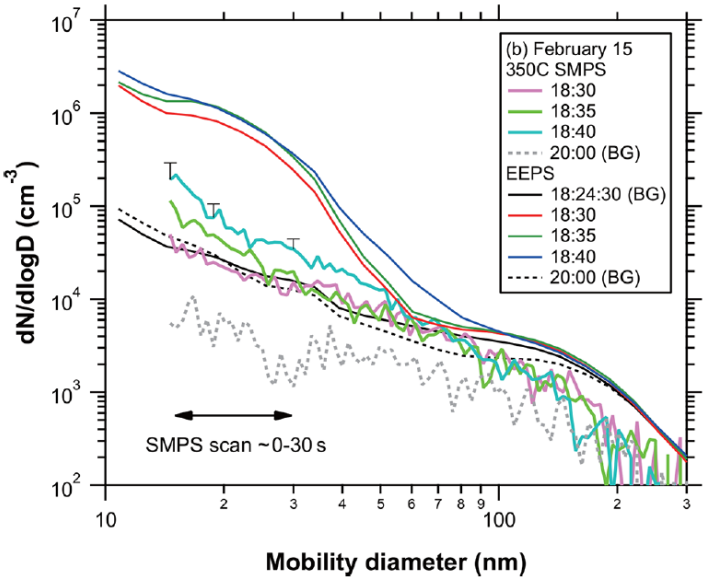


Fig. 1 Particle number size distributions measured near a runway at Narita International Airport, Japan in February 2018. "EEPS": sum of volatile and non-volatile particles measured by engine exhaust particle sizer; "350C SMPS": non-volatile particles measured by scanning mobility particle sizer with 350-°C heated mode. "BG" indicates a time period with negligible impact of aircraft emissions from the nearby runway. (excerpt from Takegawa et al. 2021, licensed under CC BY 4.0 https://creativecommons.org/licenses/by/4.0/)

Reference:

Takegawa N., Murashima Y., Fushimi A., Misawa K., Fujitani Y., Saitoh K., Sakurai H. (2021) Characteristics of sub-10 nm particle emissions from in-use commercial aircraft observed at Narita International Airport. *Atmospheric Chemistry and Physics*, 21, 1085–1104

2. Intellectual Research Infrastructure Development

2.1 Strontium isotopic composition of NIES Certified Reference Material No. 28, Urban Aerosols

Recent studies have assessed the usefulness of the strontium (Sr) isotopes $^{87}Sr/^{86}Sr$ for identifying the sources of atmospheric particulate matter (PM). However, the Sr isotopic compositions of PM reference materials have not been reported. To overcome this limitation, we aim to obtain a value of the $^{87}Sr/^{86}Sr$ ratio for NIES CRM (Certified Reference Material) No. 28, Urban Aerosols. This NIES CRM, collected from the filters of the central ventilating system of a building located in Beijing city center, was produced to evaluate the analytical accuracy of determining the mass fractions of selected elements (18 certified and 14 reference values). The certified value of Sr is 469 ± 16 mg/kg. (A certificate is available in English at https://www.nies.go.jp/labo/crm-e/hrfba300000ble6p-att/No.28_E.pdf.)

The Sr isotopic composition was measured by using multicollector-inductively coupled plasma-mass spectrometry (MC-ICP-MS) to confirm the CRM's within- and between-bottle homogeneity. The results gave an $^{87}Sr/^{86}Sr$ value of 0.710227 ± 0.000019 (2SD, n = 18). The Sr isotopic compositions were intercompared by different instruments using thermal ionization mass spectrometry (TIMS), which

gave good agreement with the values obtained at NIES (Fig. 2). Subsequently, consistency of $^{87}Sr/^{86}Sr$ ratio values was observed between two different dissolution (hotplate vs. high-pressure bomb) and Sr separation (Sr-spec resin vs. cation exchange resin) methods. Our results show that NIES CRM No. 28 is appropriate for use in measuring Sr isotopes in environmental and geochemical studies for the quality control of particulate matter analyses.

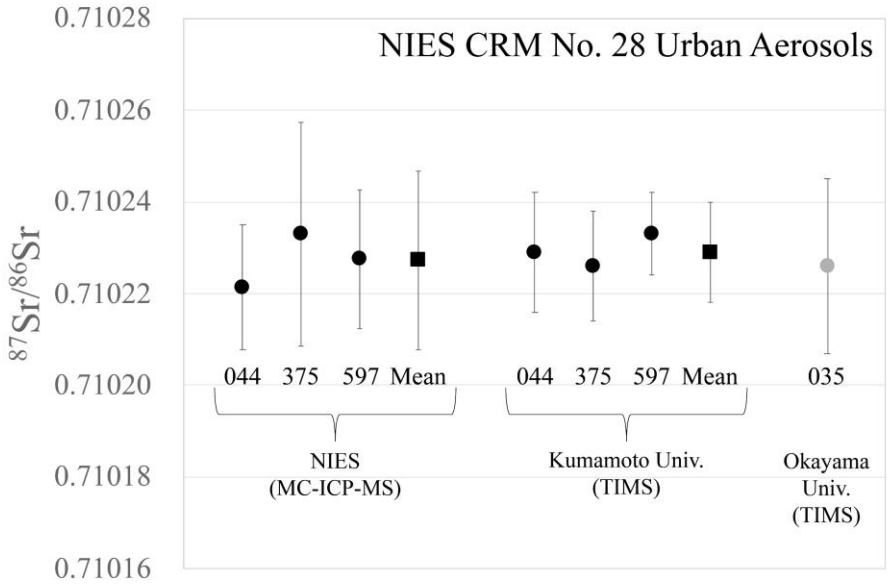


Fig. 2 $^{87}Sr/^{86}Sr$ ratios of NIES CRM No. 28, Urban Aerosols. All Sr isotopic data were adjusted to the US National Institute of Standards and Technology Standard Reference Material 987 $^{87}Sr/^{86}Sr$ value of 0.710248. The numbers listed below the plots indicate the number of each bottle. (Yamakawa et al., 2021, licensed under CC BY 4.0. https://creativecommons.org/licenses/by/4.0/; this figure is a partial modification of the original)

Reference:

Yamakawa A., Nagano K., Ukachi M., Onishi K., Yamashita K., Shibata T., Takamiya K., Kani T., Bérail S., Donard O. F. X., Amouroux D. (2021) Sr isotopic composition of NIES Certified Reference Material No. 28 Urban Aerosols. *Frontiers in Environmental Chemistry*, 2, 771759. doi: 10.3389/fenvc.2021.771759

Research Projects

Satellite Observation Project

The Satellite Observation Center (SOC) contributes to improving 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 the Greenhouse gases Observing SATellite (GOSAT), launched in 2009; GOSAT-2, launched in 2018; and the Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW), 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 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 2021 are as follows:

1. GOSAT

Operational data processing for GOSAT, which has been in space for more than 13 years, continued, as did the generation, validation, and distribution of GOSAT products, such as the concentrations and fluxes of carbon dioxide (CO_2) and methane (CH_4). The concentration products up to February 2022 (V02.90/91), CO_2 flux products up to October 2019 (V02.07), and CH_4 flux products up to September 2019 (V01.06) are freely available from the online data distribution service (GOSAT Data Archive Service, GDAS; https://data2.gosat.nies.go.jp). Maintenance and operation of the GOSAT Data Handling Facility, a computer system necessary for these activities, were also conducted. Moreover, we have continued to provide GOSAT FTS (Fourier Transform Spectrometer) Level 2 CO_2 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.

GOSAT whole-atmosphere monthly mean concentration data on CO_2 and CH_4 were used in the contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Fig. 1) (IPCC 2021) [1)] to show the global concentration trends in the past decade.

GOSAT CH_4 flux products were used to investigate meteorological controls of Subtropical South American (SSA) CH_4 emissions (Fig. 2) (Takagi et al. 2021) [2)]. Clear correlations among GOSAT CH_4 flux, terrestrial water storage, and the extent of the inundated area in the SSA region have been found.

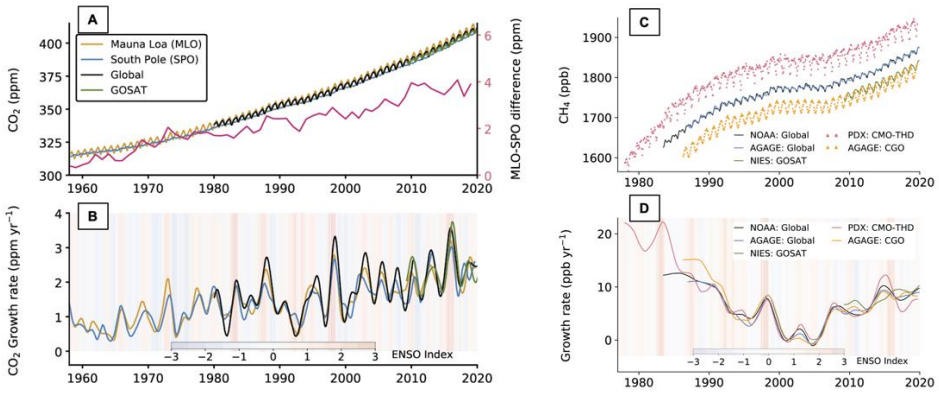


Fig. 1 Figures from the IPCC AR6 WG1 report, with NIES GOSAT data (Figures 5.6 and 5.13). (Left panels) Time series of CO_2 concentrations (A) and growth rates (B). (Right panels) Time series of CH_4 concentrations (C) and growth rates (D). The GOSAT data were well correlated with the data from other ground-based networks.

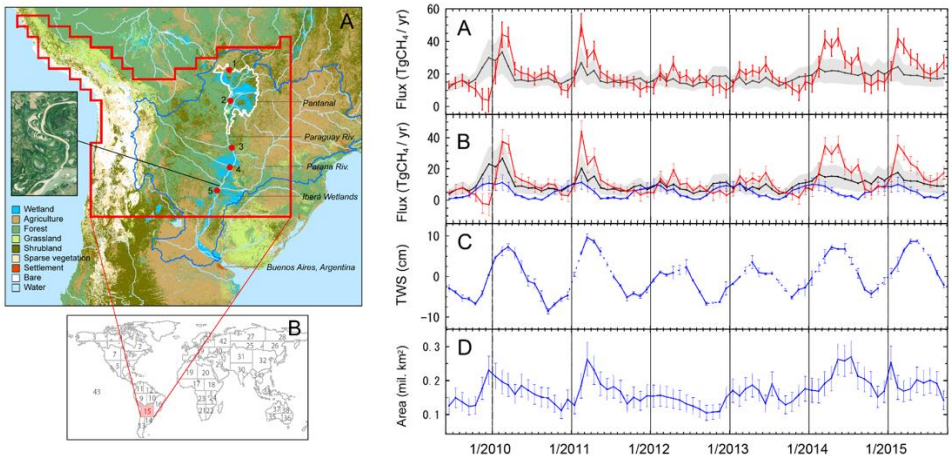


Fig. 2 (Left) (A) European Space Agency – Climate Change Initiative land cover, 2015. Left inset: areal view over the confluence of the Paraguay and Paraná rivers. (B) Boundaries of GOSAT Level 4 CH_4 flux source regions. (Right panels) (A) Monthly net posterior (red) and prior (black) CH_4 fluxes for the SSA region. (B) SSA posterior wetland emission (red), SSA prior wetland emission (black), and WetCHARTs model ensemble mean (blue). (C) GRACE terrestrial water storage (TWS). (D) Extent of inundated SSA area.

2. GOSAT-2

GOSAT-2 data have been distributed by the GOSAT-2 Product Archive (https://prdct.gosat-2.nies.go.jp) for Research Announcement users and General Users since 2019. New versions of the CAI-2 L2 Cloud Discrimination Product (V01.04), FTS-2 SWIR L2 Chlorophyll Fluorescence and Proxy-method Product (V01.04/V01.07), and the Column-averaged Dry-air Mole Fraction Product (V01.07) were released in FY 2021. GOSAT-2 Science Team Meetings were held twice in FY 2021 to discuss issues such as validation and release of the above-mentioned products.

A modified algorithm for the FTS-2 SWIR L2 Column-averaged Dry-air Mole Fraction Product was developed to improve the precision of the product. The validation using ground-based data from TCCON (the Total Carbon Column Observing Network) suggests that the new version (V02.00) is more precise than the current version (Fig. 3). The modified algorithm will be used to update the product in FY 2022.

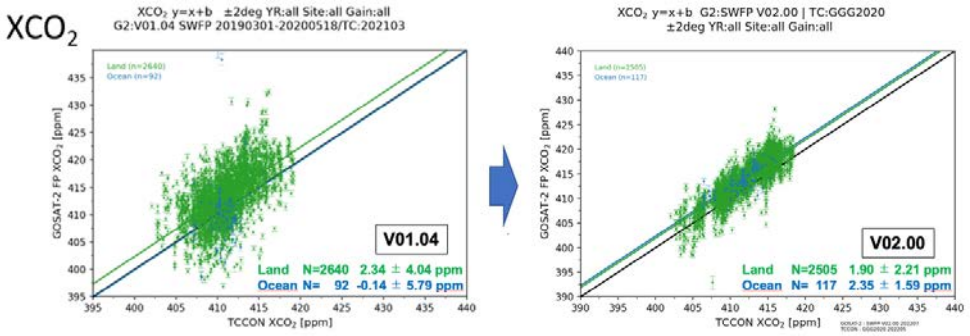


Fig. 3 XCO_2 comparisons between the GOSAT-2 FTS-2 SWIR L2 Column-averaged Dry-air Mole Fraction Product and ground-based data. (Left) GOSAT V01.04 and TCCON (GGG2014) (Right) GOSAT V02.00 and TCCON (GGG2020). Scatters against TCCON data are substantially reduced in V02.00 compared with V01.04.

3. GOSAT-GW

In FY 2021, critical design reviews of Total Anthropogenic and Natural emissions mapping SpectrOmeter 3 (TANSO-3) and related ground systems, including NIES' GOSAT third-generation Data Processing/operating System (G3DPS) and the GOSAT-GW Nitrogen dioxide (NO_2) Data Processing System (GNDPS), were held by JAXA, NIES, and their contractors. The appropriateness of these designs was mostly confirmed. The confirmed designs will be used in FY 2022 to manufacture instruments and ground systems. A contract was signed to install G3DPS in a building owned by the University of Tsukuba, and some network facilities were put in place (Fig. 4). The TANSO-3 Validation Plan was prepared and the TANSO-3 Validation Implementation Plan was discussed in FY 2021. The procurements and installations of ground-based observation instruments for validation are ongoing.

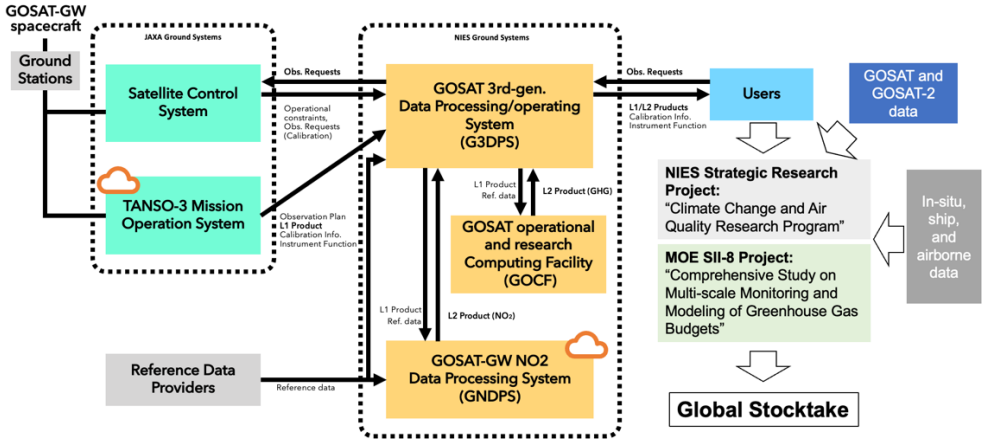


Fig. 4 G3DPS, GNDPS, and other ground systems associated with GOSAT-GW and TANSO-3's data flow from the GOSAT-GW spacecraft to the Global Stocktake hosted by the United Nations Framework Convention on Climate Change. The TANSO-3 data will be integrated with GOSAT, GOSAT-2, and other data via an inversion model for submission to the Global Stocktake.

4. Collaboration with other organizations

Research Announcements on the GOSAT Series (GOSAT Series RAs) have been issued three times 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. Currently, a total of 47 joint studies are in progress.

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

5. Hosting of meetings

The Second GOSAT Series RA Principal Investigators (PIs) Meeting was held online on 5 and 6 July 2021, with the first day's meeting scheduled in the evening and the second day's in the morning to accommodate time differences among overseas participants. The 2-day meeting featured four invited talks (20 min each) and 14 short talks (2 min each) by RA PIs, in addition to project status reports from NIES and JAXA. The discussions with RA PIs were very fruitful and will help to promote GOSAT Series projects.

At the 17th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-17), which was held virtually in June 2021, the NIES proposal to host IWGGMS-18 in Japan in 2022 was welcomed. The IWGGMS-18 secretariat was established in SOC, and the first circular of IWGGMS-18 was issued in January 2022. Preparation to host the 18th workshop in July 2022 in Takamatsu, Japan, is ongoing.

6. Participation in international events

In November 2021, SOC participated in the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC COP26) by means of an online exhibit. Various posters and movies on the GOSAT series were posted on the website designated by the UNFCCC COP26 secretariat.

The Atmospheric Composition Virtual Constellation (AC-VC) is an initiative led by the Committee on Earth Observation Satellites (CEOS) to collect and deliver data to improve the monitoring and assessment of, and ability to predict, changes in the ozone layer, air quality, and climate forcing through the coordination of existing and future international space assets. An update on the GOSAT-GW project was presented at the 18th Meeting of the AC-VC, which was held virtually in March 2022.

7. Press releases

SOC issued the following press release in FY 2021:
"Annual increase in whole-atmosphere mean methane concentration for 2021 marks the largest since 2011" (March 2022) (Fig. 5).

See: https://www.nies.go.jp/whatsnew/20220323/20220323-e.html and https://www.eurekalert.org/news-releases/946874

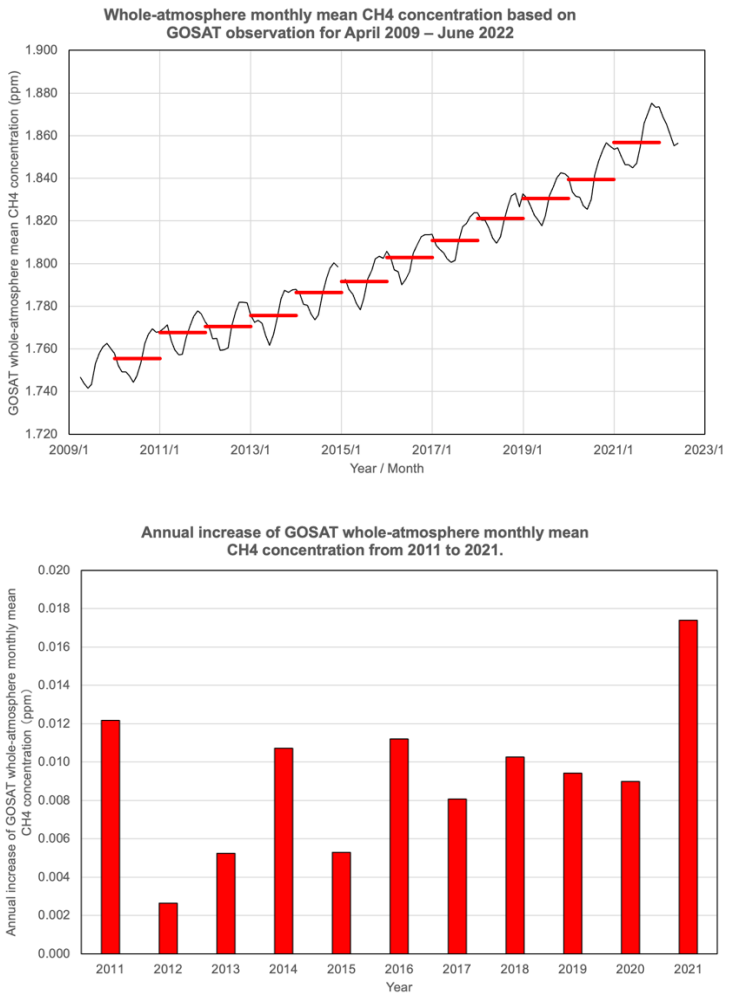


Fig. 5 (Top) GOSAT whole-atmosphere monthly mean CH_4 concentration (monthly mean, black) and its annual mean (red) from 2009. CH_4 concentrations have been increasing in the past decade, with variable annual increases. (Bottom) Annual increase of GOSAT whole-atmosphere monthly mean CH_4 concentration from 2011 to 2021. The increase in 2021 was 17 ppb—almost double the average of the previous 10 years. The root cause of this sudden increase is not yet known.

Reference:

1) IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896

2) Takagi H., Ito A., Kim H.-S., Maksyutov S., Saito M., Matsunaga T. (2021) Meteorological control of subtropical south american methane emissions estimated from GOSAT observations, *SOLA*, 17, 213−219, doi:10.2151/sola.2021-037

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

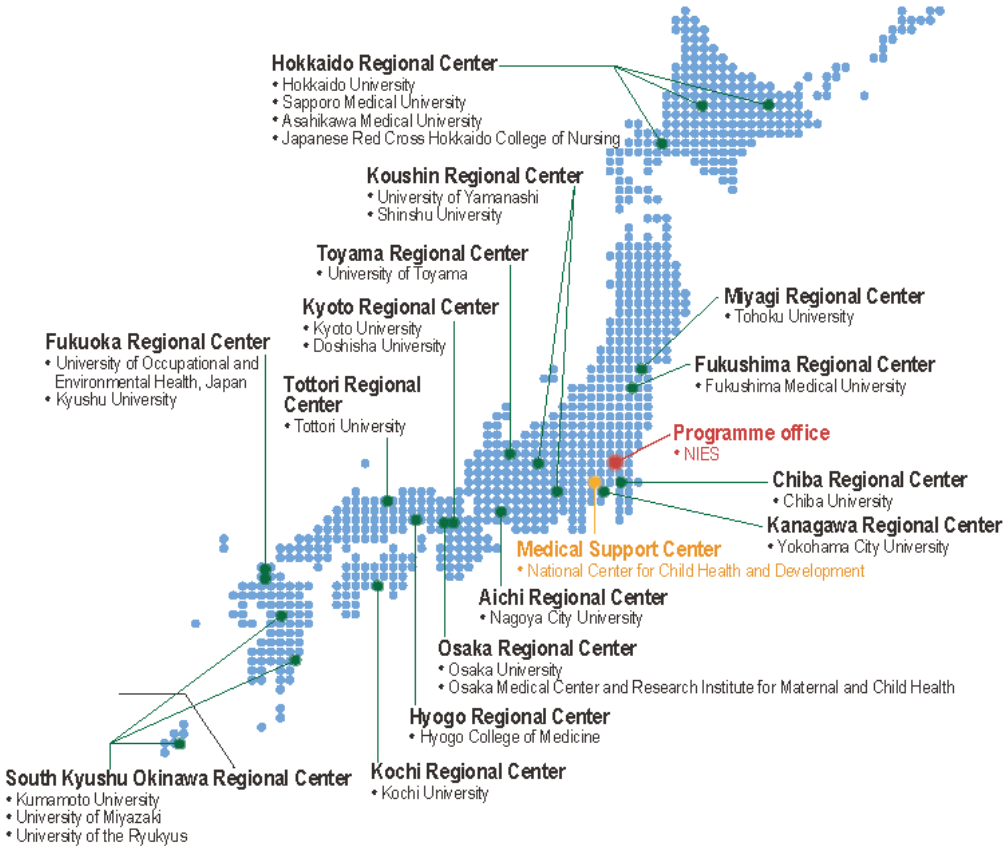
We started recruiting participants in January 2011, and recruitment continued until March 2014, by which time the number of participating mothers had reached 103,099. Recruited participants were pregnant women and their partners (when accessible). JECS began to collect data when the mothers were pregnant 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 S.F. 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. (2022) Study design and participants' profile in the Sub-Cohort Study in the Japan Environment and Children's Study (JECS). *Journal of Epidemiology*, 32(5), 228–236, doi:10.2188/jea.JE20200448

5. Activity report for FY 2021

The children participating in the Main Study reached the ages of 7 to 10 years in FY 2021. We continued to administer questionnaires to participants to collect a wide range of information on the children's health and development and their exposure to environmental factors. We analyzed 100,000 maternal urine samples for pyrethroids and 5000 child blood samples for perfluorinated alkyl substances. As part of the Sub-Cohort study, approximately 2200 eight-year-old participants were tested developmentally and examined by a pediatrician, and blood and urine samples were also collected and tested.

Promotion of Climate Change Adaptation

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 2021 are described below.

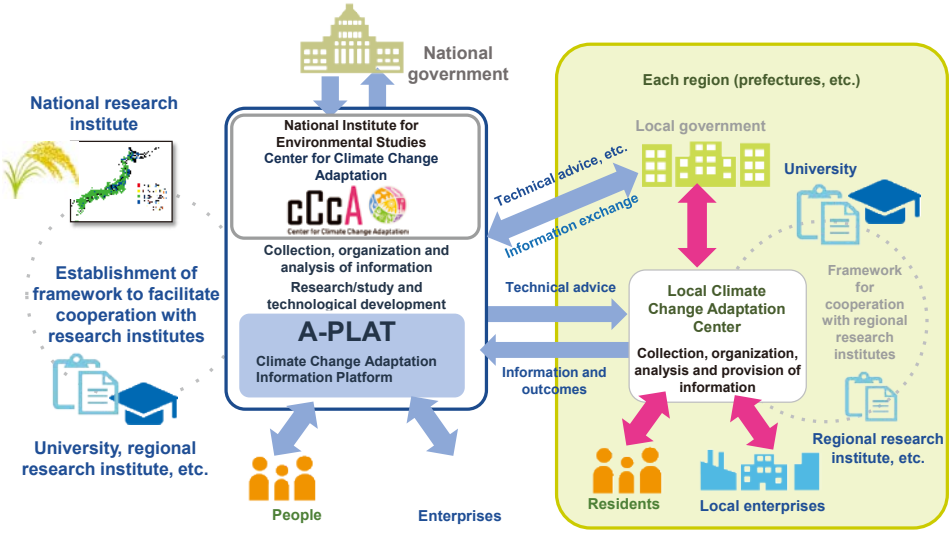


Fig. 1 Role of the Center for Climate Change Adaptation

1. Promotion of climate change adaptation

1.1 Technical support for local governments

We held meetings with local government and LCCACs to identify their needs for technical help. 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 5,000 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 in 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:

- Five workshops were held in 2021 (Fig. 2), and a discussion meeting was held in October 2021 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 2022 with the theme of climate change adaptation. Related research was shared with regional environmental research institutes.
- In October 2021, NIES, with MOE, organized the "Fourth 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 2021

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

The Climate Change Adaptation Information Platform (A-PLAT) hosted by NIES integrates and disseminates information on climate change adaptation. The following measures were taken to enhance the dissemination of information on adaptation in Japan and abroad:

- The "Adaptation Efforts by the National Government" of the A-PLAT was expanded to introduce the initiatives of ministries, agencies, and national research institutes

- Eighteen indicators on climate change impact projections were presented in WebGIS format.
- Web pages featuring the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 26) and the Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) were released.

The "A-PLAT Kids" website for children was launched to educate the general public. In addition, we promoted information dissemination through various media, such as the renewal of the English version of A-PLAT (Fig. 3), the development of a smartphone application "Minna-no Adaptation (Adaptation for everyone) A-PLAT+," and the enhancement of information dissemination via Twitter and Facebook. The number of page views was 1.63 million, a substantial increase compared with the previous year (approximately 900,000). In addition, the number of social networking systems (Twitter, Facebook, and LinkedIn) feeds reached 1,955, substantially exceeding the target.

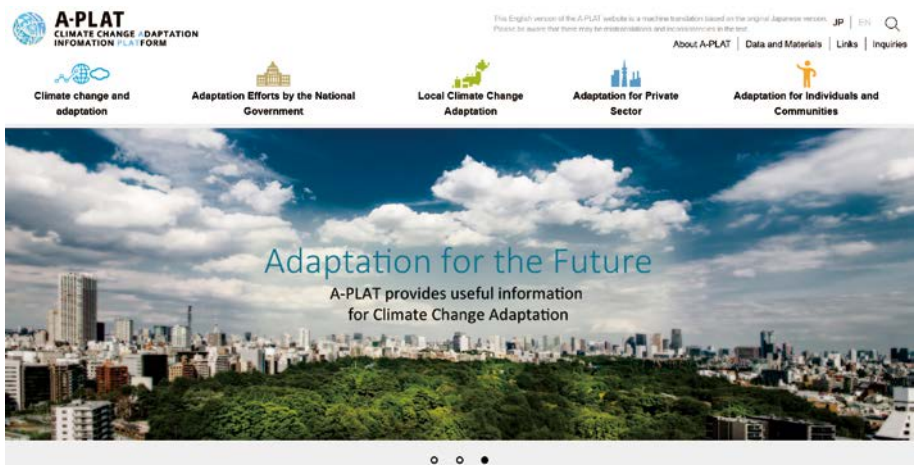


Fig. 3 Home page of the English version of the A-PLAT website (https://adaptation-platform.nies.go.jp/en/)

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 have developed the "Asia-Pacific Adaptation Information Platform" (AP-PLAT). Collected CMIP6 (Coupled Model Intercomparison Project Phase 6 of the World Climate Research Programme) data and impact assessment results were visualized by using WebGIS and published in AP-PLAT (Fig. 4).
We strengthened cooperation with the Asia-Pacific Network for Global Change Research (APN) and other related domestic and international organizations, and we contributed to human resource development through the dispatch of committee members. We also organized an international workshop on information platforms for adaptation at the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26). Through these activities, the needs and issues related to the promotion of adaptation in the Asia-Pacific region were organized and analyzed.

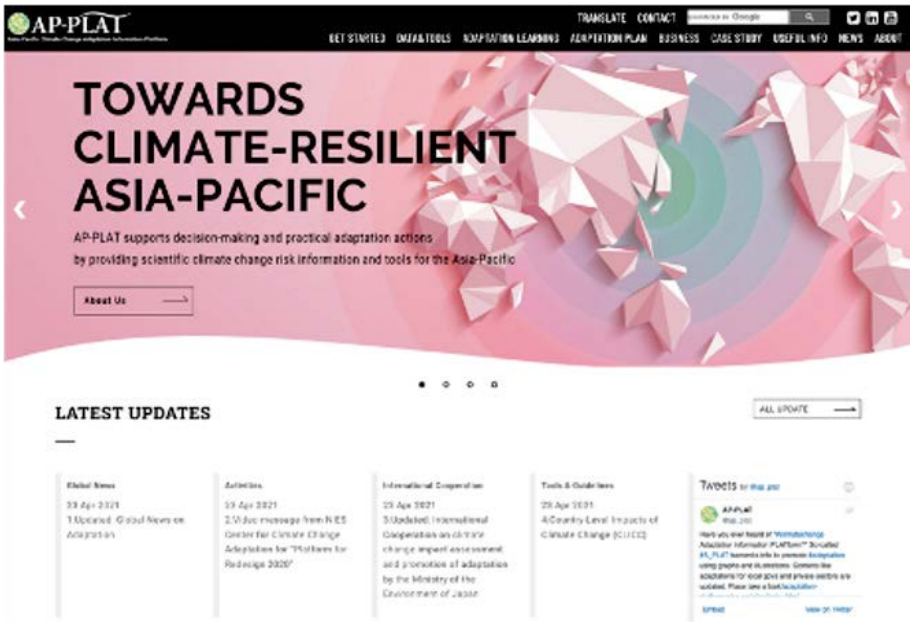


Fig. 4 Home page of the AP-PLAT website (https://ap-plat.nies.go.jp/)

1.4 Contribution to climate change policy

Through participation in deliberative councils and investigative conferences, such as Assessment Subcommittees of the Japanese government's Central Environment Council and meetings with the Ministry of the Environment, we contributed to the revision of National Plan for Adaptation to the Impacts of Climate Change and helped to promote climate change policy.

2. Climate change impact and adaptation research

Through scientific knowledge of climate change impacts and adaptation, our goal is to provide technical help to municipalities and various sectors on adaptation, and here we conducted both a basic project and a research program. The basic project promoted the monitoring of climate change impacts, creation of a scenario database, and analysis of adaptation information. A new data set (NIES 2020, https://ccca-scenario.nies.go.jp/data/jpn_cdfdm/nies2020/) for climate change in Japan was created and is available on our database site (A-PLAT Pro, https://ccca-scenario.nies.go.jp/).

The research program consists of three research projects, an overview of which is shown in Figure 5. Some topics under each project are discussed below.

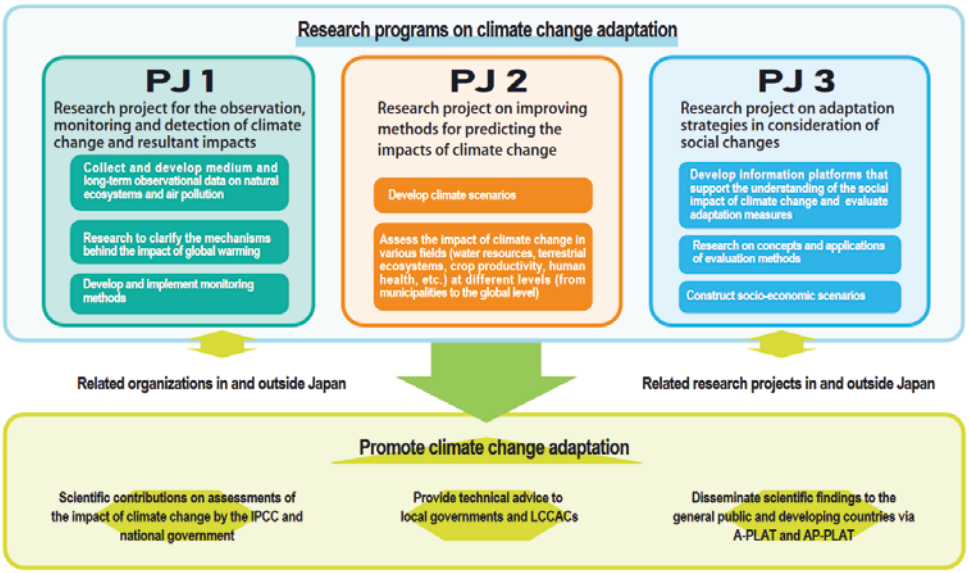


Fig. 5 Structure of our research projects

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

Under this project, we are conducting research in Japan and other Asian countries with the aim of clarifying the effects of climate change on biodiversity, ecosystem functions, rice cultivation, and human health. This year, we published review papers on the current status of monitoring of terrestrial and freshwater ecosystems as a basis for research on climate change impacts (in Japanese). As original research, field surveys were conducted to detect changes in species composition and vegetation structure at forest sites where vegetation surveys had been conducted in the past. Long-term changes in lake water quality were analyzed, and findings on the relationship between water-level fluctuations and transparency were published. In coastal ecosystems, field surveys were conducted on the benthos inhabiting tidal flats in inner bays, coral reefs, and seaweed or seagrass beds to assess the effects of climate change. As part of a study of mangroves, mapping of the global distribution of each species has been developed. In addition, growth responses to various temperatures were experimentally examined for several representative species (Fig. 6). These results will be useful in conserving the species in response to climate change and in planning for Eco-DRR (Ecosystem-based Disaster Risk Reduction). In addition to research on ecosystems and biodiversity, we have also made progress in analysis of the effects of climate change on human health. The factors that influence the occurrence of heat stroke were analyzed in Japan, and the effects of climate and air pollution on the risk of child mortality were analyzed in Malaysia.

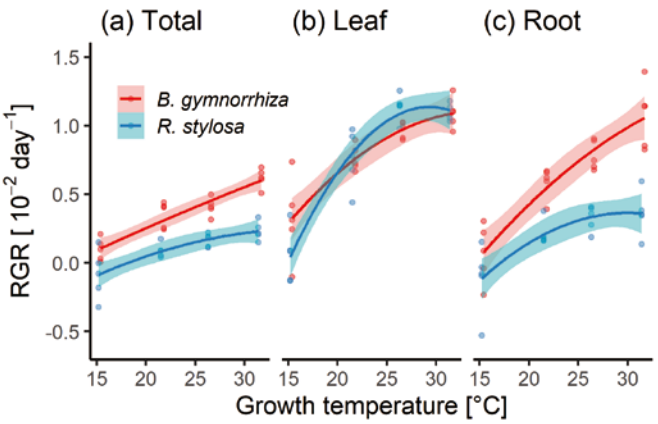


Fig. 6 Temperature dependencies of relative growth rates (RGRs) of seedlings, leaves, and roots of two Rhizophoraceae species (*Bruguiera gymnorrhiza* and *Rhizophora stylosa*). Curves fitted with a second-order polynomial regression model are shown; red and blue shading indicate the 95% confidence interval. (Inoue et al., 2022, *Annals of Botany* 129, 15–28)

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

We worked on 12 sub-projects to conduct climate change impact assessments at multiple scales (e.g. global, Asia-Pacific region, Japan, and river basins) and across multiple sectors (e.g. water resources, ecosystems, crop yields, and human heath). 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 the latest climate projections by using the non-hydrostatic regional climate model (NHRCM) of the Meteorological Research Institute, Japan. We also made our latest climate change impact assessment results publicly available through the A-PLAT WebGIS.

2.3 Adaptation strategies in consideration of social changes (PJ3)

To elucidate the interactions among multiple sectors through water resources, we scaled down the global coupled model CROVER (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014MS000402) to estimate water resources and agricultural productivity at a river basin level in Japan. Furthermore, to analyze the impacts of climate change on multiple sectors, we started to develop a method of exploring regional differences in the impacts of climate change on various sectors. In addition, the concept of compound risks and climate change and security in Japan was introduced with regard to the socioeconomic impacts of climate change; this concept was featured in the “Climate Change Impact Assessment Report” and the “Defense of Japan 2021”.

In relation to the registration of Amami Oshima Island, Tokunoshima Island, northern Okinawa Island, and Iriomote Island as World Natural Heritage sites, an agreement was concluded with the relevant organizations to monitor the vegetation in these areas, and research was initiated. In targeting the Kerama Islands (southwest of Okinawa), where tourism of the coral reef ecosystem has been active, we identified sites where coral conservation should be prioritized to maintain current coral tourism use and conservation points. Targeting the valleys around the Inba-Numa area (in northwestern Chiba Prefecture), studies and trials were conducted on how to utilize abandoned rice paddies as green infrastructure to provide multifunctional functions, including climate change adaptation.

The LCCACs were categorized on the basis of their adaptive capacity, and the difficulties faced by the centers in each category were investigated. We also analyzed the implementation status of climate-change-adaptation-related measures in the city of Koriyama, in Fukushima Prefecture. Additionally, we analyzed the contents of local climate change adaptation plans using a content analysis approach.

Environmental Information Department

Environmental Information Department

The Environmental Information Department provides information technology (IT) support for research and related functions at NIES; supports public relations initiatives 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 2021, 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 2022, the NIES library (Fig. 2) held 73,045 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 introduce 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

1.4 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 and papers written by our researchers. Accordingly, we have set up a system for publishing URLs (metadata) associated with DOIs on the NIES website and our institutional repository.

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 grasped the actual state of products and activities by our researchers, especially the results point to the articles on publishers' sites.

2. Other activities

2.1 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).

2.1.1 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.

2.1.2 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.

2.1.3 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.

2.2 Tasks commissioned by the Ministry of the Environment

In FY 2021, 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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