ISSN 2187-9486

NIES Annual Report 2023

AE - 29 - 2023

National Institute for Environmental Studies
https://www.nies.go.jp/

ISSN 2187-9486

NIES Annual Report

2023

AE - 29 - 2023

National Institute for Environmental Studies
https://www.nies.go.jp/

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 2022 (FY2022: April 2022 to March 2023) which marked the second year of our Fifth Five-Year Plan (FY2021-FY2025).

Under the Fifth Five-Year Plan, NIES has been steadily engaged 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) to form the pillars of environmental research and two fields (Environmental Emergency and Resilience; Climate Change Adaptation) which we aim 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 are also steadily developing *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 are being conducted in a focused and comprehensive manner with awareness to achieve goals within the Fifth Five-Year Plan. The climate crisis issues are particularly promoted in an integrated manner under *Climate Crisis Research Initiative*, which coordinates four related programs.

Based on national plans, NIES continues to conduct the satellite-based global observation of greenhouse gases (GOSAT) and the nationwide birth cohort study of 100,000 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. Preparations for data processing for the third GOSAT to be launched, as well as continuation of the birth cohort study to children 13 years of age and onward has been approved. As for climate change adaptation, we are conducting research and providing 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 has been renamed to Fukushima Regional Collaborative Research Center to clearly demonstrate our intention to contribute to the regional community by collaborating with various entities. The Research Collaboration Division and the Fukushima Regional Collaborative Research Center together made their first challenge for crowdfunding and made it a success with the understanding of the public.

Research activities such as monitoring abroad has been conducted with minimum impact of pandemic, and we achieved good marks for our high research quality from professionals outside the institute. However, we believe that such achievement was made possible due to the adequacy of the plan and our expectations for its results. We will continue to enhance our activities as we move into the second half of the 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
December 2023

Contents

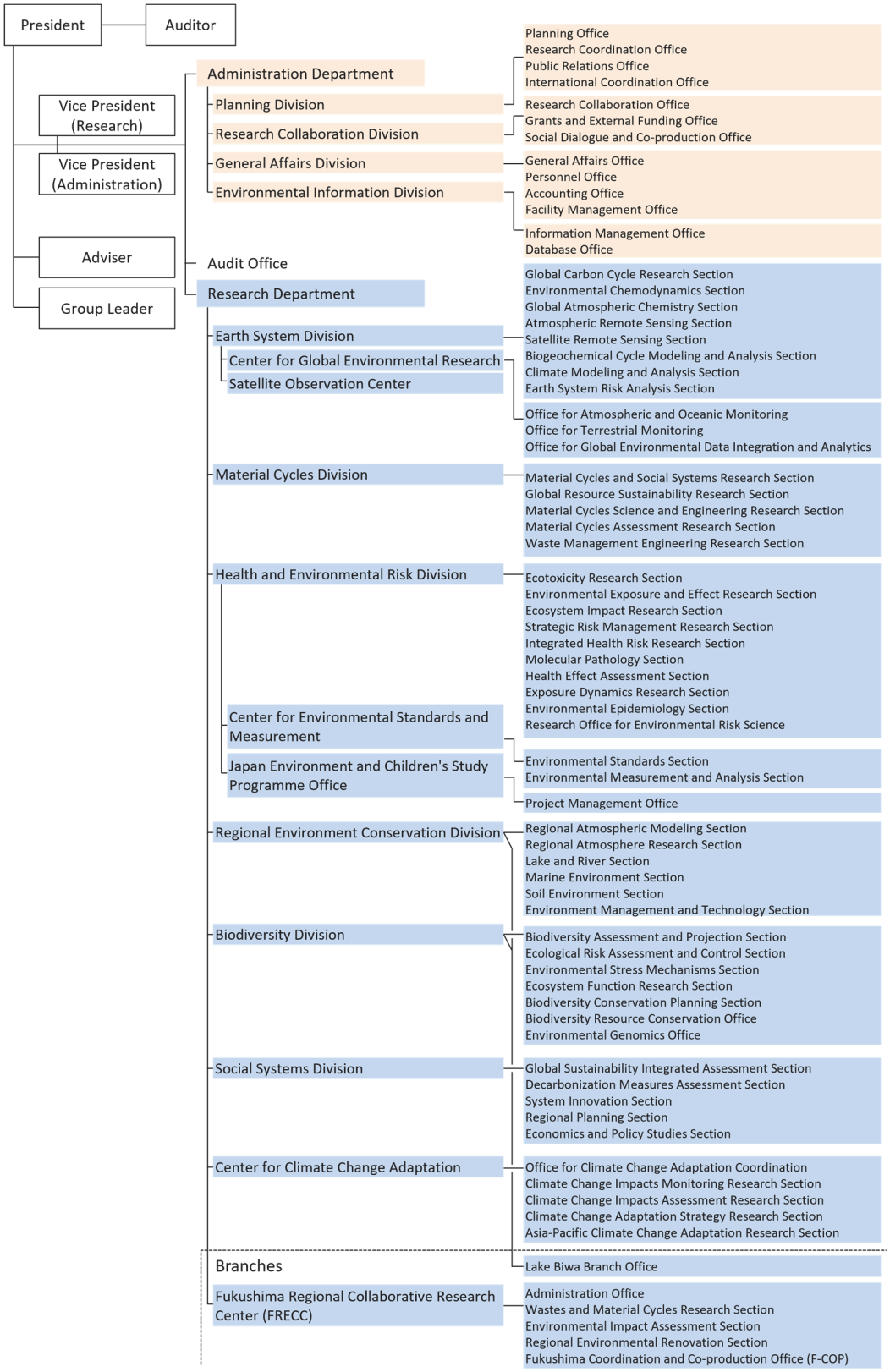
During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established in 1971 as part of the Japanese government to develop measures to counteract serious problems associated with environmental pollution, such 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. Our latest organization chart is shown in Fig. 1.

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, 2022, there are 298 NIES permanent staff and 640 contract staff (Table 1; Figs. 2 to 5). The total budget for FY2022 was 20,750 million yen (Table 2).

Table 1 Numbers of permanent staff

Administration Department	58
Research Department	234
Audit Office	1
Executives and Advisers	5
Total	298

(As of April 1, 2022)

Table 2 Budget for the Fifth Five-Year Plan

(Unit: million yen)

	Category	2021-2025 Budget (5 years)	Fiscal Year 2022 Budget
Revenue	Grants for Operating Costs	85,277	16,387
	Subsidies for Facilities	2,003	727
	Commissioned Work	18,428	3,636
	Total	105,708	20,750
Expenditure	Project Costs	66,315	12,581
	Facility Improvements	2,003	727
	Expenses for Commissioned Work	18,179	3,636
	Personnel Expenses	17,069	3,365
	General Administrative Expenses	2,141	441
	Total	105,708	20,750

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	:	234	(5)
Audit Office	:	1	
Executives and Advisers	:	5	
Total		298	(5)

Notes:
1. Data is as of April 1, 2022.

2. Figures in parentheses indicate number of foreign nationals.

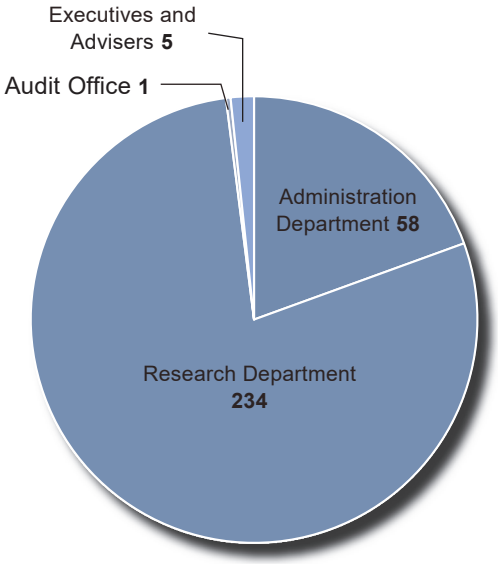


Fig. 2 Permanent staff breakdown

Basic Sciences	:	98	43.75%
Engineering	:	68	30.36%
Agricultural Sciences	:	35	15.63%
Medical Sciences	:	10	4.46%
Pharmaceutical Sciences	:	3	1.34%
Veterinary Medicine	:	1	0.45%
Social Sciences	:	9	4.01%
Total		224	

Note: Data is as of April 1, 2022.

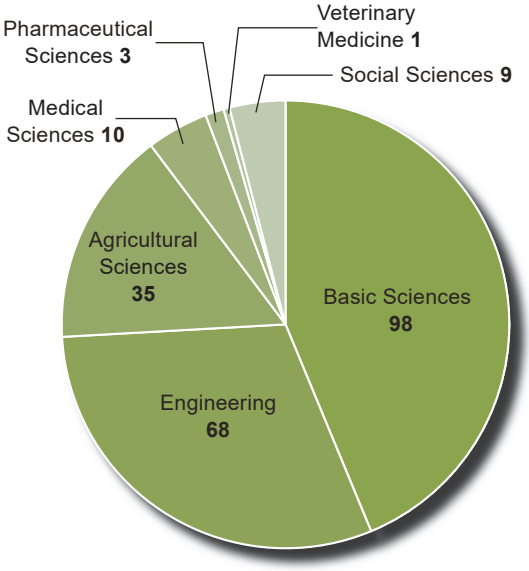


Fig. 3 Fields of expertise（Researchers holding doctorates（96.4%））

Senior Fellow	:	1	
Fellow	:	4	
Research Associate	:	79	(33)
Junior Research Associate	:	9	(2)
Research Assistant	:	22	(4)
Expert	:	256	(10)
Assistant Staff	:	254	
Senior Staff	:	3	
Senior Research Associate	:	12	
Total		640	(49)

Notes:
1. Data is as of April 1, 2022.

2. Figures in parentheses indicate number of foreign nationals.

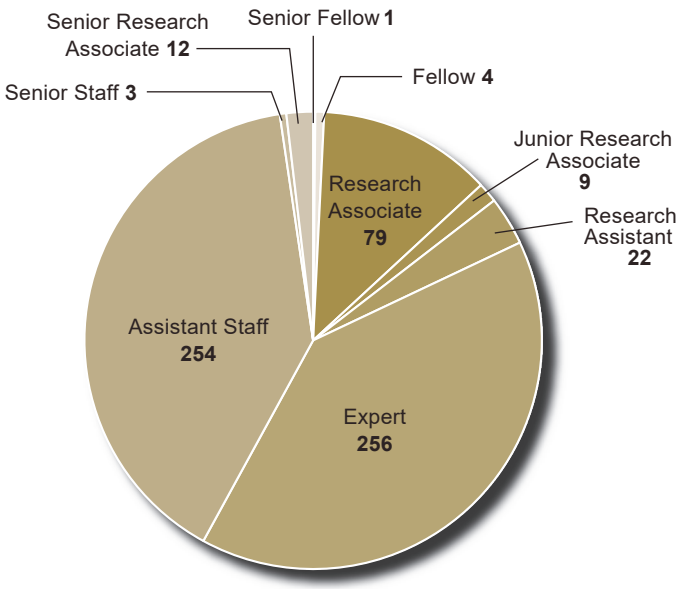


Fig. 4 Contract Staff Breakdown

Visiting Researcher	206	(20)
Collaborative Researcher	85	(14)
Research Student	37	(11)
Interns	10	(6)
Total	338	(51)

Notes:

1. Data is the total number accepted in FY2022.

2. Figures in parentheses indicate number of foreign nationals.

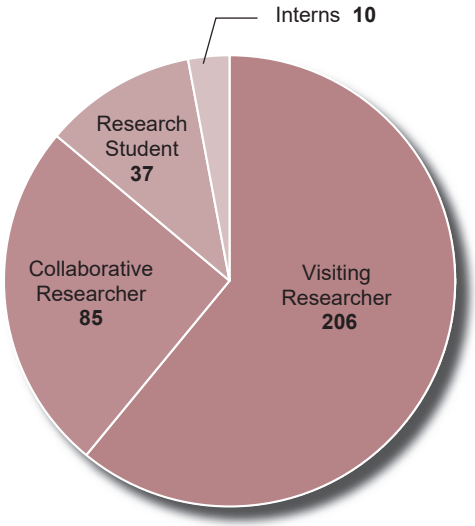


Fig. 5 Visiting and Collaborative Researchers, Research Students, and Interns

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).

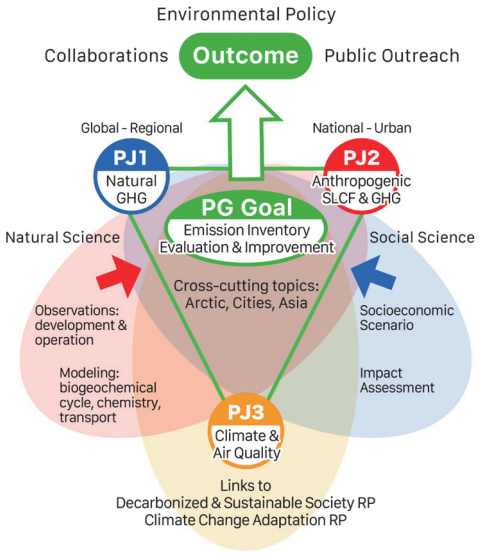


Fig.1 Conceptual schematic of the Climate Change and Air Quality Research Program. PG, Program; PJ, project

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 carbon (C) and nitrogen (N) dynamics associated with human activities.

We incorporated a novel set of inversion schemes into a state-of-the-art inverse analysis system named NISMON-CO_2 (Nonhydrostatic Icosahedral Atmospheric Model-based Inverse Simulation for Monitoring CO_2). The schemes include a grid conversion, observational weighting, and anisotropic prior error covariance.

Moreover, pseudo-observation experiments were performed to examine the effect of the new schemes and to assess the reliability of NISMON-CO_2 for long-term analysis with practical inhomogeneous observations. The experiment results demonstrated the advantages of the grid conversion scheme for high-resolution (1° × 1°) flux estimation (Fig. 2), with notable improvements being achieved by the observational weighting and anisotropic prior error covariance. Furthermore, the estimated seasonal and interannual variations in regional CO_2 fluxes were confirmed to be reliable. These results will therefore be useful for interpreting the flux variations that result from real-observation inverse analysis by NISMON-CO_2 ver. 2021.1 and later versions. Data from NISMON-CO_2 will help us to better understand the mechanisms underlying natural CO_2 flux variations. These mechanisms have remained unclear, resulting in considerable uncertainties in the global warming predictions made by using Earth system models equipped with climate–carbon cycle feedbacks.

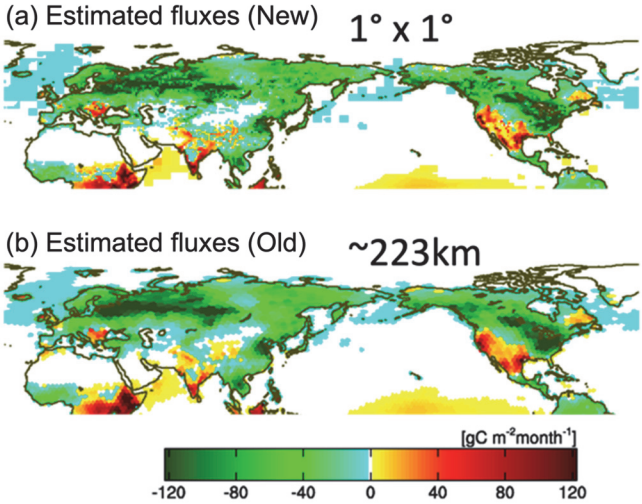


Fig. 2
Distributions of CO_2 fluxes for July 2011 estimated by using the new (a) and old (d) schemes. The white areas depict fluxes close to zero. Fossil fuel emissions, which were not optimized, were excluded.[1)]

Reference:

1) Niwa, Y., Ishijima, K., Ito, A., Iida, Y. (2022) Toward a long-term atmospheric CO_2 inversion for elucidating natural carbon fluxes: technical notes of NISMON-CO_2 v2021.1, *Progress in Earth and Planetary Science*, 9, 42

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 in modeling studies of both climate and air quality. We perform four main activities: (1) expansion of our 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) building of high-resolution inventories.

Urban areas are responsible for more than 40% of global-energy-related CO_2

emissions. We conducted an intensive field campaign in the Tokyo metropolitan area—one of the most populated regions in the world—from February to April 2016 to measure column-averaged dry-air mole fractions of CO_2 (XCO_2) by using three ground-based Fourier transform spectrometers. By combining the XCO_2 observations with high-resolution modeling, we developed an urban-scale inversion system in which spatially resolved CO_2 emission fluxes at >3 km resolution and a scaling factor for large point-source emissions were estimated. The posterior (top-down) CO_2 emissions agreed with the bottom-up data from the ODIAC (Open-source Data Inventory for Anthropogenic CO_2) and MOSAIC (Multiscale Overlap Scheme for Analyzing national Inventory of anthropogenic CO_2) emission inventories in which the large-point-source emissions had been corrected by using the latest official statistics, within the posterior uncertainty (Fig. 3). Operational observations in the Tokyo metropolitan area are being prepared to estimate annual emissions.

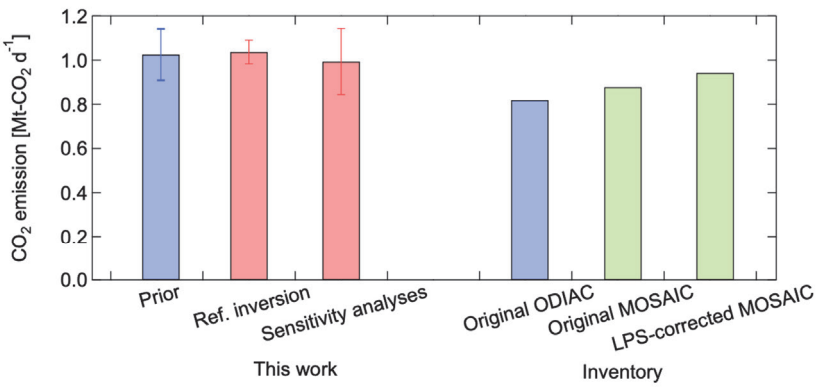


Fig. 3 Comparison of CO_2 emissions in the Tokyo metropolitan area between top-down estimates based on inverse analyses using atmospheric observations at three sites and bottom-up emission inventories. The error bars for the prior and posterior (reference inversion) emission fluxes are the respectively estimated uncertainties, whereas that for the sensitivity analyses is the standard deviation of the results run with different settings. For the ODIAC and MOSAIC data, both original and large-point-source (LPS)-corrected total emissions are shown.[1)]

Reference:

1) Ohyama, H., Frey M. M., Morino I., Shiomi K., Nishihashi M., Miyauch, T., Yamada H., Saito M., Wakasa M., Blumenstock T., Hase F. (2023) Anthropogenic CO_2 emission estimates in the Tokyo metropolitan area from ground-based CO_2 column observations, Atmospheric Chemistry and Physics, 23, 15097–15119, https://doi.org/10.5194/acp-23-15097-2023, 2023.

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.

Future projections of global mean precipitation change (ΔP) based on Earth system models (ESMs) have larger uncertainties than those of global mean temperature changes. We first succeeded in constraining the uncertainty of ΔP. By analyzing the CMIP (Coupled Model Intercomparison Project) Phase 5 and 6 ensembles, we found that ΔP for 2051–2100 was well correlated with the global mean temperature trends during recent decades after 1980 (Fig. 4). Because some ESMs overestimate the observed recent past trend of temperature, the ΔP values of those ESMs are considered less reliable. We can now lower the upper bound of ΔP from 6.2% to

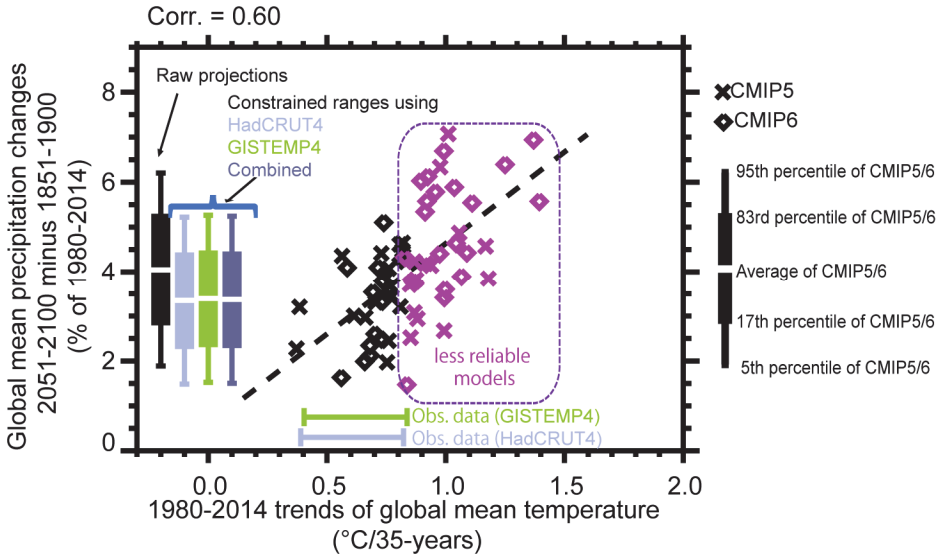


Fig. 4 Observational constraints on ΔP of the CMIP5 and CMIP6 ESMs. There was a significant correlation between past temperature trends and ΔP. Crosses/diamonds in purple denote ESMs for which the past temperature trends were higher than the upper bound of the observed data (HadCRUT4). On the basis of the correlation and the biases relative to the observations, we can lower the upper bound of ΔP.[1)]

5.2%–5.7%. The variance of ΔP can be reduced by 8%–30%. The observationally constrained ranges of ΔP should provide further reliable information for impact assessments.

Reference:

1) Shiogama, H., Watanabe, M., Kim, H., Hirota, N. (2022) Emergent constraints on future precipitation changes, Nature, 602, 612–616. https://doi.org/10.1038/s41586-021-04310-8.

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).

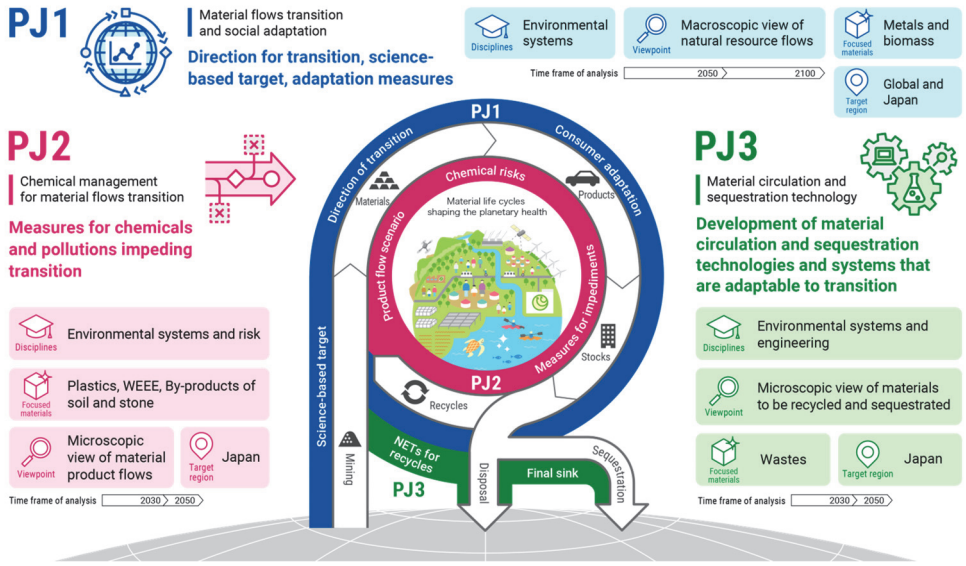


Fig. 1 Overall diagram of the project structure of the Material Flow Innovation Research Program; NETs stands for Negative Emission Technologies

In FY 2022, we promoted the implementation of our research results in society and strengthened our cross-project collaborations. We published animated video clips of our research findings, in addition to scientific papers. We also developed and published free application software for calculating individual carbon footprints. Many organizations, including private companies, industrial associations, and local governments, expressed interest in this tool, and they contacted us for an exchange of views. Some were interested in the nexus of carbon neutrality and material use, and others were interested in using the tool. We engaged experts to organize workshops to strengthen collaboration and mutual understanding among these organizations.

Cross-project collaborations have been strengthened by linking two ongoing areas of research. In accordance with our research plan, Project 2 will assess the potential risks associated with the use of recycled materials, and Project 3 will develop recycling technologies contributing to net-zero carbon emissions. By linking these two areas, we assessed the safety of food-packaging paper containing water repellent with a view to using this paper to produce biochars. Likewise, Project 1 will develop a methodology to detect the possibility of inappropriate international

mercury trade, and Project 3 will examine technologies to prevent the leaching of heavy metals, including mercury. We consolidated the achievements of Projects 2 and 3, and we made recommendations to the Ministry of the Environment of Japan and the Secretariat of the Minamata Convention on Mercury on monitoring and controlling the movement of mercury from wastes into the environment in relation to Article 22 (Effectiveness Evaluation) of the Convention.

Highlighted research findings

Project 1: Material flows transition and social adaptation

We conducted a systematic literature review (meta-analysis) of circular economy strategies and measures to reduce GHG emissions and of methods for evaluating their effects, and we identified specific measures with relatively high backfire risks (i.e., measures that could increase GHG emissions). In addition, by utilizing the carbon footprint reduction potential visualization tool (i.e., software) that we had developed for public use in FY 2021, we developed another web-based application tool that visualizes an individual's carbon footprint and proposes low carbon lifestyle options to elicit behavioral changes in that individual.

We also conducted a systematic literature review of the potential for reducing GHG emissions via circular economy strategies and of methods for assessing these strategies. The cross-sectional review, which covered 10 types of strategies, 103 documents, and 1513 scenarios, found that relatively reliable GHG emission reduction (GHG improvement scores: 0.4 to 1.0; see the left axis of Fig. 2) can be expected from the strategies of "pooling" (simultaneous use), "upgrading" (adding new functions), "refurbishment/remanufacturing," and "repair." For reference, GHG improvement scores give the relative ability of each strategy to reduce GHG emissions, with consideration of the differences between product types. A score of 0 indicates no GHG improvement between before and after the introduction of the strategy. The higher the score, the greater the GHG emission reduction that is achieved, in relative terms, by implementing the strategy.

We found that the strategies of "sharing," "reuse," and "servitization (the use of results-oriented product–service systems)" can produce medium to high GHG emission-reduction effects when properly implemented (GHG improvement scores: 0.7 to 1.0), but these strategies also carry a relatively high risk of increasing GHG emissions owing to backfire effects (proportion of scenarios with backfire effects in the reviewed reports: 10% to 20%; see the right axis of Fig. 2). Factors contributing to the GHG emissions increase included increased frequency and distance of transport, changes in the frequency of product use and product lifetime, imperfect substitution of products, product maintenance, and changes in product use patterns. These results demonstrate that it is important to implement, as far as possible, circular economy strategies with low backfire risks. It also shows the need to prioritize strategies with high GHG emission-reduction potential and low risks and to design appropriate product cycles and services to control backfire effects.

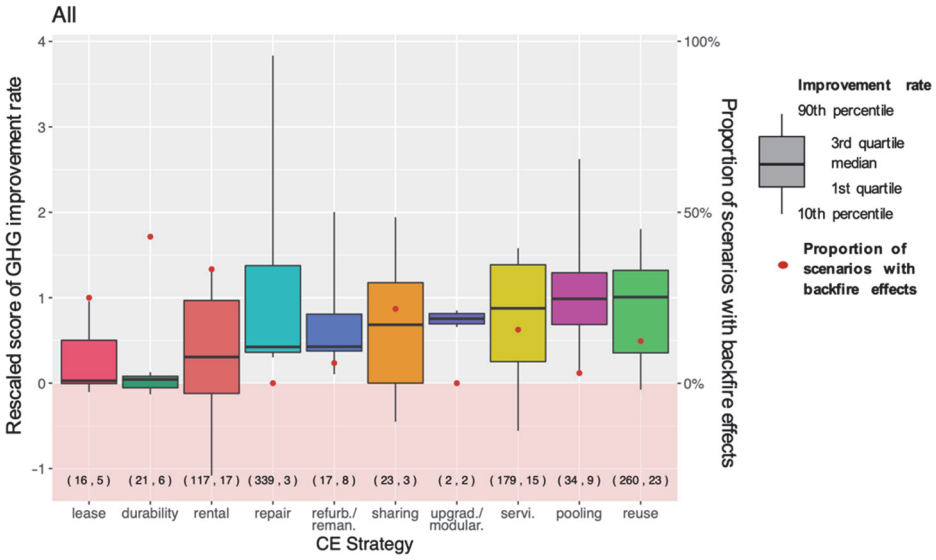


Fig. 2 Impacts of adapting circular economy strategies. Shown are rescaled scores for GHG improvement rates and proportions of scenarios with backfire effects. On the left-hand axis, a value of 1 indicates a GHG emission-reduction rate corresponding to the interquartile range for each product type in the reviewed scenarios.[1)] The first and second numbers in parenthesis refer to the number of scenarios and studies included in each subcategory, respectively.

To elicit changes in human behavior, jointly with a general incorporated association, Code for Japan, we developed a web-based application software ("*Jibun-goto* Planet") that visualizes the carbon footprints of individuals and proposes low carbon lifestyle options (Fig. 3). As part of this effort, we devised a new method for estimating an individual's carbon footprint on the basis of a database ("Carbon footprints in 52 Japanese cities") that we developed in 2021.[2)] Upon responding to questions in the four areas (i.e., mobility, housing, food, and goods and services), this software estimates an approximately 40-item user-specific carbon footprint per person per year and compares it against Japan's national average. Further, based on the user's carbon footprint estimation, it presents a list of personalized low-carbon actions out of a total of over 30 actions so that the user can select an implementation rate in the range from 25 to 100%. The source code and data sets have been made available free of charge as open source tools, and the software is expected to encourage various entities, such as companies and local governments, to make more efforts toward a decarbonized society.

Fig. 3 Screenshots from a web-based application for visualizing individual carbon footprints (https://jibungoto-planet.jp)

References:

1) Koide, R., Murakami, S., Nansai, K. (2022) Prioritising low-risk and high-potential circular economy strategies for decarbonisation: A meta-analysis on consumer-oriented product-service systems. *Renewable and Sustainable Energy Reviews*, 155, 111858
2) Koide, R. Kojima, S., Nansai, K. Lettenmeier, M., Asakawa, K., Liu, C., Murakami, S. (2021) Exploring carbon footprint reduction pathways through urban lifestyle changes: a practical approach applied to Japanese cities, *Environmental Research Letters*, 16, 084001

Project 2: Chemical management for material flows transition

From among the 20 chemical substances we had identified in 2021 that potentially harm the environment and hinder plastic recycling, we chose to investigate the chlorinated paraffin (CP) concentrations in PVC (poly vinyl chloride) products. CPs are highly complex mixtures of polychlorinated alkanes, and they have been produced and used in large quantities in paints, plasticizers, flame retardants, and metal-working fluids and lubricants. There are different types of CPs according to their carbon chain length: short-chain CPs (SCCPs), medium-chain CPs (MCCPs), and long-chain CPs (LCCPs). Of these CP types, SCCPs are listed as a persistent organic pollutant (POP) in Annex A of the Stockholm Convention on POPs, which requires parties to eliminate its production and use. However, sufficient knowledge has not been obtained globally on the actual CP concentrations in products. Therefore, we randomly purchased electrical and electronic cables, toys, children's products, and house interior products in Japan, and we investigated the CP concentrations in 87 soft PVC samples taken from these products. SCCPs or MCCPs were detected in approximately half of the samples (n = 42, SCCP content from 1.3 to 120 000 mg/kg, MCCP content from 1.2 to 59 000 mg/kg), and everyday products contained CPs (Fig. 4).

Four of the cable sheath samples and 10 of the toy and children's product samples

contained more than 100 mg/kg of SCCPs, exceeding the low POP content values (100 or 10000 mg/kg) proposed by the Parties to the Basel Convention. Furthermore, three of these samples contained more than 10 000 mg/kg of SCCPs. The highest CP concentration (sum of SCCPs and MCCPs) detected was 15% by weight (150 000 mg/kg). In general, the plasticizer content of soft PVC is 10% to 60% by weight, but most of the product samples that contained CPs in this study had concentrations less than 10% (sum of SCCPs and MCCPs). It is possible that small amounts of CPs were added to some of these products as secondary plasticizers to improve quality, or that unintentional contamination by CPs occurred during the production processes. We also found that many products contained both SCCPs and MCCPs. This implies that the carbon chain length is not being considered when some CP technical mixtures are produced, resulting in the inclusion of both SCCPs and MCCPs. It should be noted that many of the PVC products containing CPs are imported from abroad and sold in the Japanese market. The above results suggest that high-purity CP technical mixtures need to be produced and used widely to prevent SCCP contamination of products, recycled resources, and waste.

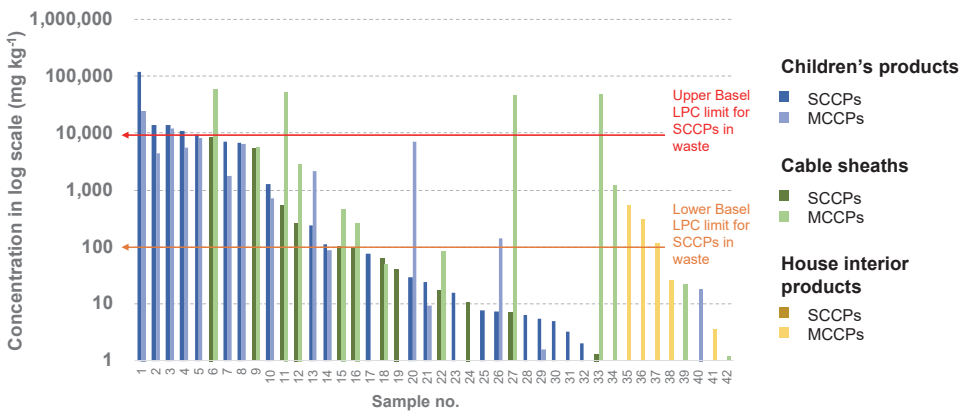


Fig. 4 SCCP and MCCP concentrations in soft PVC products. LPC, low persistent organic pollutant content

In addition, we also acquired data on the content of PFAS (polyfluoroalkyl substances) in waterproof textiles and food-contact materials, as well as environmental safety quality data on 31 chemical substances contained in recycled construction materials. As an example of the need to respond to more stringent regulations, we also reviewed the impact of potentially more stringent environmental standards for hexavalent chromium on the material flows of recycled construction materials. Furthermore, a model was developed to simulate the degradation and fragmentation behaviors of plastics and the transfer of plastics to the environment through disposal and recycling processes. We also investigated the behavior of microplastics released from waste plastic material recycling processes as a basis for creating the parameters to be incorporated into the model.

Project 3: Material circulation and sequestration technology

We clarified the relationship between the properties of biochar generated from

forestry waste by pyrolysis in a laboratory apparatus and the effect of the biochar on fatty acid biodegradation. In the pyrolysis of forestry waste, raising the treatment temperature from 400 to 800 °C increased the specific surface area of the biochar by up to 30 times, from 9 to 272 m^2/g (Fig. 5, top panel). The peak current through electron transfer at the solid–liquid interface was detected only at 800 °C (Fig. 5, center panel) when the biochar was used as a working electrode for cyclic voltammetry (CV). When the biochar was produced in the presence of alkali metal carbonates such as K_2CO_3, Rb_2CO_3, or Cs_2CO_3, its porosity and hydrophilicity were improved. In concrete terms, the specific surface area of the biochar produced at 800 °C with the addition of K_2CO_3 was approximately 700 m^2/g—more than twice that without an additive—and the peak current in the CV using a redox couple was more than tripled (Fig. 5, top and center panels). The amount of water vapor adsorption was also approximately tripled. Digestion experiments suggested that addition of the K_2CO_3-modified biochar produced at 800 °C accelerated the anaerobic biodegradation of fatty acids (substances that inhibit CO_2-methane conversion) by 1.4 times (Fig. 5, bottom panel). The results showed that the biochar achieved a high specific surface area and high electron transfer efficiency at high temperature and with the addition of K_2CO_3; these two additives improved the digestion performance through microbial electric symbiosis and thus accelerated the degradation of substances that inhibit methane production.

We examined hazardous metal insolubilization treatment by using diatomite containing a high concentration of amorphous silica as an alternative to cement. Incineration fly ash was cured in moist conditions at 25, 50, and 70 °C with the addition of diatomite. The results showed that $Ca(OH)_2$ and CaClOH (calcium chloride hydroxide) contained in the fly ash reacted to form calcium silicate hydrate. The longer the curing period and the higher the curing temperature, the lower the lead concentrations in the leachate became. When the fly ash was cured at 70 °C for 14 days with the addition of 10 wt% diatomite, the concentrations of lead in the leachate fell below 0.3 mg/L (the standard for controlled landfill sites in Japan), by more than 99%. Sequential extraction analysis of the cured fly ash showed that the content of water-soluble lead decreased through pozzolanic reaction and the lead became insoluble. These results indicate that waste containing amorphous silica can be utilized as an insolubilizer for incineration fly ash as an alternative to cement. This will enable fly ash containing lead to be disposed of at controlled landfill sites, and it may help to reduce the amount of fly ash delivered to more strictly controlled landfill sites with shielding structures.

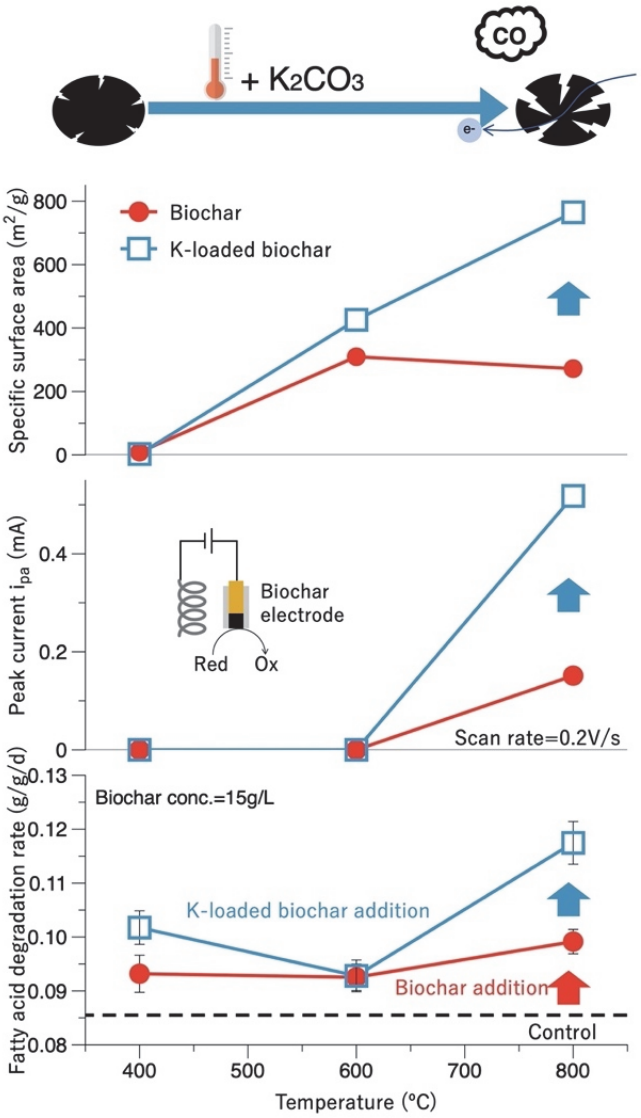


Fig. 5 Pyrolysis temperature and (Top) specific surface area of forestry-waste-derived biochar with and without the addition of K_2CO_3; (Center) peak current derived from redox at the solid–liquid interface; (Bottom) impact of biochars on fermentation improvement

Comprehensive Environmental Risk Research Program

In this program, we conducted five projects to accomplish our annual goals. We aimed to more comprehensively investigate the environmental risks of all chemicals of concern and to consider vulnerable groups and life stages of humans (Project 1) and those of other organisms (Project 2). We also upgraded our comprehensive measurements of the pollutome (Project 3) and mathematical models of the environtmental fate of chemicals (Project 4) to better assess the fate and transport of these chemicals, as well as the effects and risks that have been hard to quantify. As result of these efforts, we started a discussion to establish comprehensive health risk indexes and ecological risk indexes (Project 5).

In the second year of this Research Program we emphasized inter-project cooperation. For example, through cooperation between Projects 1 and 5, we developed a comprehensive health risk index based on the immunological effects of bisphenol A and related alternatives. Moreover, through cooperation between Projects 2 and 3, we conducted an effect-directed analysis to identify the major toxicants in river water samples. In addition, as a result of cooperation between Projects 2 and 4, we discovered that the dissolved concentration of chemicals in the pore water of sediments could be key to a better understanding of the toxic effects of these chemicals in a freshwater amphipod species. The method developed in Project 4 for predicting the distribution of the production volumes and release of chemicals all over the world helped to start our discussion on developing a comprehensive ecological risk index in Project 5. Projects 2 and 5 also cooperated in a preliminary survey on the nickel-related decrease in the number of species (Fig. 1).

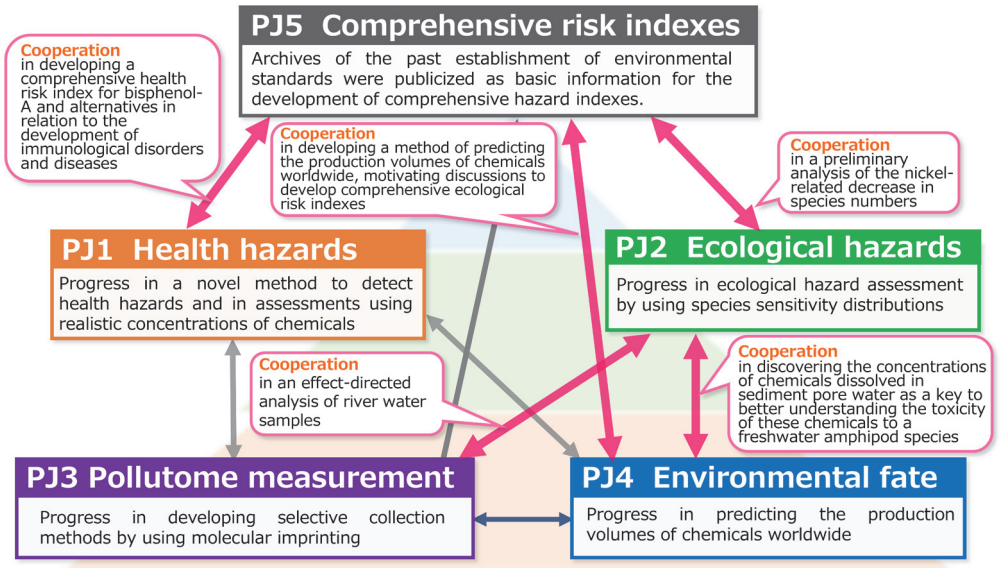


Fig. 1 Overview of inter-project cooperations started in the Comprehensive Environmental Risk Research Program

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

We established methods for assessing the human health hazards of chemicals, taking into account exposure in the general environment and vulnerable populations, and we evaluated the effects of chemicals on disease, aging, and future generations. In addition, in collaboration with Project 5, we analyzed the scientific evidence gathered in the previous fiscal year on the effects of bisphenols on disease. Our major research findings (related to neurodevelopmental disorders, allergic asthma, cardiovascular disease, and effects on future generations and aging) were as follows.

By using a human neuronal cell line, we observed the suppression of neurite outgrowth by insecticides, such as rotenone and carbaryl (Fig. 2), and brominated flame retardants. In an *in vivo* developmental neurotoxicity study, we investigated the effects of perinatal exposure to homologs of polyhalogenated dibenzofurans. We found that, in newborn mice, exposure suppressed ultrasonic vocalization—an indicator of social communication.

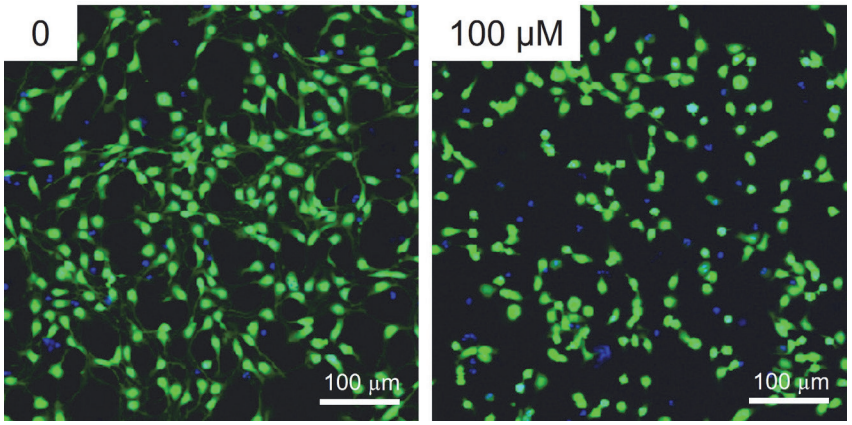


Fig. 2 Suppression of neurite outgrowth by carbaryl in a human neuronal cell line

We found that oral exposure to bisphenol F induced eosinophilic lung inflammation and the production of antigen-specific IgE and IgG_1 in a mouse model of allergic asthma. We also found differences in the relative frequencies of specific gut bacteria. We started to evaluate the effects of oral bisphenol S exposure on aging and age-related diseases by using senescence-accelerated mice (SAMP8). A memorandum of agreement was signed with Universiti Sultan Zainal Abidin, Malaysia, to conduct an international collaborative study on the effects of gestational exposure to air pollutants.

A study with a cardiovascular disease endpoint using neonatal mice found that inhalation of diesel exhaust particles impaired cardiac function, leading to the aberrant expression of uncoupling protein 3 (Ucp-3), which is a thermogenic proton carrier that bypasses ATP synthesis. To examine the effects of TDCIPP, an organophosphorus flame retardant, on future generations, we have started investigating the toxicity of this chemical in mouse preimplantation embryos. TDCIPP had little effect on blastocyst formation.

Project 2. Ecological hazards and factor analysis considering vulnerabilities

Fisheries-independent bottom-trawl surveys have been conducted along the coast of Fukushima, Japan, since October 2012 to study the megabenthic community structure after the 2011 earthquake, tsunami, and nuclear disaster. An analysis 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) showed that there has been a decreasing trend in total population densities since 2013, especially in the case of crustaceans, echinoderms, and certain fish species (Fig. 3). Although no substantial changes were observed in total biomass until 2020, total biomass seems to also have decreased thereafter, primarily because of a decrease in the biomass of fishes, such as elasmobranchs. Our results suggest that there has been no recognizable recovery in the megabenthic community despite the limited activity of commercial fisheries in Fukushima, and they also imply that megabenthic species might have been experiencing reproductive or recruitment failure. Recently, the temperature of the waters off Sanriku, including the coastal waters off Fukushima, has gradually been increasing. High water temperatures could have negative impacts, for example, on the survival of the early life-history stages of megabenthos. Additional research is needed to elucidate any reproductive or recruitment failure and to reveal the factors causing these

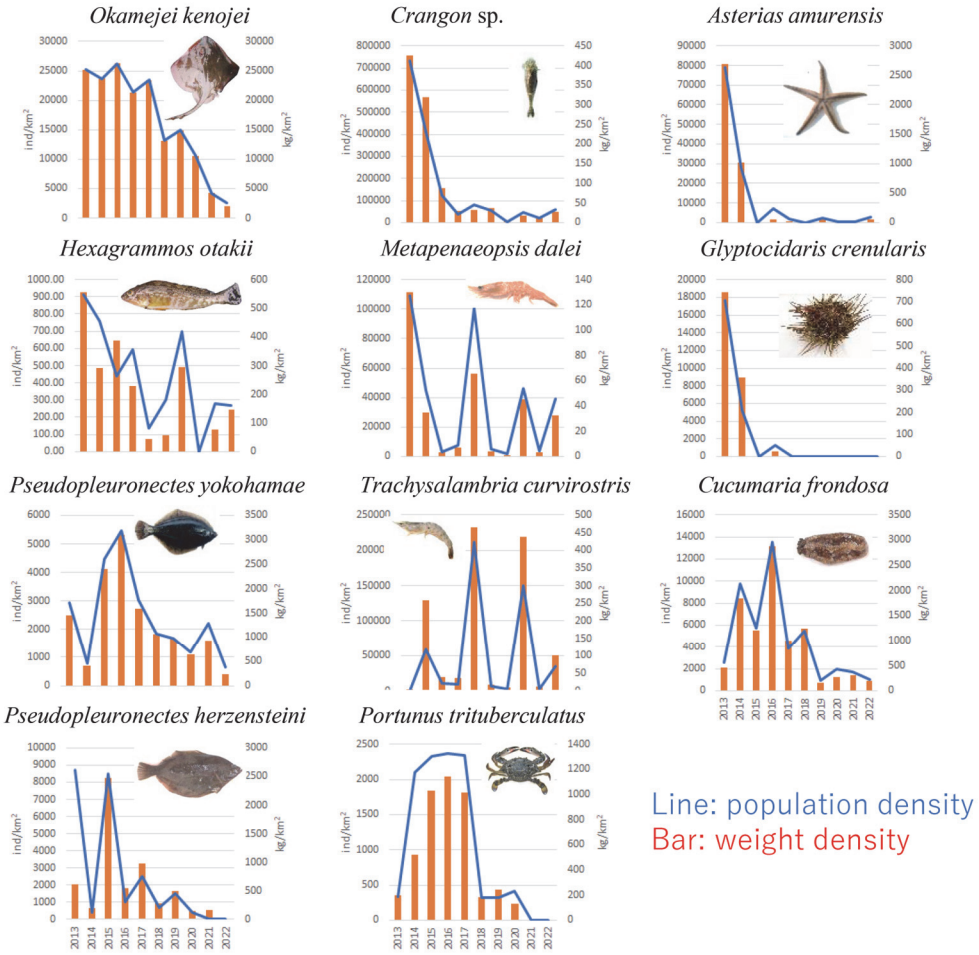


Fig. 3 Temporal changes in population and weight densities of major species of the megabenthic community in the coastal waters off Fukushima after the 2011 earthquake, tsunami, and nuclear disaster. Average densities were recorded at nine sites in the north, central, and southern Fukushima coastal waters in winter and summer surveys.

phenomena in the megabenthic communities, including those of crustaceans and flounders, in the coastal waters off Fukushima.

We continued to conduct chronic bioassays using daphnid and alga for 16 river water samples collected from all over Japan this year, and we performed comprehensive multi-target chemical analyses using inductively coupled plasma mass spectrometry (ICP-MS) and automated identification and quantification systems with gas chromatography–mass spectrometry (AIQS-GC) to identify major toxicants and possibly determine their contributions to toxicity. Some metals and pesticides were suspected as major toxicants, but we also found uncertainty, mainly due to the lack of toxicity data for the identified chemicals. We are continuing to conduct effect-directed analyses of the river water samples by fractionation and bioassays for the fractions, combined with chemical analyses.

We also continued to focus on vulnerable species by the use of species sensitivity distribution (SSD). A comparison of the hazardous concentration for 5% of species (HC5) across a diverse range of 104 chemicals revealed no significant difference between freshwater and marine species. On the other hand, we continued to investigate the SSD of the transformed compound of an antioxidant in tire rubber, 6PPD quinone (6PPD-Q), which was found to be highly toxic to one of the salmonid species studied. Although we had found no substantial acute toxicity of 6PPD-Q toward typical model aquatic organisms such as medaka and *Daphnia magna*, we found toxicity to one native Japanese salmonid species but a lack of toxicity to the other two. Analysis of the accumulation of 6PPD-Q in the gills and brain and of genetic differences revealed no significant correlations. We are continuing to investigate the reasons for the differences in toxicity among species.

We developed an ecological impact assessment method to quantify changes in the interstage flows of individuals between developmental stages as a result of environmental factors. This method incorporated interstage flow matrices into a life table response experiment. We can decompose the population growth rate into interstage flow matrix elements. Hence, even if environmental factors have the same effect on the population growth rate, the method we developed can be used to quantify different environmental effects on interstage flows; these different effects could affect the ecosystem differently. We intend to apply this ecological impact assessment method to risk assessment for multiple chemicals.

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 and establish a scheme that will help search for causative factors when new effects become apparent.

As part of developing a selective method for collecting substances with a common structure, we have investigated the use of molecularly imprinted polymer (MIP) mimicking the thyroid hormone receptor (hTR) to investigate a method of purifying substances that bind to the hTR. The relationship between TR-binding activity and the retention factor (k') ($(t_R-t_0)/t_0$, t_R: retention time of the compound, t_0: hold-up time, is the time when the peak top of a component not retained in the column appears) was investigated by using an MIP-packed column with thyroxine (T4) as a template. Various mobile phase conditions were investigated, and a positive correlation between the activity and k' was observed when methanol–acetonitrile at 50/50 (v/v) was used (Fig. 4).

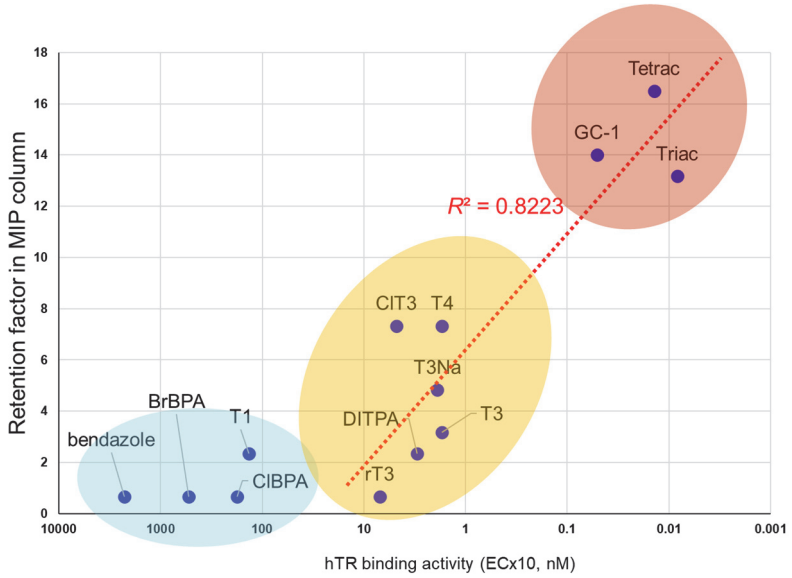


Fig. 4
Correlation of retention factor and hTR binding activity in an MIP column

Column: MIP for hTR, 4.0-mm i.d.×50 mm
Mobile phase: acetonitrile – H_20 = 50/50 (v/v)

To develop a method of analyzing groups of substances with similar structures in GC-MS measurement data, we decided to apply a mass spectral feature networking technique to the GC-MS spectra. In this method, data are networked on the basis of the similarity of their mass spectra; the spectral information on the unknown compounds is arranged, and a structural analysis is performed. On the basis of this, we started to develop a method for comprehensively extracting structural information (e.g., the compound class, structural similarity, and partial structure) of many unknown compounds in samples.

In proposing new analytical methods for difficult-to-measure substances, we have been developing a water quality analysis method for perfluoroalkyl and polyfluoroalkyl substances (PFASs). This year, we developed a solid-phase extraction cartridge method for nine neutral PFASs (FBSA, FHxSA, FOSA, N-MeFBSA, N-MeFOSA, N-EtFOSA, N-MeFBSE, N-MeFOSE, N-EtFOSE) and five zwitterionic PFASs (6:2 FTAB, 5:3 FTB, 5:1:2 FTB, N-AP-FHxSA, and N-TAmP-FHxSA).

Project 4. Modeling the environmental fate of the pollutome

In this project, we are developing methods of deriving 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 enable us to perform more reliable simulations and future predictions.

We estimated the global chemical production volume distribution. We also constructed a simple regression model to estimate emission factors on the basis of limited data on about 2609 substances for which both production volume and emission factor were available or could be estimated. In the future, a model for estimating ecotoxicity values will be constructed, and comprehensive ecological risk indicator values for all chemical products will be estimated by Monte Carlo simulations using these models.

We updated our global model for chlorinated and brominated organic compounds so as to be able to perform future simulations. This fiscal year, we performed simulations for the years 1930–2100 for selected polychlorinated biphenyl (PCB) congeners for which gridded global emission inventories are available. The simulated global contents of ΣPCBs in the lower troposphere and upper ocean will decrease to 10% by 2035 and to 1% by 2044, as compared with that in 2010. On such a multi-decadal timescale, we could not find any significant impacts of climate change on the global contents of ΣPCBs.

The bioaccumulation behavior of ionizable compounds—perfluoroalkyl acids—in the aquatic food web was mathematically modeled. Model-predicted concentrations in aquatic organisms were in good agreement with the field observations for medium-chain-length compounds, whereas the agreement was poor for relatively short- and long-chain compounds (Fig. 5). In addition, the sorption of the cationic surfactant benzyldimethyldodecyl ammonium by sediment and its transfer to benthic organisms were investigated. Exposure tests showed that amphipods take up the substance mainly from sediment pore water; our findings suggested that measuring the freely dissolved concentration in the pore water is useful.

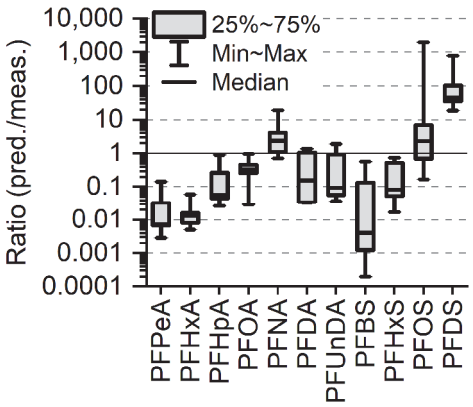


Fig. 5 Comparison of measured (Kobayashi et al. 2018) and model-predicted concentrations of perfluoroalkyl acids in aquatic organisms in the Omuta River estuary

Reference:

Kobayashi J., Maeda Y., Imuta Y., Ishihara F., Nakashima N., Komorita T., Sakurai T. (2018) Bioaccumulation patterns of perfluoroalkyl acids in an estuary of the Ariake Sea, Japan. *Bulletin of Environmental Contamination and Toxicology*, 100, 536–540

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

In this research project, we have organized workshops comprising members who include the leaders of other projects in the Comprehensive Environmental Risk Research Program. In the workshops, we have discussed approaches to comprehensive risk assessment and created a conceptual diagram (Fig.6). In the diagram, we considered two-dimensional approaches to achieving the development of comprehensive risk indexes: one dimension concerns the number of chemicals simultaneously assessed, and the other involves a hazard assessment index. Depending on the risk scenarios, we would take different approaches, ranging from the current regulatory risk assessment scheme to comprehensive risk assessment, including the proposal of comprehensive indexes. For instance, in cooperation with Project 1, we are trying to estimate the health risks posed by exposure to bisphenol A and analogous chemicals by proposing comprehensive health hazard indicators. In cooperation with Project 2, we have investigated preliminary hazard indexes, such as the nickel-related decrease in aquatic species number in Japan. In cooperation with Project 4, we are proposing a different approach. We are planning to estimate comprehensive and (semi-)quantitative ecological risks by using simple regression models that estimate both production volumes and emission factors for various classes of chemicals.

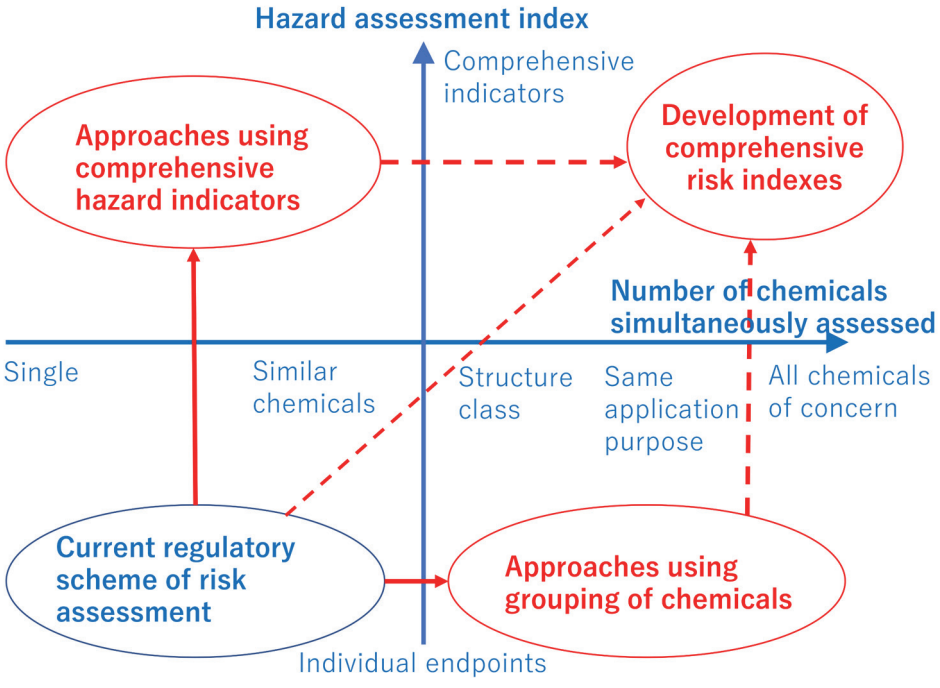


Fig. 6 Conceptual diagram of directions toward the comprehensive assessment of health and ecological risks. Red solid lines imply potentially directly feasible approaches and red dotted lines imply potentially complicated and indirect approaches.

In addition, with the cooperation of the Water and Atmospheric Environment Bureau of the Ministry of the Environment, a website, “Compendium of Reference Materials on the Grounds for the Establishment of Environmental Quality Standards,” has been released (https://www.nies.go.jp/eqsbasis/). The website is presented only in Japanese at present, but the summary parts will be translated into English within a few years. This Compendium has collected and organized approximately 330 original administrative documents and related literature associated with the setting of all environmental standards for air, water, soil, and noise. The Compendium is expected to serve as an important source of information for considering comprehensive environmental risk assessment approaches.

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 2022 were as follows:

Project 1: Sustainable ecosystem management strategies for a society with a declining population
Project 2: Management of ecological risk causative factors that threaten biodiversity and human society
Project 3: Biological responses, acclimations, adaptations, and resiliencies to environmental changes
Project 4: Research on problem solving using ecosystem functions
Project 5: 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.

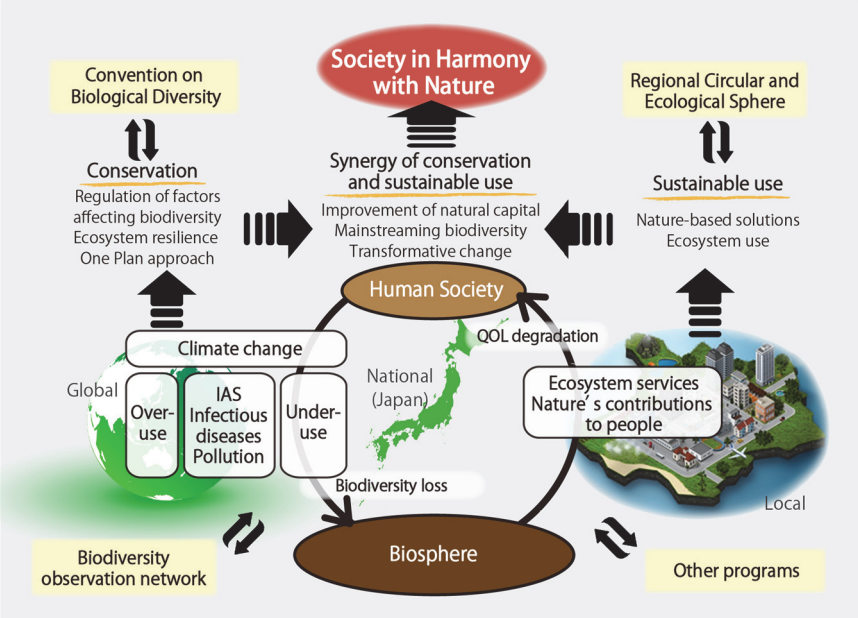


Fig. 1 Overall structure of the Harmonization with Nature Research Program. IAS, Invasive Alien Species; QOL, quality of life

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

To develop national-scale strategies for conserving butterflies that inhabit *satoyama* landscapes, such as ways of selecting effective conservation areas, we need to determine which species decrease (negative impacts) or increase (positive impacts) in abundance in response to land abandonment on a broad scale.

To find a general rule that determines the species-specific response of butterflies to land abandonment, we tested a hypothesis that cold-adapted species (i.e., species negatively affected by high temperatures) tend to be affected negatively by land abandonment. We analyzed the data from a national-scale survey of butterflies in abandoned settlements by using a hierarchical model incorporating correlated responses to multiple environmental factors.

Of the 43 butterfly species observed, negative impacts of land abandonment on occurence were detected in 13, whereas positive impacts were detected in only three species. From the coefficients of mean annual temperture, 15 and 5 species were judged as cold- and warm-adapted species, respectively. There was no clear difference in the occurrence of species between cultivated land and land used for building.

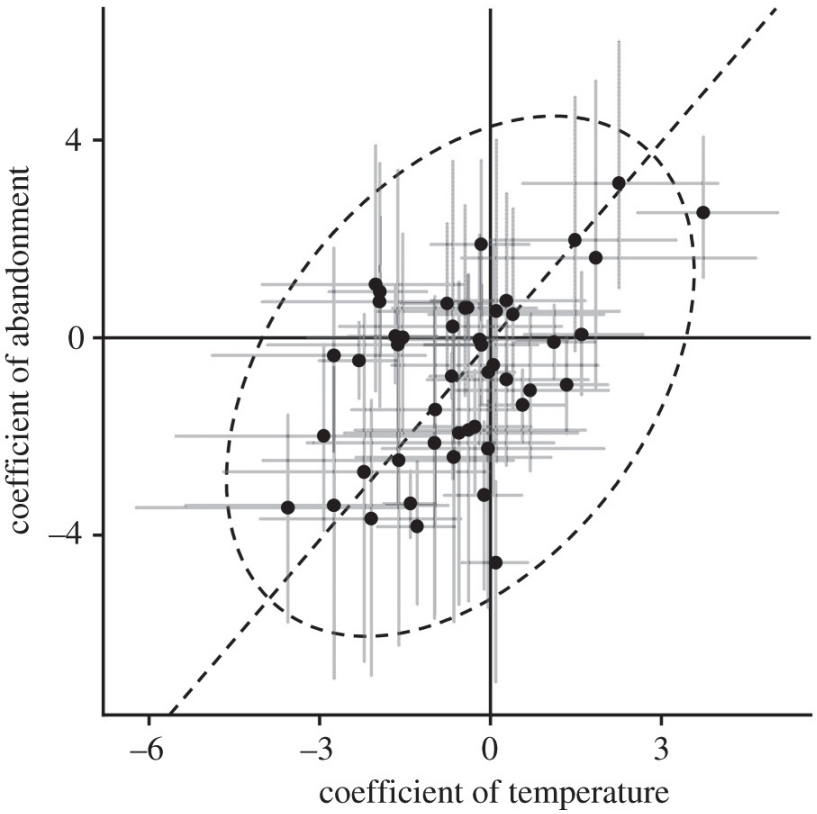


Fig. 2 Relationship between coefficients of mean annual temperature and land abandonment. Black dots indicate posterior means and grey error bars are 95% credible intervals of butterfly species. The dashed ellipsoid is the 95% equiprobability ellipsoid and the dashed line is the principal axis of coefficients.[1)] CC BY 4.0

There was a clear positive correlation between the effects of land abandonment and the mean annual temperature for each species (Fig. 2). This indicates that many of the species that decline because of land abandonment are adapted to cold climates. Comparison by habitat type showed that species that preferred grasslands, farmlands, and urban areas were more negatively affected by land abandonment than were species that preferred other habitat types. However, forest-preferring species were not necessarily positively affected by land abandonment.

Species adapted to cold climates are vulnerable to global warming, and increased land abandonment and global warming will pose dual threats to cold-adapted butterflies. The conservation of rural landscapes will be important for biodiversity conservation under future climate change, as it will provide a chance for climate change adaptation to conserve cold-adapted butterflies. If we can conduct similar assessments on various taxonomic groups, it will be possible to evaluate biodiversity change in response to future changes in population distribution. The results can then be used to select conservation areas.

Reference:

1) Sugimoto N., Fukasawa K., Asahara A., Kasada M., Matsuba M., Miyashita T. (2022) Positive and negative effects of land abandonment on butterfly communities revealed by a hierarchical sampling design across climatic regions. *Proceedings of the Royal Society B*, 289(1971): 20212222

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

Chemical control method for tick populations in the field

Since the first case was confirmed domestically in 2012, severe fever with thrombocytopenia syndrome (SFTS), an emerging infectious disease transmitted by ticks, has been spreading, primarily in western Japan, with the number of infected individuals on the rise. The area of infection occurrence is also beginning to expand eastward.

Recently, ticks have been extending their distribution to familiar green spaces such as parks and farmlands, and this has potentially increased the likelihood of people being bitten. The migration of wild hosts of ticks, such as deer and wild boar, from mountainous areas to lowlands has been highlighted as a factor contributing to the encroachment of ticks, which were originally found in nature-rich wooded mountain regions, upon human society. Furthermore, invasive animals such as raccoons, and pets such as dogs and cats, also serve as hosts for ticks, and pathological investigations have shown that they play a role in introducing ticks and viruses into human habitats.

There are currently no vaccines or specific treatments available for tick-borne viral

infections such as SFTS, and the fatality rates for these infections are high (10 – 30%). NIES is collaborating with Earth Corporation to develop emergency pest-control methods to be applied when there is a massive outbreak of ticks in green spaces such as parks and stadiums.

In FY 2021, through laboratory screening tests of various chemical agents, we selected pyrethroid-like insecticide "E" as the most effective for tick control. In FY 2022, we tested the effectiveness of the insecticide for tick population control in the field. The results were as follows.

Test site: A total of eight tick habitat plots (5 × 5 m each) were selected within a green space at the Earth Corporation Research and Development Headquarters (Akō City, Hyōgo Prefecture). Four of the plots were designated as insecticide-treated areas, and the remaining four were left untreated as controls. Notably, each treated plot and untreated plot were designed to be adjacent to each other.

Test period: 8 August 2022 to 20 September 2022

Tick population measurement: We used a flagging method to perform an initial survey of the number of ticks captured in each test plot. A flag is prepared by attaching a handle to a white flannel cloth 70 cm wide and 100 cm long. The flag is dragged through the grass. The number of ticks attached to the surface of the cloth is measured to determine the density of ticks in the test area. After collection and counting of the ticks on the flag, we released the ticks to their respective test plots. In all test plots, four species of ticks were identified. The total number of ticks ranged from 50 to 600 per plot.

Insecticide treatment: We treated each plot by spraying with 5 L of insecticide "E" emulsion prepared at 100 ppm. Water was sprayed on the control plots.

Insecticide efficacy evaluation: We collected and counted the ticks in each plot by using the above-described flagging method 1 day, 3 days, 1 week, 2 weeks, 3 weeks, 4 weeks, and 6 weeks after spraying of the insecticide. Animal species that appeared in the test area were also recorded by fixed-point videography during the test period.

Results: Deer, wild boar, and civet were observed to enter the area regularly during the study period. Although 50 to 600 ticks were observed in each test plot immediately before the insecticide treatment, the tick density in all treated plots decreased quickly immediately after insecticide treatment and remained at a low density (less than 10 ticks per plot) for the 6-week test period (Fig. 3). The continuous presence of ticks of all stages, from juvenile to adult, in the control plots suggested that animals entering and leaving the test area were a source of ticks. Although tick recruitment was constantly occurring, the tick density was completely controlled in the insecticide-treated plots for at least 6 weeks, indicating that insecticide "E" had extremely high residual efficacy against all tick stages.

From these results, we concluded that insecticide "E" was extremely effective for controlling wild tick populations. The chemical control method tested in this study is expected to become standard for tick control in the field in Japan.

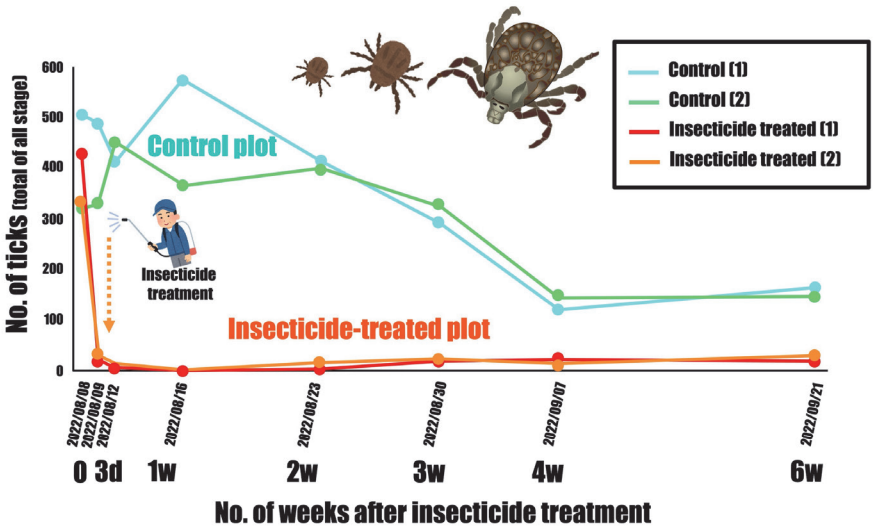


Fig. 3 Tick population dynamics in two insecticide-treated plots and the adjacent two control plots. The number of ticks included all stages of development.

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

Temperature dependence of O_2 respiration in mangrove leaves and roots: implications for seedling dispersal phenology

Seasonal differences in the diaspore dispersal of the mangrove species *Kandelia obovata*, *Bruguiera gymnorrhiza*, and *Rhizophora stylosa* suggest that respiratory energy production and demand may differ as a result of inter-specific differences in the temperature dependence of growth and maintenance processes during seedling establishment. We analyzed the growth, temperature dependency of respiratory O_2 consumption, and amounts of respiratory chain enzymes in seedlings of these species grown at various temperatures, 15°C, 20°C, 25°C, and 30°C. R_{REF}—the respiration rate measured at a low reference temperature of 15 °C—was highest in the leaves of 15°C-grown *K. obovata*, the dispersal of which occurs in the cold season, whereas the root R_{REF} of 15°C-grown *R. stylosa* was 60% of those of the other species, possibly as a result of warm temperatures during theestablishment phase. In the leaves and roots of *K. obovata* and the leaves of *R. stylosa*, the overall activation energy, E_o, changed with the growth temperature and was associated with changes in the ratio of COXII to AOX mitochondrial proteins in two respiratory pathways. However, the E_o of seedlings of *B. gymnorrhiza*, which has a long dispersal phase, was constant and independent of growth temperature. The differences in the temperature responses of seedling respiration and growth among

these three species may reflect the different seasonal temperature ranges of seedling dispersal (Fig. 4) and establishment in each species. The species-specific responses of respiration revealed in this study suggest that the seedling dispersal phenology and growth of the three mangrove species will respond differently to the anticipated temperature changes associated with global warming. The seedlings of *K. obovata* may not necessarily respond to cool temperatures by enhancing R_{15}, whereas the seedling establishment of *R. stylosa* may move to more northern regions in the future under a warmer climate.[2)]

Reference:

2) Inoue T, Akaji Y, Baba S, Noguchi K. (2023) Temperature dependence of O_2 respiration in mangrove leaves and roots: implications for seedling dispersal phenology. *New Phytologist*, 237: 100–112.

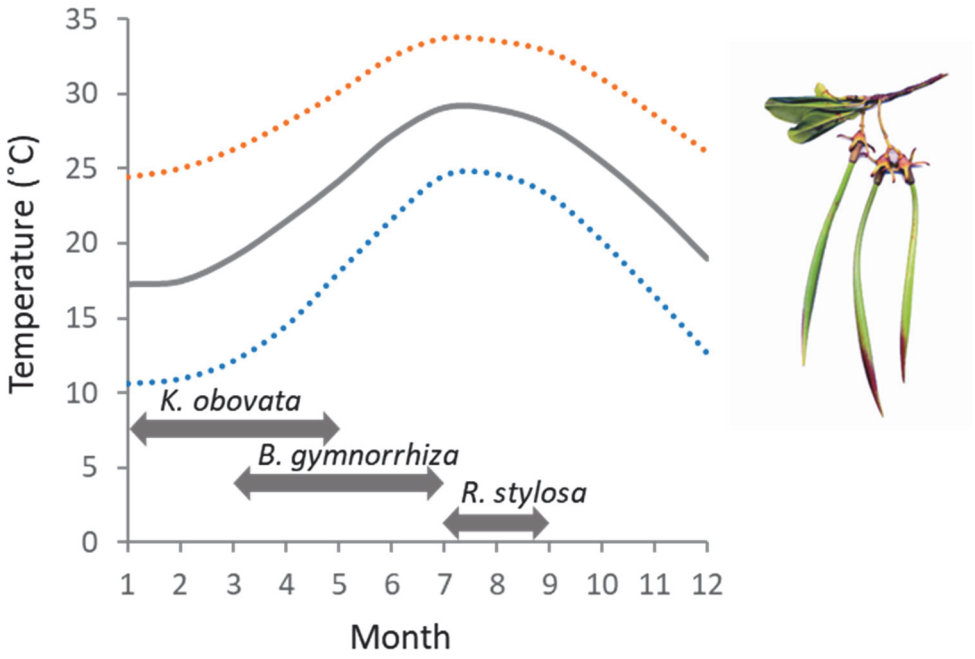


Fig. 4 Air temperature and seedling dispersal ranges of three Rhizophoraceae species in Okinawa, Japan. Solid line, monthly mean air temperature; dashed red line, monthly highest air temperature; and dashed blue line, monthly lowest air temperature during 1990–2020. Arrows indicate seedling dispersal phases of the three Rhizophoraceae species.

Project 4. Research on problem solving using ecosystem functions

Recently, the ability of flowers to attract predators and increase the effectiveness of pest control has been demonstrated in agricultural ecosystems. We tested whether planted flowers function to maintain arthropod diversity and suppress pest infestation in urban parks as well. A study of the rate of feeding of arthropods on cherry leaves in 14 parks in urban areas of Tsukuba and Tsuchiura revealed that the feeding rate decreased significantly during the azalea flowering season. This suggests that azalea flowers attracted predators and increased predation pressure on arthropod pests that feed on cherry leaves.

Management of legacy N accumulated in soils as a result of agriculture is necessary to achieve both efficient agricultural production and environmental protection. Unfertilized lotus fields in the Lake Inba watershed use spring water from the uplands, where an agricultural ecosystem dominates. We confirmed the presence of legacy N in this spring water and found that NO_3-N and total nitrogen concentrations decreased as the water passed through the lotus field (Fig. 5). eDNA (environmental DNA) analysis detected endangered fish species in the lotus fields, suggesting that lotus fields have a moderate fish conservation function. This study is a good example of using a nature-based solution to reduce legacy N (Matsuzaki et al. 2023 Nature-Based Solutions).

Reference:

3) Matsuzaki, S.S, Kohzu, A., Watanabe, M., Kondo, N.I., Tatsuta, A. (2023) Use of legacy nitrogen as a resource: Unfertilized lotus fields contribute to water quality improvement and biodiversity conservation. *Nature-Based Solutions*, 100080. https://doi.org/10.1016/j.nbsj.2023.100080

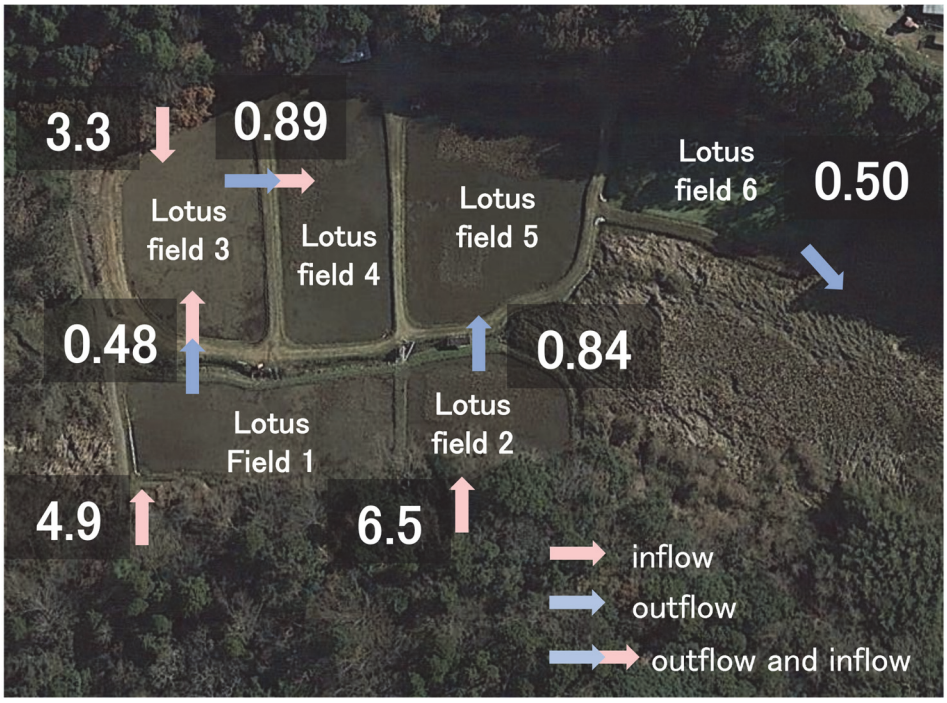


Fig. 5 Nitrate nitrogen concentrations (mg N/L) in inflow and outflow of an unfertilized lotus field in Yatsu. Agriculture is conducted on the plateau surrounding the lotus fields, and spring water from the plateau, including legacy N, is directed to the lotus fields. When the spring water passed through the unfertilized lotus field, the nitrate nitrogen concentration decreased.[3)]

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

To support the formulation of measures to balance the conservation and utilization of biodiversity, we refined tools for planning effective management implementation sites. There are multiple future climate scenarios for predicting the impact of climate change on biodiversity. However, it is unclear which of these scenarios will

be realized, and there are uncertainties in model predictions for future biodiversity distributions. To make measures robust against uncertainties in future scenarios and model predictions, we studied the application of portfolio theory—an economic theory—for conservation prioritization, and we applied it to a case study of climate-change adaptation measures for alpine vegetation in Daisetsuzan National Park in Hokkaido. Alpine vegetation is valuable as both a target of biodiversity conservation and a tourism resource.

Under two climate scenarios—Representative Concentration Pathway (RCP)8.5 and RCP2.6—future climate values from three general circulation climate models (GCMs) were used to predict the future distribution of alpine vegetation by means of a species distribution model. We then used the predicted distribution of alpine vegetation (i.e. two scenarios × three GCMs = six predictions) to select sites for implementation of countermeasures. Possible conservation measures for alpine vegetation against climate change include mowing invading small bamboos as temperatures rise and suppressing trampling by tourists. The measures that will achieve the smallest variance in conservation effects for alpine vegetation among the climate scenarios and model predictions are robust to uncertainty and are desirable. The portfolio theory selects robust sites by combining, at appropriate ratios, sites with different patterns of future changes in areas of alpine vegetation due to climate change. This method has been shown to reduce the variance (risk) of the conservation effects of countermeasures among climate scenarios and GCMs to about 1/10th that with the conventional method (i.e., by using Marxan analysis). However, risk dispersion by combining different sites increased the area of sites for the implementation of countermeasures, and this would increase the cost of the countermeasures.

Therefore, to balance cost and risk reduction, we further conducted a portfolio analysis to minimize the variance in conservation effects per unit cost, rather than minimizing the variance of conservation effectiveness. As a cost, the time required to reach the desired location from the trailhead was considered. We found that the central region—far from the trailhead—was less likely to be selected as the site for implementing countermeasures, whereas the southern and western regions, which were closer to the trailhead and had the next-highest risk-dispersion effect after the central region, were more likely to be selected. As a result, a better balance between cost and risk dispersion was achieved in the prioritization of sites for achieving conservation goals with only a small increase in the variance of conservation effectiveness.

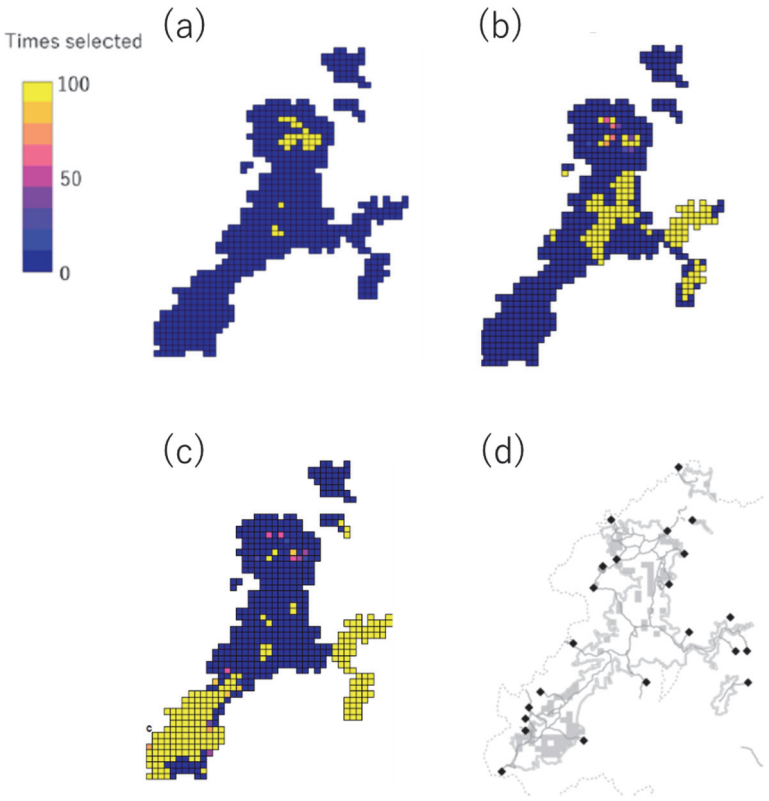


Fig. 6 An example of the spatial arrangement of sites selected by the conservation planning tool to implement measures to conserve alpine vegetation under climate change in Daisetsuzan National Park. (a) with existing methods, portfolio theory (b) minimizing the variability of conservation effectiveness, and (c) minimizing the variability relative to the ratio of conservation effectiveness to cost. Cost is the time required to reach the location from the nearest trailhead (d).

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 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 use 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 2022, we performed analyses by using a technology-oriented global bottom-up model named AIM/Enduse [Global], which covers reduction measures for GHGs and SLCFs from energy combustion and industrial processes. We estimated the global decarbonization scenario required to achieve the 1.5-°C target in which developed

countries will become carbon neutral by 2050 and developing countries by 2060. We also developed a global renewable energy model to estimate the potential of global solar and onshore wind power, taking into consideration technological and economic factors such as improved conversion efficiency and lower technology costs, as well as theoretical factors such as resource information, national land information, and suitable locations. In addition, as part of our analyses of innovative technologies, we not only examined hydrogen production by using renewable energy but also conducted an impact assessment of ammonia co-firing technology for coal-fired power generation; this latter subject has been the focus of much attention in Japan in recent years.

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 2022, we conducted a factor decomposition of global hunger risk under the 2050 decarbonization scenario of the Paris Agreement (Fig. 1). Previous studies have pointed out that rising food prices caused by decarbonization strategies in the agricultural and land-use sectors have the potential to have adverse effects on food security. However, which of the decarbonization strategies (expanding the production of bioenergy crops or large-scale afforestation) would cause a food price increase has not been clarified. Our study showed the extent to which these three factors would change agricultural markets and food security under the decarbonization scenario. The results showed that, compared with baseline, which assumes no measures to reduce GHG emissions, when all three factors were incorporated, international food prices in 2050 would be 27% higher and the number of people at risk of hunger could rise by an additional 110 million from the baseline of about 410 million (the median of the five model results). Of the three factors, we found that large-scale afforestation could have the greatest impact on food security.

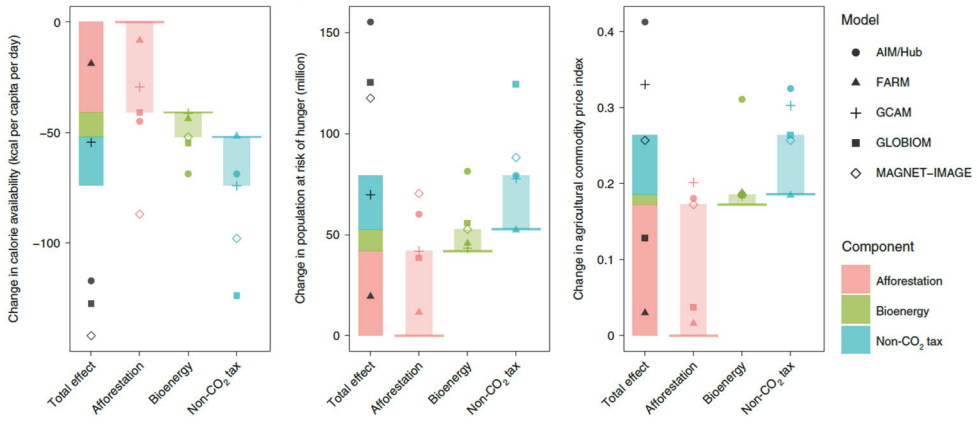


Fig. 1 Decomposition of three factors, namely change in calorie availability (left); change in population at risk of hunger (center); and change in the agricultural commodity price index (right) for the Paris Agreement mitigation scenario under the Shared Socioeconomic Pathway (SSP)2 (“middle of the road”) socioeconomic scenario

Subtheme 3 is developing an Earth–human system model that incorporates a state-of-the-art Earth system model with human activity models that have critical impacts

on climate states and policies on, for example, water use, crop growth, land use, and economic activities. By using the Earth–human system model (MIROC-INTEG-ES), we are investigating the long-term behavior of Earth–human systems under future socioeconomic scenarios, and we are trying to reveal the future social risks of climate change. In FY 2022, we used a part of the model that deals only with land processes (MIROC-INTEG-LAND) to conduct future projection experiments under various climates and scenarios with the aim of further analyzing the interaction between Earth and human systems. We also analyzed the results of future projections using MIROC-INTEG-LAND, together with a model of terrestrial hydrological processes, to estimate the timing of continuous droughts exceeding the maximum ever recorded. In parallel, we continued to develop MIROC-INTEG-ES, and we developed scenarios for long-term future projections (up to 2500 years) and conducted control and historical replication experiments. We also analyzed the CMIP6 (Coupled Model Intercomparison Project Phase 6) Earth system model and performed an unprecedented analysis of the effects of land-use change on carbon cycle feedbacks. To gain an understanding of the societal drivers of past and future climate change, we also assessed the contribution of the world's major countries and industrial sectors to climate change in the form of radiative forcing, and we discussed the importance of international community coordination on residual carbon budgets. We also investigated the future of permafrost, which will play a critical role in future changes in the Earth system. We used 1-km-resolution climate scenarios to estimate the current distribution of permafrost across Japan and to project its future. We showed that permafrost may exist at previously unobserved sites and that its extent is likely to be substantially reduced by climate change.

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 Asian countries will be quantified. For Japan and some Asian countries, 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, that are consistent with achieving the 1.5-°C 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 2022, we updated our analysis by using our power plant model to evaluate the availability of

renewable energy for Japan considering the hourly supply and demand of electricity. We also analyzed the impact of Japan's hydrogen production—which is regarded as one of the key technologies for achieving a decarbonized society—on the renewable energy supply. The results of this analysis suggested that, in order to expand Japan's renewable energy supply—especially offshore wind power—it is important to combine measures such as hydrogen production from surplus electricity, as well as to promote the use of storage batteries. Coinciding with the release of the IPCC Sixth Assessment Report Working Group III in April 2022, an explanatory video on its Summary for Policymakers, along with other materials, was prepared and was made available on the NIES website (https://www-iam.nies.go.jp/aim/ipcc/index.html).

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 aspects of 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 the institutional and technical issues faced by each country in formulating long-term development strategies. In FY 2022, we developed models for the iron and steel sector in China, the residential sector in India, and food production sectors in Indonesia. For example, we improved a passenger and freight transportation model, combined with AIM/Enduse, that covered 31 provinces in China, and we analyzed decarbonization policy packages by using an "Avoid-Shift-Improve" framework with the aim of achieving carbon neutrality by 2060 in China. We found that, by combining all decarbonization strategies (i.e. avoid, shift, improve) and instruments (i.e. technology, regulation, information, price), CO_2 emissions in the transportation sector can be reduced by 58% by 2030 and up to 81% by 2060 compared with the baseline (Fig. 2). In addition, we have been contributing to developing countries in Asia by using AIM models and scenarios. For example, in November 2022, the Thai government submitted a revised long-term low GHG emission strategy to the Secretariat of the United Nations Framework Convention on Climate Change, and the AIM models were clearly stated in this strategy.

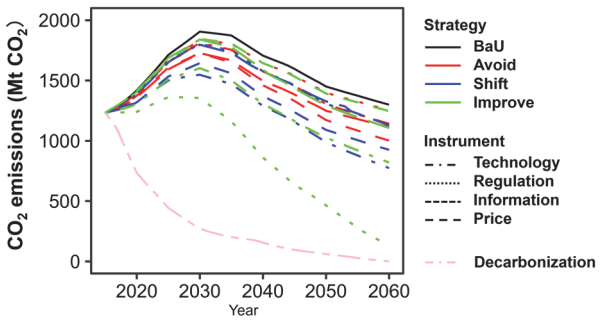


Fig. 2 CO_2 emission projections in the transportation sector from 2015 to 2060 in China. BaU, business as usual

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: norms, indicators, institutions, and surveys. These elements are intertwined; subtheme 1 addresses mainly norms and indicators for intergenerational equity and justice, and subtheme 2 addresses institutions and surveys for the benefit of future generations.

In **sub-theme 1**, an evaluation matrix for normative discussion was developed in order to incorporate the normative and ELSI (Ethical, Legal and Social Issues) perspectives into environmental policy evaluation. The matrix is based on the risk pathway–target, which consists of three main normative evaluation axes (well-being, equity/rights, and intrinsic values such as culture and nature), along with the pathway through which policies affect risk magnitude. A workshop that used the evaluation matrix for normative discussions found that, if social change is undertaken in a way that respects diverse values, the transition to a decarbonized society will take a long time; moreover, in some cases, it may be impossible to achieve consensus. We derived a sustainability indicator that expresses the investment per capita and wealth per capita required to sustain consumption per capita theoretically (the extended Hartwick's rule); we found that current and future population projections affect sustainability. However, application of the indicator to recent empirical data on genuine savings showed that actual investment might have been insufficient in some countries where future population growth is expected and where the gap between consumption and wages is large.

In **sub-theme 2**, we continued our literature review of those institutions considering future generations, and we updated the typology of these institutions. In addition, because traditional methods of deliberation involve only those members of the public who can participate on the time and day of the meeting, they may fail to reflect diverse perspectives, including multi-generational perspectives. We therefore examined using a digital democracy platform that has fewer restrictions. Although the platform can improve public representativeness, limitations remain in terms of the validity of the opinions expressed, such as whether the participants are able to speak for future generations. We analyzed the results of an Internet survey we conducted the previous year to determine, in a two-choice question, the degree to which Japanese would like to preserve their local resources for future generations, as well as to find out what personal attributes influenced their choices. The influence of time perspective scales was greater than that of demographic attributes (e.g., gender and age). In particular, the altruism scale had the greatest influence on the decision to sustainably pass on local resources, resulting in a positive impact, whereas the future neglect scale had a significant negative impact on this decision (Fig. 3). We also surveyed the length of time into the future people thought about in their decision-making, in reality and ideally. We found a three-fold difference in the estimated average number of years between the ideal and the actual. Moreover, on decisions about private matters, the respondents thought that we should

consider 6 to 8 years into the future, whereas on public matters they thought that we should consider about 25 years into the future.

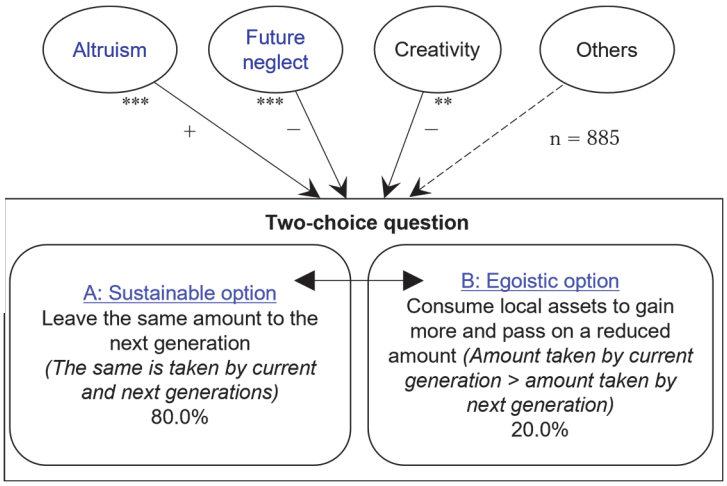


Fig. 3 Factors influencing choices about the preservation of local assets (Asterisks indicate statistically significant effects: ***<0.001, ** <0.01, and * <0.05)

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 evaluation 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

In cooperation with the town of Mishima, in Fukushima Prefecture, we lobbied for formulation of the Mishima Zero Carbon Vision (announced in May 2022), which aims to achieve Decarbonization of the town by 2050, mainly through the utilization of forest resources, and we conducted scenario setting and simulation studies. The Mishima Local Government and NIES then jointly made the Mishima Town 2050 Zero Carbon Declaration. A survey of forest resources was conducted by using UAV (unmanned aerial vehicle) laser measurement technology, and the data obtained were used as a basis for discussions with the departments in charge of both forest boundary delineation and measures to educate forest owners. These results were presented to the Mishima Town Council's Committee for Promotion of a Regional Recycling and Symbiosis Zone. This Committee consists of town officials involved in the utilization of forest resources, with NIES in an advisory role. By using a social impact evaluation method, the Committee started to conduct surveys (e.g., workshops and interviews with local residents) to visualize the multifaceted value of the wood boiler project in Mishima, including the public benefits of the project.

Shiga Prefecture has developed 13 "Mother Lake Goals" (MLGs) for achieving the

conservation of Lake Biwa and realizing a sustainable society around it by 2030. One of the 13 goals is "Goal 2: Restore bountiful seafood ('lake food') resources." At the request of the prefecture, we evaluated the achievement of this goal in the first year. In addition, to help with goal achievement, we accumulated data on the spawning ecology and migration range of the native fishes used as food. Drawing from discussions with stakeholders in Shiga Prefecture and the 2030 MLGs, we conducted a survey of the relationship between the distribution of fish species and water quality. We observed a statistically significant correlation between the habitats of fish species and water quality. We plan to continue collecting data on fish communities and water quality, while exploring what constitutes a balanced water environment from the perspectives of both the ecosystem and water quality.

We aim to provide balanced solutions for multiple environmental issues. We exchanged views with stakeholders in the city of Goto, in Nagasaki Prefecture. Stakeholders in Goto include Goto City Hall, the Chamber of Commerce and Industry, the Agricultural Cooperative Association, the Fisheries Cooperative Association, the Nature Conservation Officer of the Ministry of the Environment, the Nagasaki Prefectural Government, and the Goto branch of the Japan Fisheries Research and Education Agency. In FY 2022, we organized several environmental issues in Goto that had been raised by various stakeholders, and we exchanged opinions on policies to support the resolution of these issues. Issues that NIES can support include (1) decarbonization under population decline; (2) protection and utilization of nature; (3) issues with vacant housing; and (4) maintenance of living infrastructure such as wastewater and waste treatment and transportation networks. We intend to discuss these issues with the abovementioned stakeholders, and support specific solutions.

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

In the promotion of decarbonization, responding to the need for carbon neutrality in raw materials industries is a difficult and important issue for industrial cities. As a measure to help with this response, we proposed a new waste utilization system whereby low-grade combustible municipal waste that is difficult to recycle is transported to an industrial complex in which chemical factories and paper mills are located and is incinerated in a newly built incineration facility to produce steam. This steam is needed in large amounts in plastics and paper manufacturing processes. Furthermore, in the future, we anticipate that a system will be introduced that recovers CO_2 from combustion gas, reacts it with green hydrogen, and recycles carbon into chemical raw materials. Together with multiple local governments and companies, we are promoting the social implementation of such a system. An estimated 220 000 t-CO_2/year emissions can be reduced by supplying steam using 800 t/day of waste as an alternative heat source for production processes that use coal-fired boilers. In addition, we showed that transporting one 40-foot container of low-grade waste to an industrial complex creates about 570 000 yen of added value

owing to the highly efficient use of heat and the scale effect of consolidation. If the transportation cost is lower than this amount, there will be an economic advantage.

Population decline is progressing in rural areas, and this is likely to make it difficult to maintain wastewater treatment, waste disposal, and public transportation operations. Therefore, we estimated the amounts of pollutants discharged in rural areas, collected information and considered measures to enable the operation of sustainable wastewater treatment facilities, conducted research on methane fermentation and composting of waste biomass, and studied sustainable public transportation. In an effort to operate sewage treatment efficiently in Tokushima Prefecture, we evaluated the implementation of a project. This project involved renovating a dilapidated night-soil-treatment facility into a facility for injecting night soil into sewer pipes and accepting it into a basin sewage system with surplus processing capacity. We then gave advice on formulating an appropriate plan in terms of the environment and the economy. As a result, we succeeded in receiving the planned amount of human waste at the facility, thus helping to optimize sewage treatment in the region. In the future, to study sustainable maintenance and management methods for wastewater treatment facilities, we intend to collect and organize information on operational cost issues such as power consumption and surplus sludge generation.

In sustainable waste disposal systems, methane fermentation and composting as a business has led to the increase, decrease, or conversion of capital, and value has been created as an outcome. This created value is supporting sustainable business operations, and we believe that it is the driving force for the participation of stakeholders who may be currently either inside or outside the business. In light of this, we created a guide to promote the implementation of methane fermentation and compositing business among business entities.

We then held a discussion with those managing bicycle use in prefectures where bicycle popularization is advanced (Ehime Prefecture, Ibaraki Prefecture) in regard to the popularization of bicycle culture and education of the public. In addition, we visited the village of Tsurui, in Hokkaido, where the private sector and local government are working together on measures to promote bicycle use on the basis of the characteristics of the region, and we exchanged information on real examples. Through this series of activities, the common needs of regional transportation in different regions were identified and the priority items (e.g., increasing population exchange, improving the health of residents, improving the attractiveness of the region) were determined.

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 Research Program, we intend to 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, this 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, the characteristics of the age–period–cohort effect on population trends by prefecture were categorized. A detailed housing vacancy ratio was estimated and mapped for the city of Goto. Reflections from the 2021 Kawasaki Climate Assembly, where members of the public came together to discuss climate issues, were discussed and widely shared at seminars. We provided information on zero-carbon mobility in Tokorozawa and Musashino, and we coordinated the implementation of a Climate Assembly in the city of Tsukuba.

The Project evaluated the feasibility of decarbonization by 2050 for all (1741) municipalities in Japan by assuming the actions and measures in the national decarbonization scenarios proposed by NIES's Decarbonized and Sustainable Society Research Program. By taking actions such as demand reduction, fuel switch to electricity (electrification), and efficiency improvement on the demand side, as well as the installation of renewable energies and the decarbonization of grid electricity on the supply side, more than 90% of municipalities will reduce their CO_2 emissions by 90% or more by 2050 compared with 2013 levels. In contrast, municipalities with a high share of manufacturing industries, such as chemicals and steel, or non-ferrous and metal products, will not reduce their CO_2 emissions by 80%. Such municipalities will require innovative systems and technologies, including CCUS (carbon dioxide capture, utilization, and storage), to reduce CO_2 emissions in the industrial sector and thus achieve decarbonization by 2050.

The Project studied interregional networks for enhancing the use of electricity from renewable sources, considering the geographical locations of municipalities and the distribution of electricity demand and renewable potential. The study showed that there were various types of interregional networks, depending on the group of renewable energies examined. For example, to maximize the utilization of electricity from four types of renewables (photovoltaics in the residential sector, onshore wind, small and medium hydropower, and geothermal) across Japan, an integrated network would need to be created among Hokkaido, Tohoku, and Kanto is expected in eastern Japan, with a small-scale cluster network in western Japan. When offshore wind power is added to the types of renewables, only Kanto and its surrounding areas, including the Hokuriku area, would be connected; electricity generated in Hokkaido and Tohoku would be consumed within this area.

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

We have been examining and dealing with issues in each of a number of regions, such as the city of Goto. The impact of a declining population, falling birthrate, and an aging population will be an issue in local cities owing to a lack of the labor needed to maintain social infrastructure. Other issues include the aging of septic tank installations for sewage treatment, the maintenance and renovation of incinerators because of a decrease in waste volumes and changes in waste types, and the maintenance of public transportation for use by tourists and local members of the public. Decarbonization issues include grid connectivity and household use of renewable energy. It seems to be difficult for local governments alone to plan and implement concrete plans to be carbon neutral by 2050. To build a sustainable society, it is important to control population decline. Local governments are working to increase populations through migration. The issues are that the retention rate of migrants is low, and an increase in the number of migrants can change the culture and social structure of an area. We have been studying future scenarios. The main issues identified are: 1) an increase in the number of vacant houses and the closing of elementary schools because of a declining population; 2) a shortage of labor to maintain various types of infrastructure; and 3) an increase in the amount of abandoned farmland because of a decrease in the number of farmers. It is important for stakeholders themselves to think about how to create a sustainable society under a declining population. However, at present, most people do not think that this is a major issue, and as a result, little progress has been made.

Environmental Emergency and Resilience Research Program

This relatively 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, considering 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 second year of the program, the following efforts were conducted 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

To achieve final disposal outside Fukushima Prefecture, we presented a method for predicting the mass balance and economic implications of reducing the volume of radiocesium (r-Cs)-contaminated incineration residue under diverse scenarios. The analysis revealed that, in a typical scenario, from 460 000 t of residue, 560 000 t of recyclable molten slag and 42 000 t of melting fly ash that require further treatment are generated by thermal volume-reduction treatment using melting furnaces. The economic assessment indicated that a total of 285 billion yen is required, with approximately 87% of it (248 billion yen) for thermal melting treatment and the remaining 13% (38 billion yen) for further reducing the volume of fly ash. The research not only clarified the quantities and treatment costs of the resulting products and byproducts, but also highlighted potential challenges of their future disposal outside Fukushima Prefecture. In addition, we commenced full-scale embankment experiments for effective utilization of the removed soil and the molten slag as part of joint research with JESCO (the Japan Energy Service Corporation).

2) Development of biomass utilization technology and systems as countermeasures

We investigated the behavior of r-Cs in woody power generation facilities. A mass-balance analysis of r-Cs led to the clarification of the ratio of r-Cs concentration to residue (e.g., biochar from feedstock in the power generation facilities). In addition, the leachability of hazardous heavy metals, as well as of r-Cs, from the residues was determined with a view to their recycling. We found that biochar from a downdraft gasifier can be utilized as a soil amendment to control the level of r-Cs to less than 400 Bq/kg. This utilization can be regarded as a type of carbon storage. These results will be useful in similar facilities under construction in Fukushima Prefecture.

In collaboration with Project 4, we proposed the most feasible biogas method for generating power from local waste biomass, such as the grass cuttings from highway maintenance, which are currently disposed of. Furthermore, we designed a combined system employing the biogas method and a downdraft gasifier using woody biomass as an advanced biomass power generation system. The energy and mass balances, as well as the carbon storage capacity, of the system were estimated.

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

Understanding the seasonality of ^{137}Cs concentrations in aquatic animals is crucial for reviving local inland fisheries. The seasonality of ^{137}Cs concentrations in animals is expected to vary, even if focal species consume similarly contaminated foods, because the ^{137}Cs excretion rate is species specific. Moreover, ^{137}Cs uptake by foraging autochthonous food resources also varies among seasons. Here, we conducted a seasonal monitoring survey of dissolved ^{137}Cs concentrations in a stream connected to a dam reservoir as an indicator of the contamination level of food resources. At this site we also measured ^{137}Cs concentrations in two carnivorous aquatic animals (*Palaemon paucidens* and *Rhinogobius* sp.) that shared a trophic niche. The dissolved ^{137}Cs concentration had clear seasonality: high in summer and low in winter. The ^{137}Cs concentration in the animals had different seasonal patterns—it peaked in October in *P. paucidens* and peaked in February in *Rhinogobius*. Overall, the ^{137}Cs concentration was higher in *P. paucidens* than in *Rhinogobius*, suggesting that *P. paucidens* has a lower excretion rate than *Rhinogobius*. Consequently, the seasonality of the ^{137}Cs concentration in *P. paucidens* showed temporal changes similar to those of the dissolved ^{137}Cs concentration, which were likely affected by ^{137}Cs uptake through foraging, whereas those in *Rhinogobius* were controlled by ^{137}Cs excretion. This study thus shows that the seasonality of ^{137}Cs concentration can differ between sympatric animals that share a trophic niche. Accumulating knowledge and comparing the seasonality of ^{137}Cs concentrations in fisheries species on the basis of the balance between uptake and excretion will be valuable for determining the appropriate seasons in which to obtain less-contaminated products.

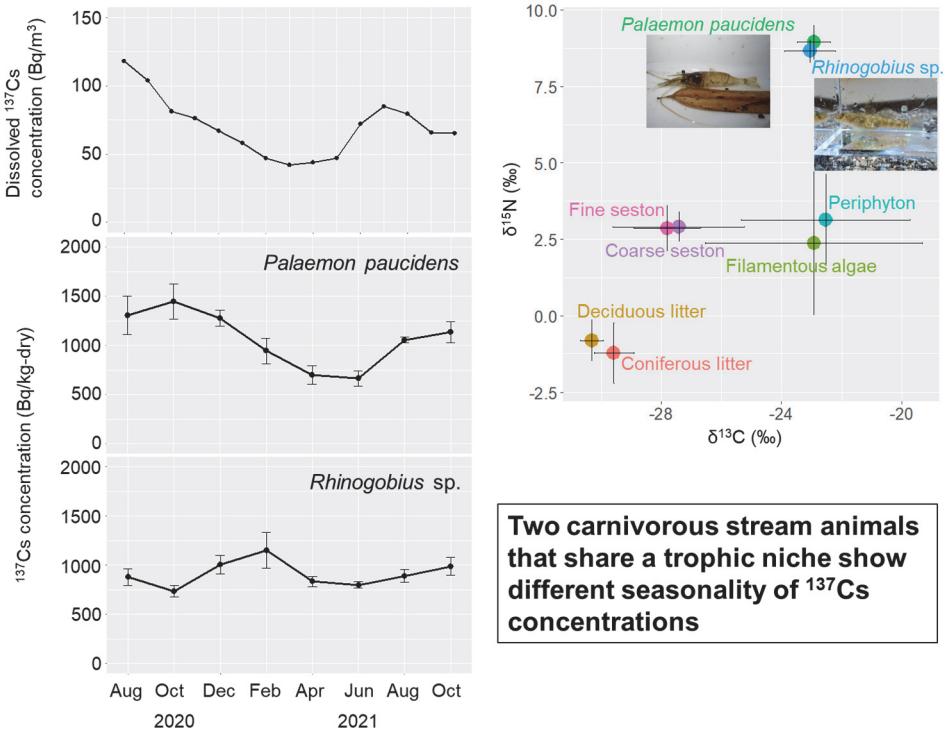


Fig. 1 Seasonal changes in the activity concentration of dissolved ^{137}Cs (top left), the ^{137}Cs activity concentration in *Palaemon paucidens* (center left), and the ^{137}Cs activity concentration in *Rhinogobius* sp. (bottom left) in the study reach. The mean and one standard deviation values for δ^{15}N and δ^{13}C in basal food resources, *Palaemon paucidens* and *Rhinogobius* sp., were calculated by using all the samples obtained in the study (right).

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

We continued to construct a reconstruction status database. Furthermore, we collected, estimated, and organized information on demographics, including areas where evacuation orders were lifted, as well as on resumption of farming, potential for solar sharing (farming-type solar power generation), work or school commuting structure, and non-resident population. Of these, we analyzed the residency rate in areas where evacuation orders were lifted (i.e., the percentage of registered residents in the area who were actually living in the same area) and the factors affecting the monthly recovery of the residency rate. Thus, we confirmed that the length of the period from the disaster's occurrence until the evacuation order was lifted, the length of the period after the evacuation order was lifted, and proximity to the nuclear power plant were statistically significant factors that had a negative impact on recovery of the residency rate. The area of unrestricted places within the same municipality, or the aging rate, did not have a significant effect. Additionally, in areas where the residency rate had remained unchanged for over 2 years, the residency rate was close to the sum of the percentage of individuals choosing the options "I want to return" and "I cannot decide yet" in an intention survey conducted by the municipalities. Moreover, this level had not been reached in areas where the residency rate was continuing to increase. These findings should serve as a reference for future recovery of the resident population of Fukushima. In the development of the reboot-type regional integrated assessment model (R2-AIM; Asia-Pacific Integrated Model), the recovery of the abovementioned residency rate was extrapolated and incorporated as a reference value for the future population. Alongside this, as part of the development of a regional analysis system, we

obtained residential power monitoring data that were developed under a partnership agreement between the town of Shinchi, in Fukushima Prefecture, and NIES. We used the data to develop a power demand forecasting method for houses, based on temperature sensitivity, as an energy forecasting method for the horizontal development of a community energy project. The power demand forecast was then expanded to the entirety of Fukushima Prefecture on the basis of temperature distribution by using this method. Next, we enhanced a demand–response control model, in which consumers adjust their power consumption and cooperate in adjusting the balance between supply and demand, and calculated the appropriate scale of photovoltaic installation. We also evaluated the available amount of renewable energy that could be used for each weather condition scenario.

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

The main themes of Project 4 are the recovery and reconstruction of natural 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 for this fiscal year are described below.

Subtopic 1: We have begun to examine safe local resource utilization and waste disposal systems to reconstruct areas where evacuation orders have been lifted. We regularly exchanged opinions with local government officials to design a biomass-utilization system in an industrial park as part of the reconstruction base project of the town of Okuma. In particular, we positioned a combined gasification–methane-fermentation heat and power generation facility, which is currently under development in Project 1, and we determined the implementation issues on the basis of local needs.

Subtopic 2: We investigated the methodology used to apply valuable practical knowledge of good community development practices promoting community development recovery in areas where evacuation orders have been lifted. This fiscal year, we developed and conducted internal tests of workshop programs to apply the extracted findings, or patterns, to the Hamadori area in Fukushima Prefecture. After the trial workshop, we obtained feedback from the participants regarding the program structure and the sense of adaptability of each pattern to the disaster-affected area; the results suggested that many of the patterns may be suitable for the Hamadori area. This allowed us to construct an overall framework that ranged from case studies to workshop program development.

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

From a governance perspective, we used a questionnaire and desktop survey to study the actual state and characteristics of coordination among those involved in disaster waste management in the 2019 Typhoon Hagibis. The results suggest that the level of coordination increases as the disaster waste load increases but then converges to a certain level. The results also suggested that those involved should be coordinated in ways that differ according to regional characteristics such as population density and regional linkages.

To support disaster waste management, on the basis of a prototype developed last year, we developed an online tool called *Kari-Hai*, which automatically creates a layout map of temporary storage sites for disaster waste. A floor plan showing the location and area of each type of disaster waste and the lines of flow within a site will be created when the user enters parameters such as the dimensions of the land. The system is expected to be used to make advance preparations for temporary storage facilities during normal times and to establish new temporary storage facilities, or to change the layout of temporary storage facilities, at the time of a disaster.

From a technical perspective, we first focused on concrete rubble to present a business scheme that seamlessly links recycling systems in normal times and in times of mega-disasters. To estimate the amount of concrete rubble that could be generated by the anticipated mega-earthquake beneath the Tokyo Metropolitan area, we adopted the latest estimation method that takes into account past disaster experience, building structure, and earthquake resistance. We estimated that approximately 41 million tonnes of disaster waste could be generated in the Kanto region, of which 24 million tonnes would be concrete rubble. Next, we compared the total estimated cost in two waste treatment scenarios, one with conventional treatment as roadbed material, and another anticipating a new recycling destination in the ocean, including the creation of algae beds. The results showed that the total cost of the latter scenario was higher than that of the conventional scenario. In the future, a comparative evaluation based on the benefits of using concrete rubble is needed, as well as an evaluation from the perspective of decarbonization. In addition, to ensure environmental safety in the use of concrete rubble in the ocean, we developed an evaluation framework based on the Ministry of the Environment's guidelines on the effective use of sediment and other materials. We also accumulated the findings of previous studies on the leaching of hexavalent chromium from concrete rubble.

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 subthemes.

In **Subtheme 1**, the following activities were performed: collection of information on past chemical substance release accidents; conducting of a questionnaire survey of business operators and analyzing their responses; and creation of an information infrastructure system. In relation to the information infrastructure system, we conducted several desktop exercises based on specific case studies, implemented a map display function to enhance convenience, and expanded various menus for different situations and purposes. We implemented various map display functions, including the display of pollutant release and transfer register information and estimated inventory, the acquisition of nearby AMeDAS (Automated Meteorological Data Acquisition System) information, the drawing of nearby rivers, the input of user information, the drawing of GIS data, and reference to external maps of the same location.

In **Subtheme 2**, for the automatic identification and quantification system (AIQS)-GC (-gas chromatography) for semi-volatile substances, we conducted a round-robin test using common samples. We found that the average relative standard deviation of the measured values for 66 targeted substances was within about 17%. We also confirmed that the addition recovery rate by solid-phase extraction was good. For AIQS-LC (-liquid-chromatography) for hydrophilic substances, we transferred the existing system, which was available only for a specific instrument, to a higher-end model and started sensitivity comparisons. For the rapid air sampling method, when medium volatile organic compounds such as PCBs were analyzed, there was a proportional relationship between the surface area of the liquid phase for collection and the concentration detected, suggesting that the method was applicable to the general atmosphere. In the change prediction of coastal ecosystems, we also analyzed benthic faunal survey data collected by the Ministry of the Environment, and we estimated secular changes in the benthic fauna and geographical variations among tidal flats and their factors after the earthquake. Furthermore, to estimate the origin of various oil spill incidents in the sea and to evaluate the impact of pollution, we started joint research with Mitsui O.S.K. Lines Technology Research Center this fiscal year to conduct a comprehensive analysis of PAHs (polycyclic aromatic hydrocarbons) and other substances contained in various oil samples and to construct a database.

In **Subtheme 3**, we developed Japanese versions of tools for environmental and epidemiological surveys during disasters, following on from the previous year. We selected four survey tools that should be highly effective for disasters in Japan, and we translated them into Japanese. We agreed with the NIEHS (National Institute of Environmental Health Sciences) to jointly hold a kick-off meeting of the International Disaster Research Response Network in the next fiscal year and beyond.

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 also collaborates with Harmonization with Nature Research Program, Material Flow Innovation Research Program, and other divisions, and it consolidates and disseminates findings that are relevant to public concerns (Fig. 1).

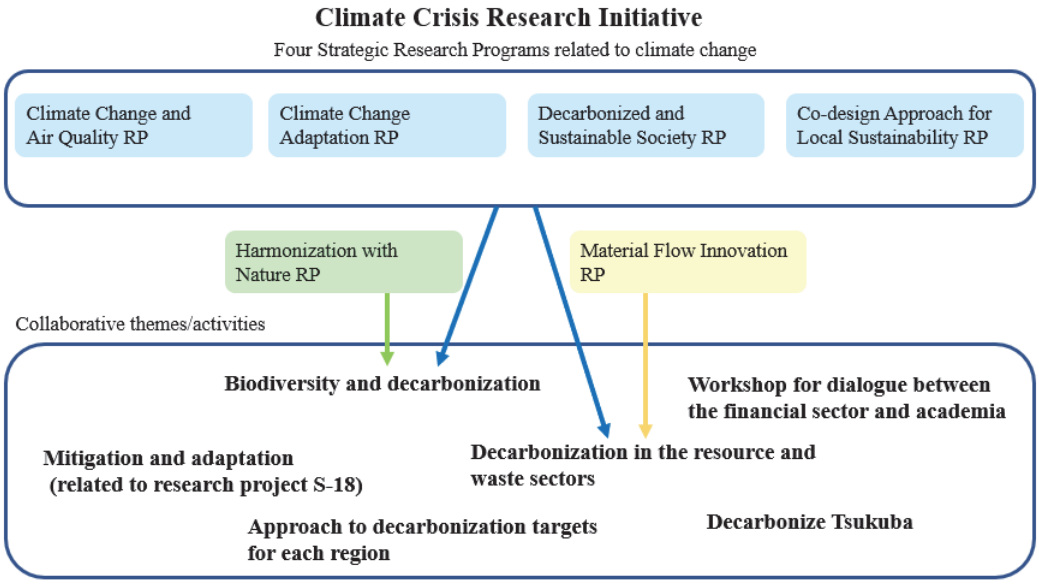


Fig. 1 Structure of the Climate Crisis Research Initiative and the four Strategic Research Programs related to climate change (Climate Change and Air Quality Research Program, Climate Change Adaptation Research Program, Decarbonized and Sustainable Society Research Program, and Co-design Approach for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

2. Activities in FY 2022

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 Domain, Biodiversity Domain, 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 Collaborative themes

The Initiative has identified cross-disciplinary issues as collaborative themes, which are discussed mainly at the regular meetings. The six themes are as follows.

2.2.1 Biodiversity and decarbonization

We discussed the compatibility of nature conservation and renewable energy

deployment. The resulting insights were provided to the formulation process of the Revised Act on Promotion of Global Warming Countermeasures and presented at the Tsukuba City Biodiversity Conference. We also worked to register some green space at NIES as an OECM (other effective area-based conservation measures) site.

2.2.2 Workshop for dialogue between the financial sector and academia

As a follow-up to the Workshop between Academia and the Financial Community on the Global Environment conducted in FY 2021, we have disseminated the insights from the workshop and extended the discussion to cover the latest findings and issues. Specifically, we have published a report on the workshop, provided input to international conferences [Stockholm+50 and SRI (Sustainability Research & Innovation) 2022], and conducted meetings to exchange opinions with financial experts. We also held a workshop on TNFD (Taskforce on Nature-related Financial Disclosures) at the Institute of Life Cycle Assessment, Japan.

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

Following the interim evaluation of S-18 (Comprehensive Research on Projection of Climate Change Impacts and Evaluation of Adaptation), we have discussed the relationships between mitigation and adaptation, focusing mainly on the secondary impacts of climate change on people's livelihoods and on industry, and their economic evaluation.

2.2.4 Decarbonization in the resource and waste sectors

Since research project 3-2201 of the Environment Research and Technology Development Fund, "Elucidating the structure of material flow in Japan in harmony with the carbon neutrality goal," was launched, in collaboration with the Material Flow Innovation Research Program, we have started to discuss the materials uses that are compatible with the carbon neutrality goal.

2.2.5 Approach to decarbonization targets for each region

We have discussed the concept of municipality-level targets corresponding to the national 2030 greenhouse gas emission reduction goal of 46% (compared with 2013), considering the industries involved and the measures taken in each municipality. In the example of the city of Goto, in Nagasaki Prefecture, the city estimated that it could reduce emissions by 22% through population reduction, 7.7% through offshore wind power generation, and 2.7% through public facilities, for a total reduction of 33%. It is important for municipalities to promote feasible measures through dialogue with members of the public, business operators, and other stakeholders.

2.2.6 Decarbonize Tsukuba

We have been conducting research and outreach activities in Tsukuba Science City, where NIES is based. One of the two pillars of our activities is the Decarbonization of NIES, in which we discussed the need to consider ZEB (Net Zero Energy

Building) when constructing a new building within NIES and to balance it with the preservation of green space within the Institute. We also started to precisely measure the power consumption of different parts of the Institute. The other pillar is the Decarbonization of Tsukuba City, in which we discussed carbon-negative strategies with the mayor of Tsukuba City and started to coordinate the Citizens' Climate Assembly in Tsukuba.

2.3 Public webinar

To generate and disseminate knowledge that is relevant to the interests of society, we held a public webinar, "What is being discussed in the world today about climate change scenarios?" in September 2022 (Fig. 2). The aim of the seminar was to report on the Scenarios Forum 2022, held at the International Institute for Applied Systems Analysis (Austria) in June. The key issues included the nature of scenarios, with a view to contributing to IPCC AR7 and a framework that contributes to consistent scenario analysis in collaboration with various research areas. We intended to share this content more broadly, for example, with government officials involved in international negotiations, local government officials in charge of regional mitigation and adaptation promotion, businesspeople who need to analyze transition and physical risk scenarios in the context of TCFD (Task Force on Climate-related Financial Disclosures) responses, and media reporting on climate change. In our webinar, participants in the Scenarios Forum from Japan were invited as panelists to share key points of discussion and their own views on the issues and to discuss them with the participants. More than 300 participants attended the webinar, confirming the high level of public interest in this topic.

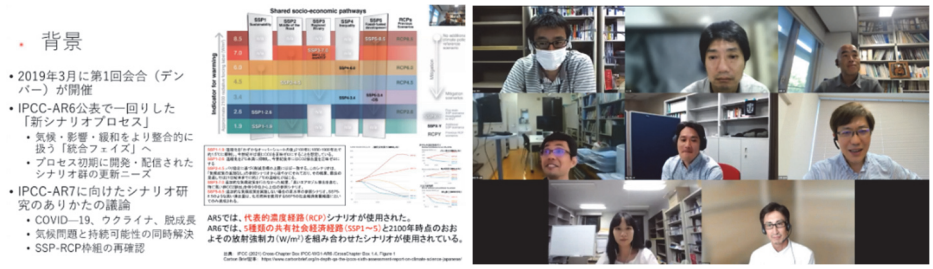


Fig. 2 Webinar on "What is being discussed in the world today about climate change scenarios?"

2.4 Linkage mapping with external research funding projects

A linkage chart has been devised to show external research funding projects and how they relate to the four Strategic Research Programs. It provides a perspective on the coverage of research themes and their interrelationships, including collaboration with external organizations in the four research programs. In addition to collaboration with the four research programs, the importance of collaboration with the Harmonization with Nature Research Program and the Material Flow Innovation Research Program through the externally funded research themes was confirmed.

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 needed 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

Relationship of leaf terpene content to terpene emission profiles in Japanese cedar (Cryptomeria japonica)

Plants protect themselves against various stresses by using volatile terpenes, which are also key precursors of climate-relevant constituents of the atmosphere. Conifers store terpenes in storage pools, which serve as emission sources. However, how the leaf terpene content influences the quantity and composition of emissions is uncertain. Here, we examined whether the terpene content explains the profile of terpene emissions by measuring seven monoterpenes and two diterpenes stored in, and emitted from, the same branches of 10 local populations of Japanese cedar (*Cryptomeria japonica*), a conifer common in Japan. We estimated the partial pressures of terpenes from the leaf terpene contents by using a thermodynamic algorithm. The estimated emission profiles of the monoterpenes were well correlated with the measured emissions (Fig. 1), suggesting the release of monoterpenes from the storage pools. The high tree-to-tree variations in the

emissions of individual terpenes were not correlated with variations in the concentrations of the corresponding terpenes in the leaves.

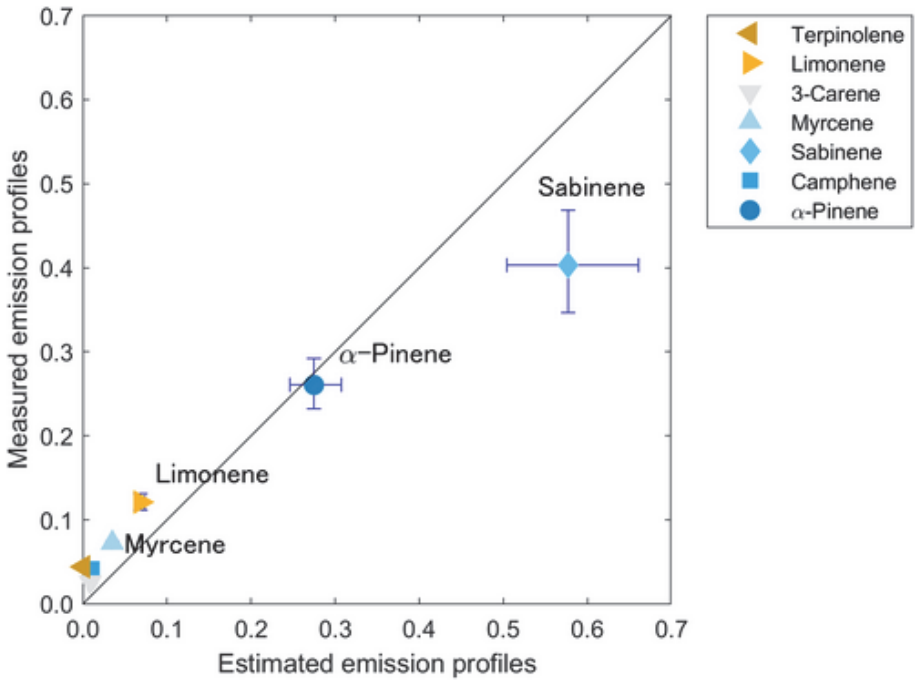


Fig. 1 Correlations between measured foliar emission profiles of monoterpenes from Japanese cedar and emission profiles estimated from foliar monoterpene contents. Symbols, geometric means; error bars, standard deviations

Reference:

Saito, T., Kusumoto, N., Hiura, T. (2023) Relation of leaf terpene contents to terpene emission profiles in Japanese cedar (*Cryptomeria japonica*). E*cological Research*, 38(1): 74-82
https://esj-journals.onlinelibrary.wiley.com/doi/10.1111/1440-1703.12323

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), SYKE researchers visited NIES in March 2023 and held a workshop on short-lived climate forcers and forest research to exchange information on these studies and discuss the future of research collaboration. We also organized a session on atmospheric composition and Arctic environment/climate at the Seventh International Symposium on Arctic Research (ISAR-7), held in Tachikawa, Tokyo, together with NIES, SYKE, and related institutes.

3. Intellectual Research Infrastructure Development

Long-term trends in atmospheric GHG concentrations observed at Cape Ochiishi, on Hateruma Island, and at the summit of Mt. Fuji

NIES has continued to observe atmospheric GHG concentrations at Hateruma Island (Okinawa), at Cape Ochiishi (Hokkaido), and at the summit of Mt. Fuji with high precision and temporal resolution. Atmospheric carbon dioxide (CO_2) at the three sites has continued to increase since the start of observations. The average rate of increase in CO_2 concentration was 2.2 ppm per year in 2021—almost the same as the average value for the last 10 years (2.3 ppm per year) (Fig. 2).

Atmospheric methane (CH_4) concentrations were maintained at low levels until about 2007, after which the rate of increase accelerated (Fig. 3). The average rate of increase in CH_4 concentrations since 2020 has exceeded 15 ppb per year—the largest increase on record. This long-term trend is consistent with those observed in other parts of the world, and the results support the possibility that some processes in the high latitudes of the Northern Hemisphere and/or tropical regions are responsible for this increase.

The datasets are provided to the WDCGG (World Data Center for Greenhouse Gases) and are also published on the Global Environmental Database at NIES. Research is under way in the Climate Change and Air Quality Research Program at 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 CO_2 and CH_4 emission reduction measures—one of the global decarbonization initiatives.

Database:

Mukai H. et al.: Continuous Observational Data of Atmospheric CO_2 Mixing Ratios on Hateruma Island (1993–).
https://www.nies.go.jp/doi/10.17595/20160901.001-e.html

Mukai H. et al.: Continuous Observational Data of Atmospheric CO_2 Mixing Ratios at Cape Ochi-ishi (1995–).
https://www.nies.go.jp/doi/10.17595/20160901.002-e.html

Nomura S. et al.: Daily Observational Data of Atmospheric CO_2 Mixing Ratios at the Summit of Mt. Fuji (2009–).
https://www.nies.go.jp/doi/10.17595/20170616.001-e.html

Tohjima Y. et al.: Continuous Observational Data of Atmospheric CH_4 Mixing Ratios on Hateruma Island (1996–).
https://www.nies.go.jp/doi/10.17595/20160901.003-e.html

Tohjima Y. et al.: Continuous Observational Data of Atmospheric CH_4 Mixing Ratios at Cape Ochiishi (1995–).
https://www.nies.go.jp/doi/10.17595/20160901.004-e.html

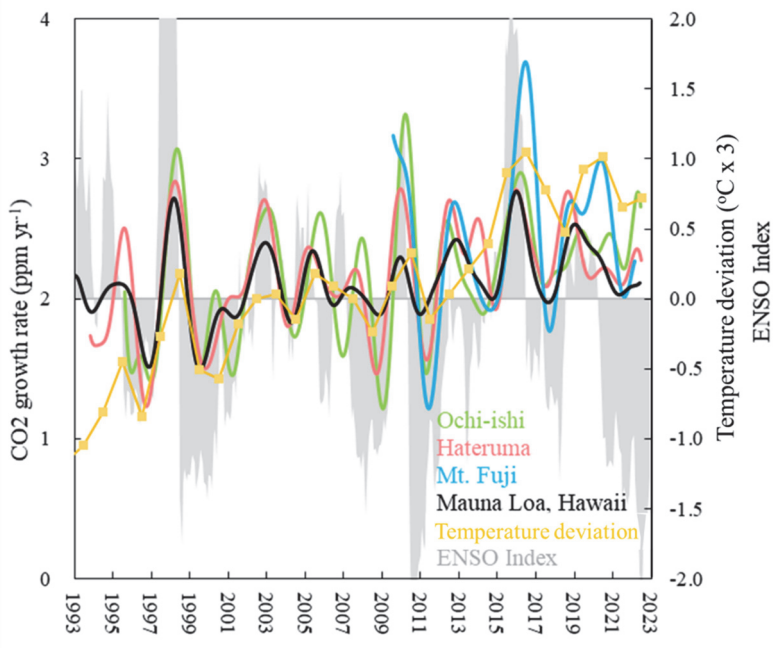


Fig. 2 Growth rates of atmospheric carbon dioxide (CO_2) concentrations observed at Cape Ochiishi (green), at Hateruma Island (pink), at the summit of Mt. Fuji (blue), and on Mauna Loa (black). The anomaly in air temperature (yellow) and the ENSO (El Niño Southern Oscillation index) (gray) are also shown.

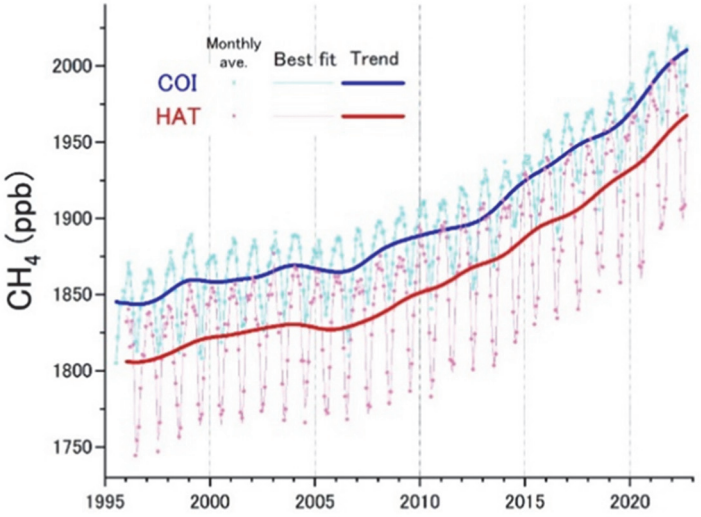


Fig. 3 Atmospheric methane (CH_4) concentrations observed at Cape Ochiishi (COI) and Hateruma Island (HAT)

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 advanced science and engineering for material cycles.

As part of our **policy-oriented research**, we have been conducting three main research activities. The first is research on social systems in material cycles and waste management. The second is impact assessment of hazardous substances in material cyclesmeasurement, testing, and evaluation of hazardous substances in the resource-recycling process. The third is advancement and implementation of waste management technologies for societyadaptation 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 not only to graph international resource flow and Japanese municipal waste data but also to improve the user interface for the data visualization.

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

Climate change is an urgent global challenge, and greenhouse gas (GHG) emissions from metal production contribute to a substantial part of total emissions. Metals play an essential role in human life, and the demand for them will increase with increasing global population and economic growth. Therefore, projecting future GHG emissions associated with metal production and exploring effective measures to alleviate GHG emissions are essential for achieving climate goals. This study projects the future GHG emissions associated with the primary and secondary production of six metals (aluminum, copper, iron, lead, nickel, and zinc) by considering the detailed metal cycles according to shared socioeconomic pathways (SSPs). Additionally, the factors influencing GHG emissions in metal cycles are explored by using decomposition and sensitivity analyses to reduce future GHG emissions.

We have shown that SSPs will have a substantial effect on GHG emissions associated with metal production. Some SSPs will lead to a decrease in annual GHG emissions late this century. However, because of increasing global metal demand (Fig. 1) and associated GHG emissions early this century, driven mainly by economic growth in the middle-income sector, the GHG emission reduction target required to maintain a temperature change below 2 °C will not be achieved under any SSP. Lowering the saturation value of per capita in-use metal stock and improving emission intensity could be effective for reducing GHG emissions, especially in the middle-income sector. Nevertheless, improving a single parameter is expected to be insufficient for achieving climate goals in terms of cumulative GHG emissions. Therefore, improving several parameters in parallel, not only in developed countries but also in developing countries, as well as following a sustainable socioeconomic pathway (i.e., SSP1, Sustainability), will be necessary. Given that parameters such as emission intensity cannot be improved promptly, implementing multiple measures immediately with international cooperation is essential for sustainable metal use in line with the climate goals.

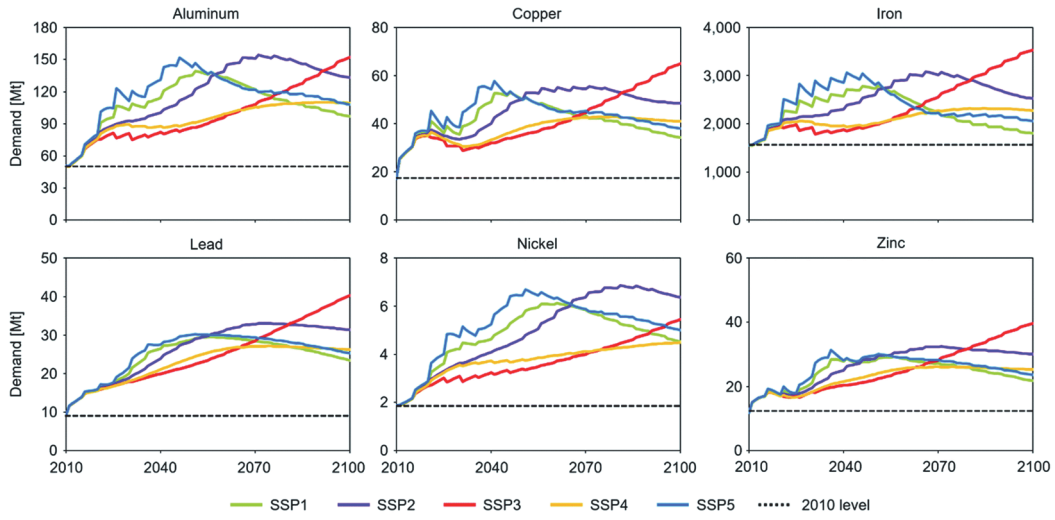


Fig. 1 Future global demand for six metals for 2010–2100, projected for each of the SSPs. The black dotted line indicates the demand level in 2010.

1.2 Advanced science and engineering for material cycles

Although the environmental fate of nanoplastics and their toxicity are of great concern, 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. Unfortunately, the mechanism of microplastics generation from plastic litter, namely by the fragmentation of plastics into microplastics, is not well understood. Therefore, we conducted two studies on two different sizes of plastics, nanoplastics and microplastics, as described below.

In a study of the fate and behavior of nanoplastics, we developed a continuous flow synthesis method to prepare standard nanoplastic particles. In the flow method, a polymer solution and anti-solvent are pumped to a microreactor (Fig. 2, left). The

method we developed enables continuous particle production under mechanically controlled conditions and prevents the aggregation of particles. Introducing the flow method improved the nanoparticle production efficiency, resulting in a 10-fold increase in the amount of particles produced. We also found that temperature control of the production system is the most critical factor in controlling the size of particles (Fig. 2, right). In addition, the mechanism underlying particle formation was investigated by using a model based on particle nucleation and growth rate. By using the nanoparticles we have prepared, we are developing analytical methods to quantify nanoplastics in the environment, and some collaborative research projects to explore the toxicity of nanoplastics are ongoing.

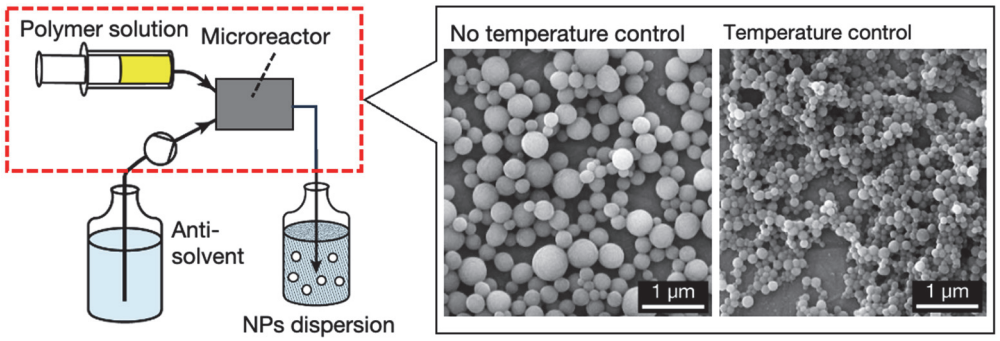


Fig. 2 Flow continuous synthesis of standard nanoplastic particles. NPs, nanoplastics

In research on the fragmentation process of plastics into microplastics, we prepared 18 plastic test pieces and started outdoor exposure tests at 10 locations throughout Japan. Some of the plastics showed substantial degradation after about 3 months, yielding useful samples for fragmentation rate analysis. We also started an accelerated exposure test utilizing a powerful ultraviolet light irradiation device that allows us to simulate long-term environmental degradation in a shorter period. Meanwhile, a new materials evaluation method that uses the combination of a scanning electron microscope and a cross-section polisher has been established for observing the internal structure of plastics. This technique can be used to evaluate the depth distribution of crazes and cracks, which is crucial in studies of plastic fragmentation. We clarified the growth state of cracks in five types of general-purpose plastics. The test results should be useful in predicting environmental emissions of microplastics and will be provided to bodies such as ISO (International Organization for Standardization) technical committees.

2. Policy-Oriented Research

2.1 Research on social systems in material cycles and waste management

First, we identified the following lifestyle changes that affect municipal waste composition and generation from various reports by governmental organizations: the spread of flea market services, clothing sharing, the use of food banks, rural migration, increased subscription services, and (with regard to work style) the increase in teleworking. Experts' opinions were incorporated into the results of

these analyses where appropriate. Next, among the extracted factors, we focused on teleworking, which has developed as a result of the COVID-19 pandemic, and we examined it from two perspectives: changes in waste composition due to changes in daily behavior and changes in demographics (daytime and nighttime populations). In our examination of the changes in daily behavior, we confirmed that there had been an increase in the disposal of cardboard boxes due to an increase in online shopping. There had also been a decrease in food loss (i.e., the edible portion of food waste) and the disposal of containers/packaging from eating out, and an increase in food loss and the disposal of containers/packaging from take-home meals and home cooking. In our examination of demographic changes, a tendency for municipal waste generation to increase in municipalities with lower day to night population ratios was observed in the Tokyo metropolitan area, but no clear relationship was observed in the Kinki and Chukyo metropolitan areas.

In the city of Tateyama, in Chiba Prefecture, which was severely damaged by Typhoon Faxai in 2019, a questionnaire survey was conducted regarding the cleanup of disaster waste. The results revealed that elderly households (with members aged 75 or older) in particular experienced problems such as not having vehicles to carry disaster waste or not being able to carry it to the designated disposal places.

In the process of site selection and development of waste treatment facilities, we examined the development of a frame for evaluating the elements needed to create a cooperative system for sustainable operation of such a project. The outcomes were eight types of capital and three elements of a collaborative framework: shared vision, capacity building for collaboration, and the fostering of mutual understanding. We are currently evaluating actual cases by using this frame, and we plan to organize the elements of the frame and improve it through this evaluation.

To examine the possibility of utilizing statistical and administrative information on waste and chemical substances, we analyzed the consistency of information between pollutant release and transfer register (PRTR)-reported transfer data and waste administrative reporting data for two prefectures as case studies. Of the PRTR data on reporting facilities, 99% was consistent with the waste administrative reporting data. About 70% of the PRTR data on waste types and treatment methods was consistent with the waste administrative reporting data, meaning that about 30% was not. The usefulness of this administrative information would be improved if the notifications are made so that the consistency of information is ensured between the different reporting systems.

A discourse from 12 Japanese stakeholders on extended producer responsibility (EPR) was analyzed. Different approaches to the introduction of EPR policy, such as the physical-responsibility-oriented approach and the policy-mix approach, were proposed, depending on the level of ambition of the stakeholders in achieving the ultimate goal, as well as on their preference for government intervention.

2.2 Impact assessment of hazardous substances in material cycles

In a study of a technique for the rapid detection of asbestos fibers in phase-contrast microscopy images by using an artificial-intelligence-based model, we attempted to improve the accuracy of an instance segmentation model called Mask-RCNN (-Region Based Convolutional Neural Network) through learning with modified training data sets. As a result, the recall rate of the model was improved to about 80%, but improvement of the precision was insufficient. We judged that the accuracy of this model could not be improved because of the difficulty in recognizing curved fibers such as those of chrysotile. We therefore selected a new semantic segmentation model, namely a Multi-level Aggregation Network (MANet), which is suitable for recognizing curved fibers. We confirmed the detection accuracy of the new model by using the same set of training and evaluation data as last year, and we found that the recall rate and the precision were significantly improved to 93% and 88%, respectively.

To elucidate whether microplastics emitted during the recycling and treatment of waste plastics are a potential source of persistent organic pollutants (POPs) in the ambient air, we continued investigating microplastics and polybrominated diphenyl ether (PBDE) emissions to the atmosphere at the same facility as last year. Microplastics number concentrations in air samples collected near the shredder were one to two orders of magnitude higher than those at the site boundary, suggesting that microplastics were released during the shredding process. Microplastics number concentrations and fluxes at the site boundary were similar to those found in previous studies in urban areas of Japan and other developed countries. PBDE concentrations near the shredder, and PBDE concentrations and fluxes at the site boundary, were similar to those found in previous studies of e-waste recycling facilities. The series of findings of this field survey suggested that the contribution of microplastics and PBDEs from waste recycling and treatment facilities to land-based sources is not substantial.

A soil-sorption-leaching test method for fluorinated POPs was investigated using one sample of Masado soil. As a result of tests on the sorption of perfluorooctane sulfonic acid (PFOS) perfluorooctanoic acid (PFOA), and perfluorohexane sulfonic acid (PFHxS) into the Masado soil sample. We found that PFOS was sorbed into the Masado soil sample in 7 to 28 days after the start of the experiment and the distribution of PFOS reached equilibrium. In contrast, the equilibrium concentrations of PFOA and PFHxS did not change after the start of the test, indicating that they are not sorbed by the Masado soil samples. Continuously, we conducted tests on the leaching of PFOS from the Masado soil sample after the sorption test.- We found that PFOS was leached from the Masado soil sample and the distribution of PFOS reached equilibrium, however we needed to conduct additional studies to elucidate the elution mechanism of PFOS sorbed in soil, including the relationship between the liquid–solid ratio or the shaking time and the equilibrium concentration of PFOS.

We analyzed the elemental composition of municipal solid waste incineration bottom ash and fly ash collected from 31 facilities nationwide, and we examined in detail the factors affecting the amount of incineration ash generated. We revealed that the waste-derived portion of the incineration fly-ash source can be divided into dust and volatile matter, and that the volatile matter is strongly affected by the chlorine concentration in the waste. We are planning a verification test regarding the technology for recovering precious metals from incineration bottom ash. In developing a method for the determination of natural/anthropogenic substances in soil, we proposed a test procedure for determining arsenic and lead at the same time. We also investigated using a rinsing method to remove the residue during extraction of the oxidized phase, and we applied the method to fluorine and boron.

In evaluating the application of slag to water purification technology utilizing the interaction between filter media, plants and microorganisms in brackish water, we investigated the applicability of slags (slag artificial stone and steel slag hydrated matrix) and mortar as a planting substrate for the wetland grass *Phragmites australis*, and we then evaluated the elution of metals. Good growth of *P. australis* was observed on slag artificial stone, although the grass died on steel slag hydrated matrix and mortar. We also demonstrated that the planting of *P. australis* caused a decrease in pH and affected the leaching behavior of several metals.

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 on 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 interviewed local governments and private companies managing landfills about their concerns regarding long-term operations until closure. Although they monitored leachate water quality for environmental safety evaluation, they lacked analytical skills and enough time to summarize time-dependent data and understand their current landfills' status. Providing them with web applications developed by our researchers was considered an effective way of helping them to unify the data and predict the fate of their landfills by themselves.

We have compiled standard operating procedures (SOPs) for the field investigation methods required when important issues concerning environmental safety and pollution arise at final waste disposal sites and illegal dumping sites. The SOPs have been published on our platform for sharing information on waste disposal site surveys (https://www.nies.go.jp/landfill_survey; in Japanese). Additionally, instructional videos demonstrating the investigation procedures have been created and made available on the NIES YouTube channel.

We examined the possibility of promoting the recycling of construction and demolition waste (CDW) in Hanoi, Vietnam, through the application of selective dismantling. We demonstrated that an increase in overall revenue from dismantling operations is achievable through a rise in sales income from recycled resources and a reduction in disposal expenses. Moreover, apart from economic benefits, the effectiveness in terms of environmental aspects was confirmed, with a potential GHG reduction of 55%. Currently, the final disposal prices of CDW are set low, but as policies and social conditions improve, the profitability should increase. To promote CDW recycling at the local level, a workshop for municipal officials was held in Quang Ninh Province.

We performed a pilot-scale experiment to prove the effectiveness of the biodrying process—a technology that involves both mechanical and biological treatment—as a rational waste disposal method for small and medium-sized municipalities in Japan. Assuming that future waste will have an increased diaper composition and reduced paper and plastic content, 37% of the input waste was separated as a fraction to be used as fuel. The fuel fraction exhibited a high energy value of 22 MJ/kg and met the necessary quality standards. Furthermore, all remaining waste was recyclable within the facility, confirming the method's excellent waste treatment and resource utilization capabilities.

We compiled a list of 19 possible scenarios (locations and actions) where infection with COVID-19 could occur in municipal solid waste collection operations from the start to the end of the work day. Specific infection-prevention measures should be taken, particularly with regard to alcohol checks of driver's exhalation at the start of work and the wearing and removal of gloves during work.

We have conducted long-term laboratory tests of on-site domestic wastewater treatment facilities (treatment capacity 1 m^3/day) under tropical conditions. Effluent water quality was good in terms of suspended solids and biochemical oxygen demand, but ammonium-nitrogen removal and sludge accumulation were highly affected by operational conditions, such as aeration. We intend to analyze in detail the characteristics of the accumulated sludge to evaluate the effects of duration and temperature on sludge storage.

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 support the return of research results through international organizations and international activities.

In FY 2022, we supported research dissemination events in the Material Cycles division,

including a joint research-based international conference and an event called “Waste Recycle and Waste Utilization—Covid 19 Aftermath; Challenges of waste decarbonization towards zero emission in developing countries.” Additionally, we provided assistance for a conference on “Mercury Legacy in Artisanal and Small-Scale Gold Mining,” which focused on collaborative research outcomes funded by the Environment Research and Technology Development Fund (JPMEERF20S20620).

Furthermore, as part of our support for international cooperation agencies, we contributed to the implementation of a workshop that was run by the Thai International Cooperation Agency’s international training program and addressed appropriate waste management in climate crisis situations. We also helped to conduct a construction waste management workshop for a JICA (Japan International Cooperation Agency) program in Quang Ninh Province, Vietnam.

Moreover, with the aim of disseminating and publicizing research outcomes obtained in the Material Cycles division, we issued press releases on policy recommendations for introducing decentralized domestic wastewater treatment in developing countries and on the holding of a conference on international information exchange concerning artisanal and small-scale gold mining.

3. Intellectual Research Infrastructure Development

We identified the time-series geographical distribution of the movement, consumption, and accumulation of 20 types of resources (including iron, copper, nickel, platinum, neodymium, and mercury) associated with international trade between countries and regions. To support the further dissemination of information, we are developing a database on the geographical distribution and a new open access web page (Fig. 3).

We are establishing a prototype version of a web page on municipal solid waste management focusing on socially and politically important data. We held an online meeting of experts to discuss the advantages and disadvantages of various recycling rates.

We have added data on per capita household food waste generation to the database on municipal solid waste management in the Asia-Pacific region (DaMSAR) established in 2021, and we released DaMSAR Ver. 1.1.

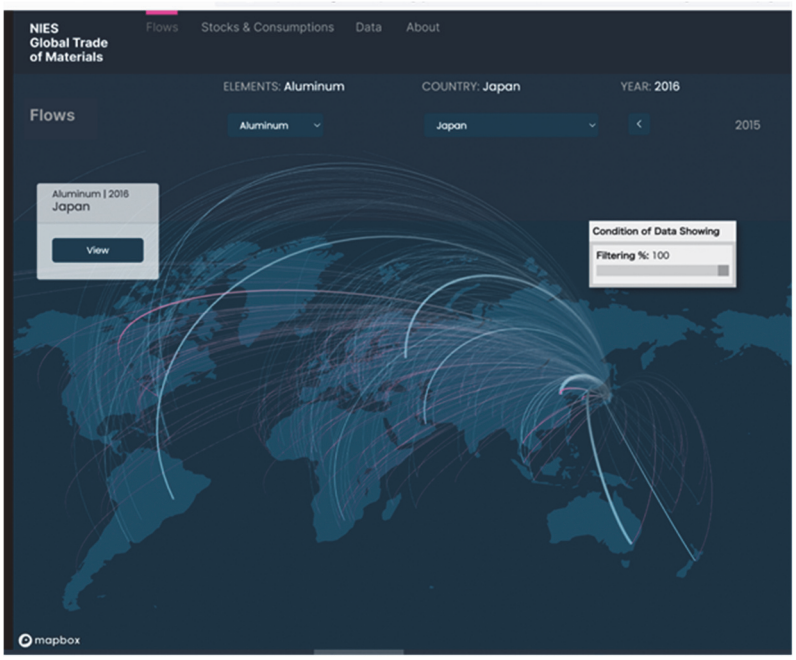


Fig.3 Draft web page on the time-series geographical distribution of the movement, consumption, and accumulation of 20 types of resources

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 $PM_{2.5}$, 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 FY2022.

1. Foresight and Advanced Basic Research

1.1 Identification of thyroid hormone receptor agonist active substances in sewage treatment plant effluent

Previously, sewage treatment plant effluent has been known to exhibit thyroid hormone receptor (TR) agonist activity, but the main component of this activity still needs to be clarified. In this study, the TR-binding activity of effluent from several sewage treatment plants in Japan was determined by using a yeast two-hybrid assay. Highly sensitive analysis by liquid chromatography with tandem mass spectrometry (LC-MSMS) and precise mass measurement by liquid chromatography with quadrupole time-of-flight mass spectrometry (LC-QTofMS) of 13 compounds

known to have the same activity indicated that the active substance was the endogenous hormone triiodothyronine (T3) or thyroxine (T4) metabolite, 3, 5, 3-triiodothyroacetic acid (TRIAC) (Fig. 1).

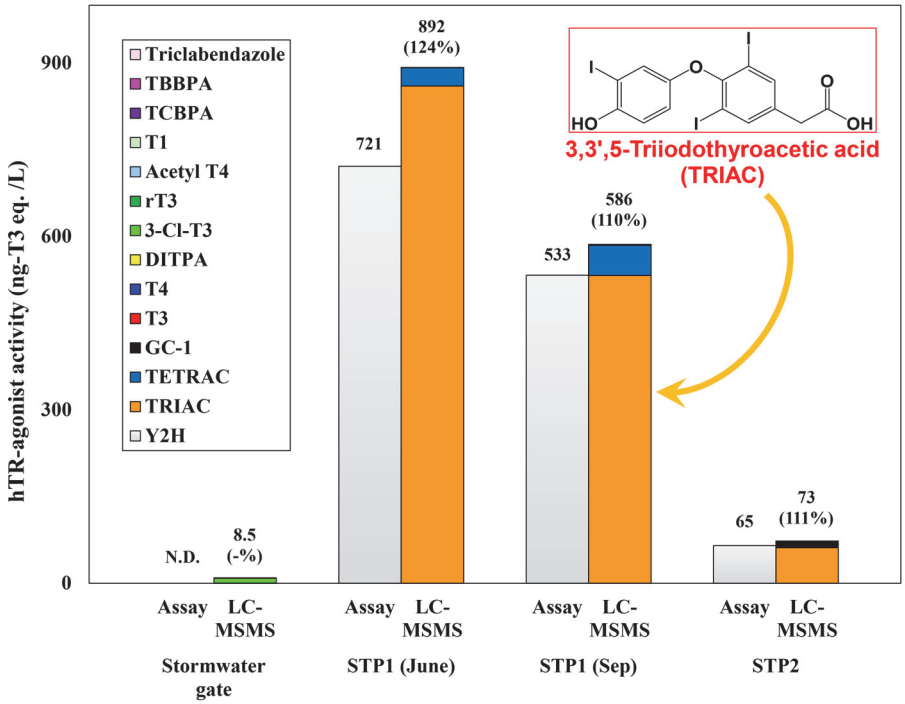


Fig. 1 Human thyroid receptor (hTR) agonist activity determined by TR yeast two-hybrid assay ("Assay"), and activity estimated from concentrations quantified by using LC-MSMS.
All values are expressed as T3-equivalent concentrations (ng-T3 eq/L). N.D.: not detected.

Determination of agonists in the sewage treatment plant's influent, intermediate treated water, and effluent showed that TRIAC was not detectable in the influent. When the influent and effluent were treated with β-galactosidase, TRIAC was not detected in the influent, either in the deconjugated water or the untreated water. In the effluent, the TRIAC concentration was not increased by deconjugation. These results suggest that the main component of TR agonist activity in sewage treatment plant effluent is TRIAC, which is generated from T3 and other substances during treatment.

1.2 Analysis of ^{90}Sr accumulation in marine fishes from the Fukushima coastal region

Research on the accumulation of ^{90}Sr derived from the accident at the Fukushima Daiichi Nuclear Plant in various marine fishes has been limited. In this study, to analyze the spatial distribution of ^{90}Sr in fishes and identify differences in ^{90}Sr radioactivity concentrations among fish species, we measured the vertebral ^{90}Sr radioactivity concentrations of various fishes collected off the coast of Fukushima Prefecture in 2014 (Fig. 2 and Kintsu et al. 2023[1)]). The spatial distribution of radioactivity concentrations tended to be high in the central area at shallow water depths, as well as throughout the southern sites. The spatial distribution of vertebral ^{90}Sr reflected that of ^{90}Sr predicted in seawater from previous modeling and measuring results. Among the species we examined, the highest radioactivity

concentrations and detection frequencies of ^{90}Sr were observed in the ocellate spot skate, *Okamejei kenojei*, an elasmobranch. Mean radioactivity concentrations (± standard deviation; omitting values below the detection limit) for this species at each site in January ranged from 27 ± 6 mBq/(g Ca) at C30 to 51 ± 22 mBq/(g Ca) at S10. Many of the rays in which ^{90}Sr was detected contained more than 30 mBq/(g Ca). *Hemitrygon akajei* also exhibited relative high radioactivity concentration, although the number of individuals measured was small. These results indicate that rays tended to contain higher radioactivity concentrations of ^{90}Sr than other species collected from the same sites. In addition, the stable Ca concentrations in ashed vertebrae were approximately 35% for most species, whereas the stable Sr concentrations in ashed vertebrae ranged from 0.1% to 0.3% and were species specific. Rays had higher ratios of the concentrations of stable Sr to Ca in ashed vertebrae than other species. Therefore, there could be differences in ^{90}Sr accumulation among marine fish species, and this may be important factor in determining ^{90}Sr radioactivity in fish.

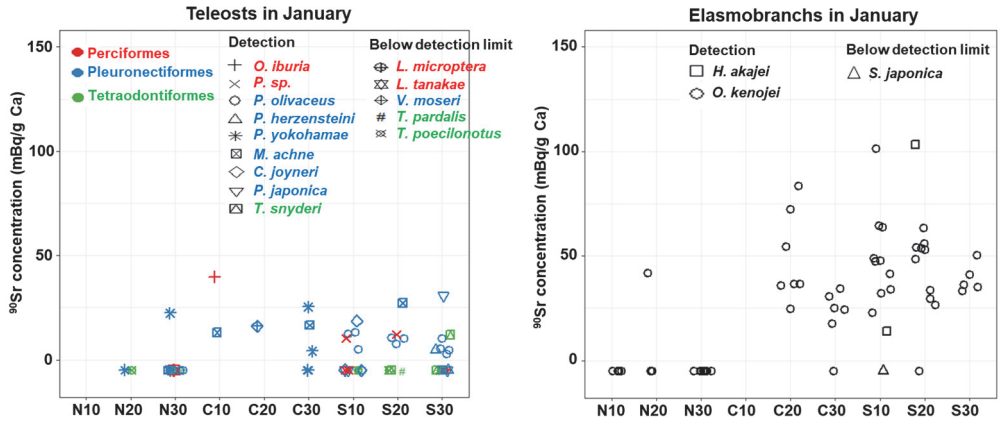


Fig. 2 Strontium-90 radioactivity concentrations in vertebrae of fish collected in January 2014 from nine sampling sites. Three broad survey regions were established at different latitudes along the coastline: off Soma (north, N), off Okuma (off the Fukushima Daiichi Nuclear Plant) (central, C), and off Iwaki (south, S). Three sampling sites of differing water depth (10 m, 20 m, and 30 m) were established in each region. Teleosts and elasmobranchs are shown separately. Symbols correspond to fish species. Data points below the detection limit are shown as negative values. (Kintsu et al. 2023[1)], Figure is cited with partial modification. We acknowledge the permission of Elsevier.)

1.3 Assessing the oxidative-stress-induction ability of $PM_{2.5}$ in cities in Japan

Concerns exist about the adverse health effects of exposure to $PM_{2.5}$ (particles with a diameter of less than 2.5 μm). Oxidative stress due to exposure to $PM_{2.5}$ via the generation of ROS (reactive oxygen species) is one of the pathways which lead to morphologic changes and lung function decrements, which are linked to asthma and chronic obstructive pulmonary disease exacerbations. However, it is unclear which chemical components in $PM_{2.5}$ have oxidative-stress-inducing ability (OSiA), especially in relation to subtypes of organic aerosols (OAs). Therefore, we performed OSiA assessments by using a cell-based method, namely a heme oxygenase-1 assay. To quantify the relative contributions of the quantities of metals and subtypes of OAs in $PM_{2.5}$ to OSiA, we also performed online measurements during sampling and offline chemical analyses. The measurements were conducted in two seasons in the cities of Tsukuba and Fukuoka in order to collect a variety of

samples, each of which was influenced by a different emission source. Combining the results of multiple linear regression analyses and the reagent-solution experimental results showed that water-soluble (WS) transition metals accounted for approximately 30% to 40% of the total OSiA in water-extracted $PM_{2.5}$ samples, whereas biomass-burning OAs (BBOAs) accounted for approximately 50%. In terms of the OSiA unit chemical mass [fold μg component^{-1}], WS-Pb was found to have the largest value among the WS transition metals and subtypes of OA. All filter samples were cluster analyzed into grouped samples with similar chemical composition profiles (Fig. 3). OSiA in WS samples on an air-volume basis (Fig. 3c) or a particle-mass basis (Fig. 3d) was the highest in Fukuoka in the high $PM_{2.5}$ concentration period, largely because of the WS-Pb and BBOAs in this group. These components may be influenced by long-range transport from the Asian continent and the presence of local biomass-burning sources near the sampling sites. In Japan, open burning of agricultural residues is not completely prohibited. Therefore, management of biomass burning activity is important to maintain good air quality and protect public health.

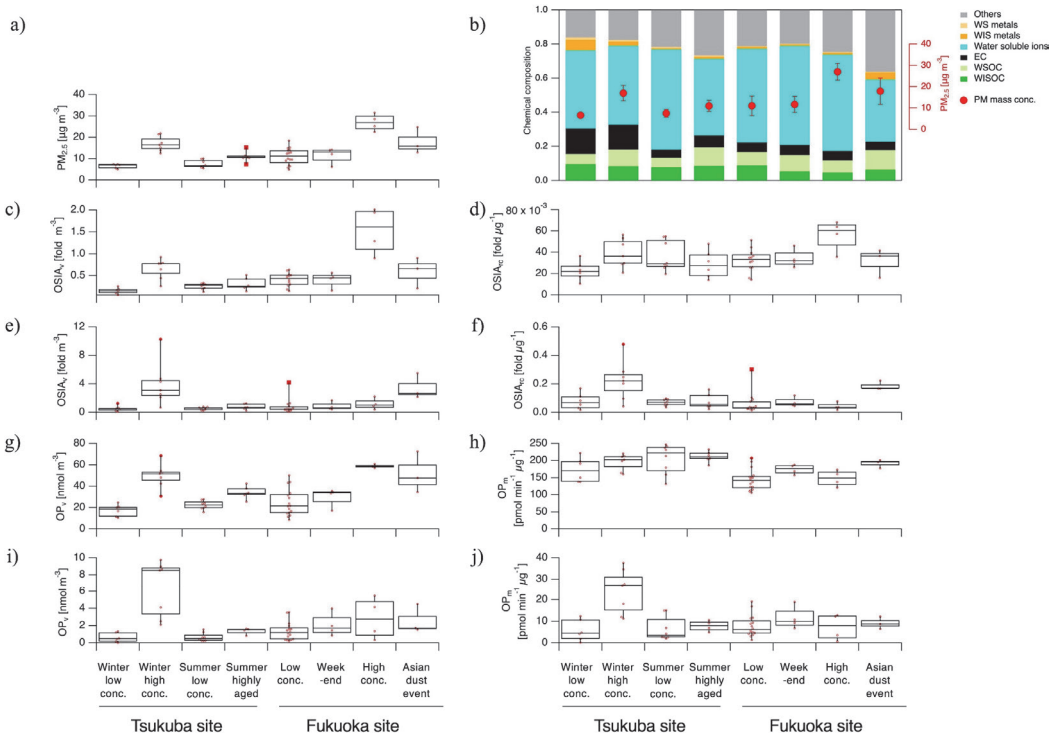


Fig. 3 Boxplots of a) $PM_{2.5}$ and c–f) oxidative-stress-induction ability (OSiA), and g–j) oxidative potential (OP), and b) mean fractions of chemical compositions, for each group classified by hierarchical cluster analysis performed at each sampling site. Graphs c, d, g, and h show the results obtained for aqueous samples, and e, f, i, and j show the results obtained for DMSO (dimethyl sulfoxide) samples. Horizontal bars in the boxes represent median values. Upper and lower bounds of the boxes represent 25th and 75th percentiles, with whiskers indicating the range in values. The error bars in b) represent the standard deviation. Elemental carbon (EC); water soluble organic carbon (WSOC), water insoluble organic carbon (WISOC) (Fujitani et al., 2023[2]), Permission from Elsevier.)

1.4 Adaptive biomarker of heat-related stress response in germ cells

Cells modulate the dynamics of organelles to adapt to stresses such as heat that produce pathological misfolded protein aggregates (proteotoxicity). The inside of a cell is roughly divided into the nucleus and cytoplasm. Stress-granule formation in the cytoplasm is a well known mechanism of heat adaptation: Translational stalling triggered by heat can protect nascent mRNAs in the granules from degradation until

the stress is relieved. However, little is known about the mechanism of adaptation against proteotoxicity in the nucleus. Here, we searched for relevant biomarkers in germ cells, with the anticipation that these biomarkers would be useful for ensuring a healthy next generation. Small ubiquitin-related modifier (SUMO) is a posttranslational protein modifier that regulates multiple cellular processes. Upon heat shock, SUMO delocalized from heterochromatin and co-localized with SC35 (a marker of nuclear speckles)-positive large compartments. This SUMO response was also induced by inhibitors of proteasome, which processes defective proteins (Fig. 4), suggesting that the response is an adaptive mechanism to proteotoxicity in the nucleus. Among the culturable developmental stages of germ cells from oocytes to pre-implantation embryos, we found that the adaptive SUMO response to proteotoxicity was seen in oocytes. Other research groups have recently reported that other nuclear organelles, namely promyelocytic leukemia (PML) nuclear bodies (PML-NBs), potentially act as a backup system for defective-protein processing. The PML proteins that constitute PML-NBs are well known to undergo SUMO modification. Although PML-NBs were not found in mouse oocytes, deliberately assembled PML-NBs inhibited the adaptive SUMO response to proteotoxicity. Together, these findings suggest that the PML-NB-free intranuclear environment in the nucleus of oocytes helps to reserve SUMO for emergent responses by redirecting the flux of SUMO. Although the temperature of mammalian germ cells is basically maintained by resilient homeostasis, there is also a backup mechanism that would deal with prolonged cellular stresses, such as in heatstroke.

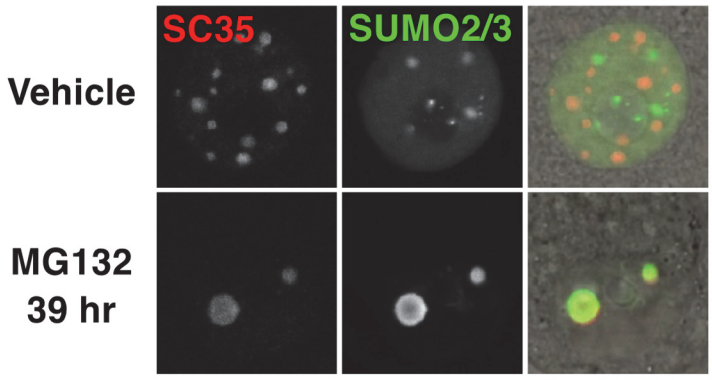


Fig. 4 Representative image of the nucleus of mouse oocytes subjected to prolonged exposure to the proteasome inhibitor MG132 (10 μM, for 39 h) or vehicle. Oocytes were stained with anti-splicing component, 35 kDa (SC35) (red) and Alexa 488-conjugated anti-SUMO2/3 (green). Brightfield images of the oocytes are merged in the right-hand panels. (Udagawa et al. 2022[3]), Licensed under CC BY 4.0; this figure is a partial modification of the original.)

References:

1) Kintsu H., Kodama K., Horiguchi T. (2023) Spatial distributions of and species differences in ^{90}Sr accumulation in marine fishes from the Fukushima coastal region. *Journal of Environmental Radioactivity*, 256: 107055. doi:10.1016/j.jenvrad.2022.107055

2) Fujitani Y., Furuyama A., Hayashi M., Hagino H., Kajino M. (2023) Assessing oxidative stress induction ability and oxidative potential of $PM_{2.5}$ in

cities in eastern and western Japan. *Chemosphere*, 324: 138308

3) Udagawa O., Kato-Udagawa A., Hirano S. (2022) Promyelocytic leukemia nuclear body-like structures can assemble in mouse oocytes. *Biology Open*, 11(6): bio059130. doi:10.1242/bio.059130; licensed under Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0)

2. Policy-Oriented Research

2.1 Adverse effects of the thyroid-hormone-disrupting chemicals 6-propyl-2-thiouracil and tetrabromobisphenol A on Japanese medaka (*Oryzias latipes*) embryos

Thyroid-hormone-disrupting chemicals (TDCs) have a significant impact, especially on vertebrates, by disrupting the body's metabolism and reducing growth. For detecting TDCs, although some animal tests are available, such as the amphibian metamorphosis assay (AMA) and the larval amphibian growth and development assay (LAGDA), which utilize *Xenopus laevis*, there is a growing need to transition to more comprehensive and animal-friendly testing methods for the sake of animal welfare. Recently, it has been reported that a test using zebrafish (*Danio rerio*) embryos is effective for screening for TDCs. In zebrafish embryos, certain TDCs have been reported to alter swim bladder inflation, eye development, growth, and thyroid-related-gene expression, including *thyroid stimulating hormone subunit beta* (*tshβ*), *thyroid hormone receptor alpha* (*trα*) and beta (*trβ*), and *deiodinase 1* and *2* (*dio1* and *dio2*). However, the influence of TDCs on Japanese medaka (*Oryzias latipes*), which is the species most widely used in Japan for the risk assessment of chemical substances, remains unclear.

We investigated the impacts of two TDCs, namely 6-propyl-2-thiouracil (PTU) and tetrabromobisphenol A (TBBPA), on Japanese medaka embryos to better understand their impact and help to develop more comprehensive and animal-friendly testing methods (Horie et al. 2023)[1)]. In this study, we evaluated PTU exposure effects such as reduced eye size and growth, and inhibition of swim bladder inflation, and we observed changes in *tshβ-like* gene expression. Phenotypic expression of these effects also led to abnormal swimming behavior as an adverse outcome. In contrast, TBBPA induced changes in the expression of *tshβ* and *tshβ-like*, but it did not substantially affect swim bladder inflation, eye development, growth, or swimming behavior in Japanese medaka embryos. This result is consistent with previous findings in zebrafish. We suggest that the test method used in this study (Fig. 5), whereby embryos are exposed to test chemicals from 4 h after fertilization to 1 day after hatching, is effective for detecting TDCs in Japanese medaka. However, our previous study indicated that the inhibition of swim bladder inflation in Japanese medaka embryos by PTU can be detected by exposing embryos from 0 days post-hatching (dph) to 1 dph (NIES 2020[2)] and 2021[3)]). Therefore, the test duration required to screen for TDCs in Japanese medaka embryos may be much

shorter than that used in our latest study.

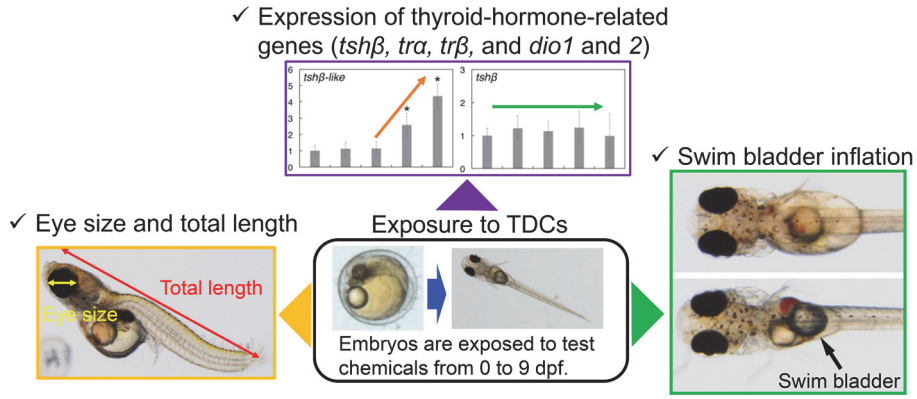


Fig. 5 Schematic diagram of the test for detecting thyroid hormone-disrupting chemicals (TDCs) by using Japanese medaka (*Oryzias latipes*) embryos. Nine days post-fertilization (dpf) equals 1 day post-hatching.

References:

1) Horie Y., Yamagishi T., Yamamoto J., Suzuki M., Oonishi Y., Chiba T., Tyler CR., Okamra H., Iguchi T. (2023) Adverse effects of thyroid-hormone-disrupting chemicals 6-propyl-2-thioureacil and tetrabromobisphenol A on Japanese medaka (*Oryzias latipes*). *Comparative Biochemistry and Physiology, Part C*, 263: 109502.

2) NIES (2020) Report on the Development of Testing Method for Endocrine-disrupting Chemicals. National Institute for Environmental Studies, Tsukuba, Japan, pp. 71–76 (in Japanese)

3) NIES (2021) Report on the Development of Testing Method for Endocrine-Disrupting chemicals. National Institute for Environmental Studies, Tsukuba, Japan, pp. 50–55 (in Japanese)

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 Principal Researcher.

In FY 2022, 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:

- A study of multiphase chemistry of hydrogen oxide radicals relevant to tropospheric ozone formation
- Effects of heat wave on dissolved oxygen (DO) in bottom water layers.

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 our important results in FY 2022.

1. Foresight and Advanced Basic Research

1.1 A study of multiphase chemistry of hydrogen oxide radicals relevant to tropospheric ozone formation

To clarify the effect of aerosol uptake of hydrogen oxide (HO_x) radicals on ozone formation, we are conducting a study, supported by NIES research funding Type A, in which we measure uptake coefficients by using a laser pump-probe method and study the reaction mechanism between iron(II) ions and peroxides in the liquid

phase by using a liquid-phase bulk reaction experimental method. We are using the experimental results to construct an atmospheric model with an improved reaction mechanism to accurately determine the interannual changes in ozone concentrations in Japan (Fig. 1). In FY 2022, we measured the hydroperoxyl (HO_2) radical uptake coefficients of inorganic particles doped with metal ions, sea salt particles from Hachijojima and Izu, and secondary organic aerosol (SOA) particles of biogenic origin (subtheme 1 in Fig. 1). We also clarified the reaction mechanism between iron(II) ions and an organic hydroperoxide (ROOH; R = *tert*-butyl group) in the liquid phase (subtheme 2); the influence of multiphase reactions on ozone concentrations and production regimes over time were evaluated by using the abovementioned atmospheric model to reproduce historical observations and changes in domestic ozone concentrations over time (subtheme 3).

In our measurements of the HO_2 radical uptake coefficients of various particles, we found that the HO_2 radical uptake coefficients of doped inorganic particles varied between 0 and 0.6, depending on the concentration of Cu(II) ions in the aerosol. The HO_2 radical uptake coefficient of sea salt particles was about 0.2. The HO_2 radical uptake coefficient of SOA particles of biogenic origin was almost zero, and the coefficient in the case of mixed particles of SOA of biogenic origin and inorganic materials was lower than that of inorganic particles alone because of the coating effect of the SOA. By including HO_2 radical uptake by aerosols in the regional atmospheric model, we found a significant effect on the ozone concentration as shown in subtheme 3 in Fig. 1. The model was used with a fixed uptake coefficient of 0.2. Furthermore, we evaluated an uptake coefficient that

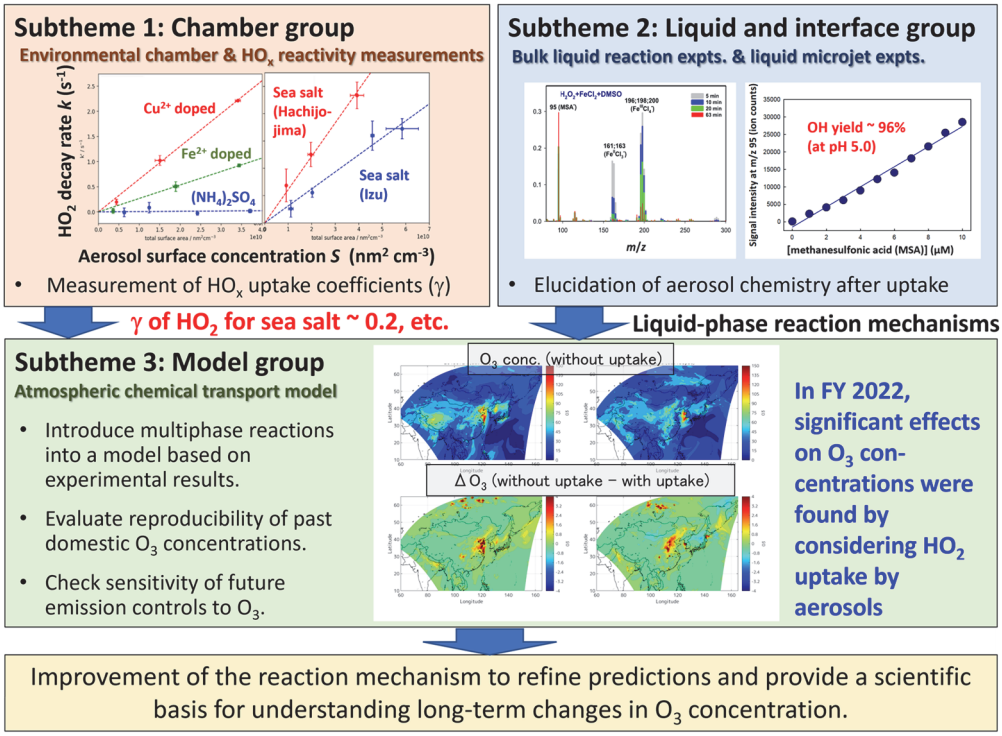


Fig. 1 Research structure and main results of NIES research funding Type A

reflected the experimentally determined dependence of the uptake on Cu(II) ion concentrations.

The Environment Research and Technology Development Fund (JPMEERF 20215002) was also conducted in FY 2022. Chamber experiments on ozone formation using nine VOCs (volatile organic compounds) and NO_x as precursors were conducted in the presence of high concentrations of Cu(II)-doped ammonium sulfate aerosols (>100 μg m^{-3}) to investigate the effect of aerosol addition on ozone formation potential. When Cu(II) was not doped, no significant change in ozone concentration was observed, even when the aerosol content was set to a high concentration of 100–200 μg m^{-3}. When Cu(II) was doped, a significant decrease in the ozone concentration was observed. Suppression of the ozone concentration depended on the aerosol surface concentration. A sub-model was constructed to calculate the effect of HO_2 radical incorporation into the aerosol in the chemical reaction model, and work began on estimation of the parameters that would enable best reproduction of the chamber experimental results.

1.2 Effects of heat wave on dissolved oxygen (DO) in bottom water layers

Recent studies have suggested that the frequency of heat waves is increasing all over the world. In Japan, we experienced a heat wave from June to July in 2022. We monitored water quality during this heat wave (e.g., the DO concentration, water temperature, and phytoplankton biomass) every 10 min in Lake Kasumigaura, a shallow, eutrophic lake, Japan (Fig. 2a). We determined whether, and how, the heat wave affected DO concentrations in the water column. A one-dimensional numerical simulation model (Fig. 2b) was used to investigate how meteorological conditions (air temperature, solar radiation, and wind speed) affected the DO concentration just above the bottom sediment.

During the heat wave, we observed bottom water hypoxia, a condition in which the bottom water DO concentration was less than 2 mg L^{-1} (Fig. 2c). Sensitivity analysis of the simulation suggested that wind speed affected the bottom water DO concentration most significantly. We also analyzed whether hypoxia occurred when solar radiation and air temperature were at their usual (non-heat-wave) levels (Fig. 2c). The results suggested that hypoxia did not occur at these times. The average wind speed in the Northern Hemisphere is slackening because of climate change, and this could induce hypoxia. However, the dual impacts of increasing solar radiation and air temperature also induce hypoxia. Because physical characteristics (e.g., water depth and land–sea breezes) similar to those at Lake Kasumigaura are found all over the world, our findings suggest that heat waves could induce hypoxia in shallow lakes globally.

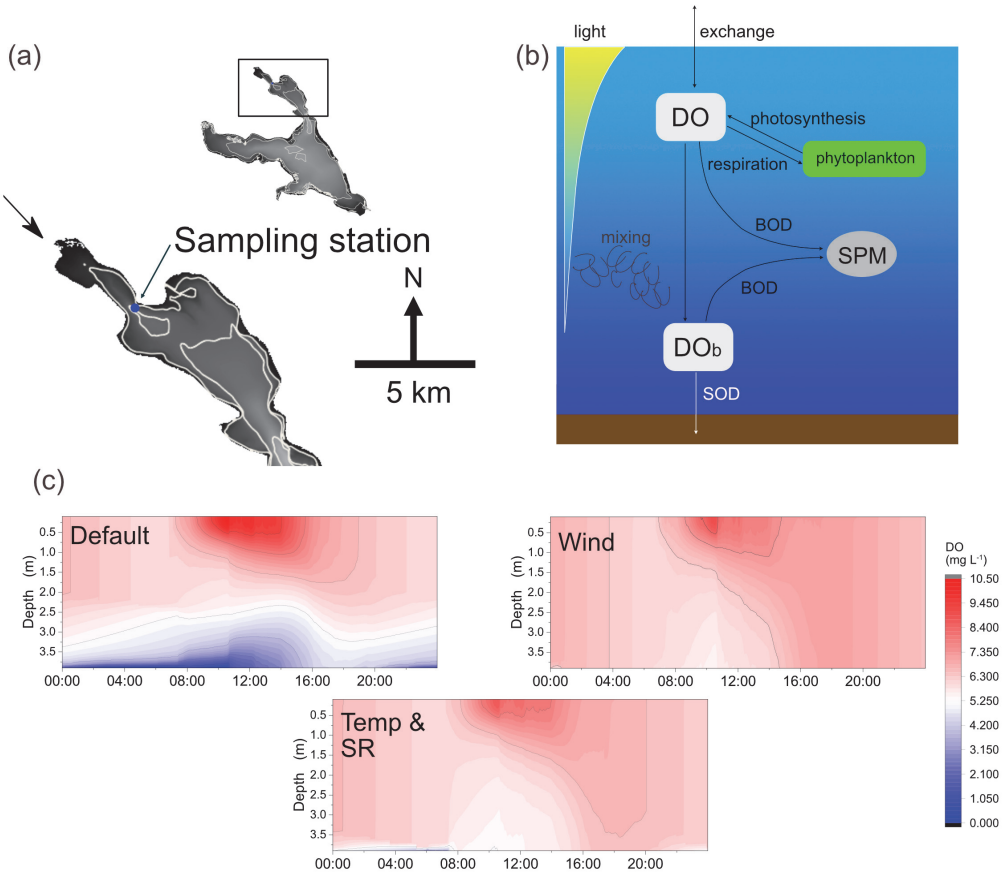


Fig. 2 (a) Map of Lake Kasumigaura, showing sampling station. (b) Schematic diagram of our model. (c) Vertical and temporal changes in the dissolved oxygen (DO) concentration on 29 June 2002 by the simulation model. "Default" means under the heat wave conditions in 2022. "Wind" means under the usual (non-heat-wave) wind conditions. "Temp & SR" means under the usual air temperature and solar radiation. BOD, biochemical oxygen demand; SPM, suspended particulate matter; SOD, sediment oxygen demand; DO_b, dissolved bottom water oxygen

2. Policy-Oriented Research

2.1 Mechanism of sediment oxygen demand in the depths of Lake Biwa

In the context of policy-oriented research, we conducted studies on preservation and regeneration of the natural environment of Lake Biwa in collaboration with Shiga Prefecture's regional revitalization efforts. This year, in cooperation with LBERI (the Lake Biwa Environmental Research Institute), which is the local environmental research institute in Shiga Prefecture, we investigated the factors affecting the variability of the sediment oxygen demand (SOD).

At the sediment–water interface, DO is consumed through the decomposition of organic matter and the oxidation of reductive substances. This consumption of DO is referred to as the SOD. This parameter substantially influences the dynamics of DO in the bottom layer—a critical aspect of Lake Biwa's benthic environment. Past studies have revealed that the SOD often registers between 0.3 to 0.4 g m^{-2} day^{-1} at the environmental reference point in the northern part of Lake Biwa, known as the *Imazuokichuo* (with a depth of approximately 90 m. The water temperature at this point remains relatively low, averaging about 8 °C throughout the year. Given the low biochemical oxygen demand, we surmised that the contribution to SOD from microbial activity at the surface of the sediment is low. To verify this hypothesis, aminoglycoside antibiotics or glutaraldehyde were added during SOD measurement

to suppress microbial activity. This allowed us to measure the oxygen consumption unrelated to microbial activity, such as the contribution of anoxic sediment pore water containing reductive iron and manganese leaching into the lake water. As a result, even when antibiotics or disinfectant were added, the SOD was not completely suppressed, suggesting that sediment oxygen consumption unrelated to microbial activity could account for 50% to 70% of the total (Fig. 3). Our joint research on SOD with the LBERI is also helping to improve the methods used to monitor the bottom layer environment of Lake Biwa. The SOD measurement method developed by the NIES Lake Biwa Branch Office has been tentatively introduced into the LBERI monitoring survey.

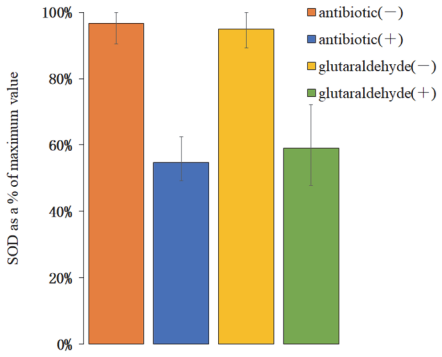


Fig. 3 Mean changes in sediment oxygen demand (SOD) upon the addition of antibiotics and glutaraldehyde (disinfectant); error bars show standard deviation.

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 NIES by building and maintaining internal and external research infrastructure, including by preserving biological samples, monitoring, providing analysis support, and developing databases.

1. Foresight and Advanced Basic Research

Because ecosystems are complex systems of various physical, biological, and chemical processes, it is challenging to reveal causal relationships among ecosystem components from time-series data. Although various causality methods have been proposed recently, most methods are not expected to be robust to dynamical complexity—that is, to different levels of stochasticity and nonlinearity. Here, we developed a new method called EcohNet, which is based on the ensemble prediction of neural networks that can seamlessly handle stochastic/deterministic and linear/nonlinear dynamics. EcohNet combines a type of recurrent neural network, called an echo state network, with a progressive selection of variables. Initially, we select a target variable and then obtain a distribution of predictive performance (prediction skills). In the next step, we choose a second variable from a group of variables other than the target variable, one by one, and adopt the one that improves the prediction skill the most. If the prediction skill does not improve, no further new variables are adopted. We applied EcohNet to long-term monitoring data on Lake Kasumigaura to examine the top-down and bottom-up causal factors of cyanobacterial dynamics; these cyanobacteria are a serious threat to ecological integrity and ecosystem services.

EcohNet showed that three cyanobacterial groups could be distinguished by different factors, and NO_3-N influenced all cyanobacterial groups (Fig. 1). We also detected the top-down control of cyanobacteria by rotifers and calanoids (rotifers→Oscillatoriales, calanoids→*Microcystis*), although large and small

cladocerans and cyclopoids had no influence. Importantly, we identified several interactions between cyanobacterial groups or between cyanobacteria and diatoms (*Nostocales*→Oscillatoriales and *Fragilaria*→*Microcystis*). Application of EcohNet to the long-term lake monitoring dataset yielded interpretable results regarding the drivers of cyanobacterial blooms. Because climate change is predicted to promote the occurrence and severity of cyanobacterial blooms, forecasting these blooms by using EcohNet is critically important for water quality management.

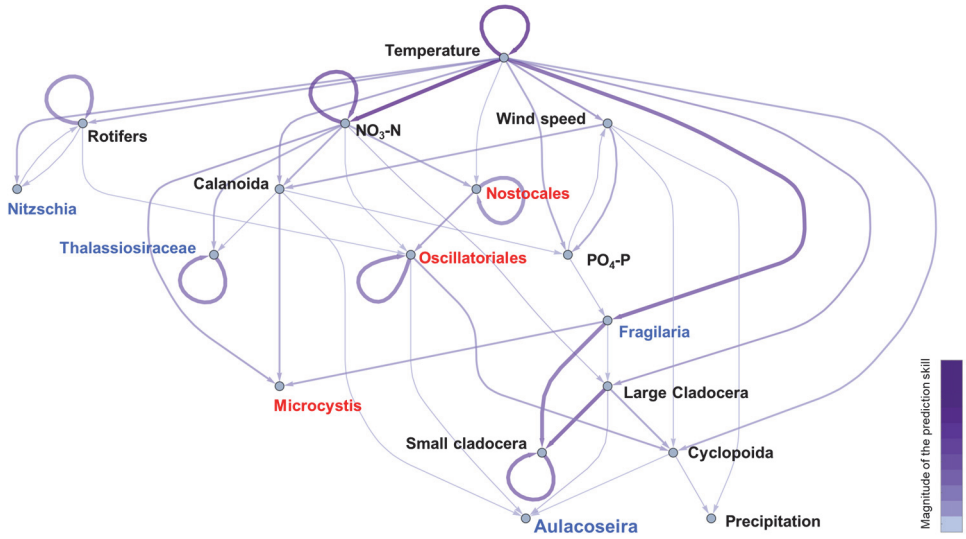


Fig. 1 Causal network of environmental factors, dominant phytoplankton groups, and zooplankton in Lake Kasumigaura. The magnitude of the prediction skill is indicated by both the thickness and color of arrows. Three dominant cyanobacteria groups are shown in red font, and four dominant diatom groups are shown in blue font.

2. Policy-Oriented Research

Shiga Prefecture, which encompasses Lake Biwa, the largest lake in Japan, aims to realize and restore a society where people and the ecosystem centered on Lake Biwa coexist. As a symbol of this effort, the prefecture is working to restore the stocks of native cyprinid fishes, which have been eaten since ancient times. In the spawning season, these native fishes migrate from offshore to the lakeside reed zones, rice fields, and waterways to spawn. However, because of the construction of lakeside embankments and the modernization of rice paddy irrigation systems in about 1970–1990, these native fishes lost many of their spawning grounds and their population drastically decreased. As improvement measures, Shiga Prefecture is creating new reed zones along the lakeside and is encouraging the installation of fish passages in waterways to facilitate the ascent of native fishes to the rice fields. However, the effects of these measures have not yet been not fully determined.

To help improve these measures, the NIES Lake Biwa Branch Office is investigating the current state of breeding ecology of native fishes by collecting spawned eggs and performing DNA species identification. This year, we published a paper on the results of a survey of waterways and rivers in the paddy area on the northeastern shore of the lake. As these waterways and rivers are widely protected

by artificial banks, it is difficult to say whether they are good spawning grounds. However, analysis of the collected spawned eggs revealed that plants hanging down from soil slopes (Fig. 2a, b) serve as spawning substrates for *nigorobuna* (*Carassius buergeri grandoculis*) (Fig. 2c), whereas roots of willow trees extending into the water (Fig. 2d) and gravel on the riverbed (Fig. 2e) function as those for *honmoroko* (*Gnathopogon caerulescens*) (Fig. 2f). These results provide useful knowledge for considering the restoration and creation of spawning grounds in artificially modified waterways and rivers.

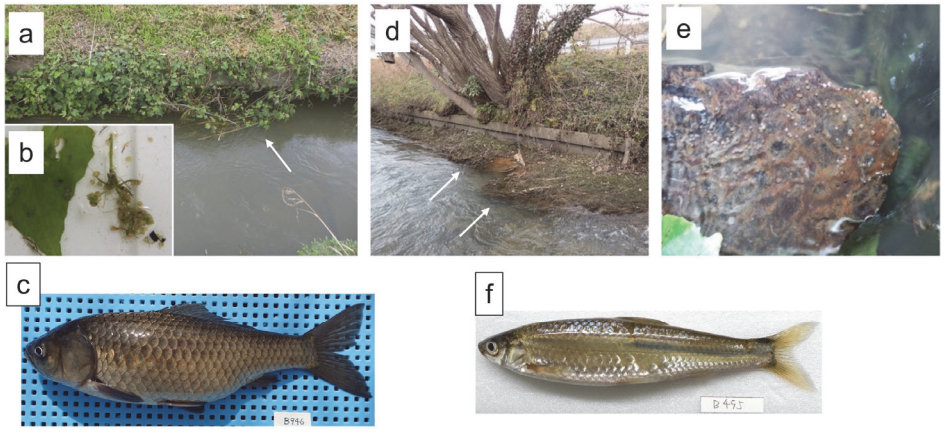


Fig. 2 Spawning habitats of two cyprinid fishes native (endemic) to Lake Biwa. See text for details.

3. Intellectual Research Infrastructure Development

The Microbial Culture Collection has continued to operate as a core facility of algal resources in the NBRP (National BioSource Project) by collecting, preserving, and distributing algal strains that are important for life science and environmental research. A total of 4134 strains are maintained, and approximately 1000 strains per year (1180 strains in FY 2022) are provided to researchers for various purposes (Fig. 3). To promote efficient management, we have been conducting various condition surveys for difficult-to-cryopreserve species, and in 2022, we successfully cryopreserved 131 strains. As a recent topic, we succeeded in establishing strains of *Karenia selliformis*, which caused serious problems in wild salmon and sea urchins by forming red tides along the Pacific coast of eastern Hokkaido in September–November 2021. These strains are now available for research. Other activities included continuing registration and updating of the strain data in the international databases, GBIF (Global Biodiversity Information Facility) and AlgaeBase, as well as ABS (Access and Benefit-Sharing) correspondence regarding five strains from Vietnam in 2022.

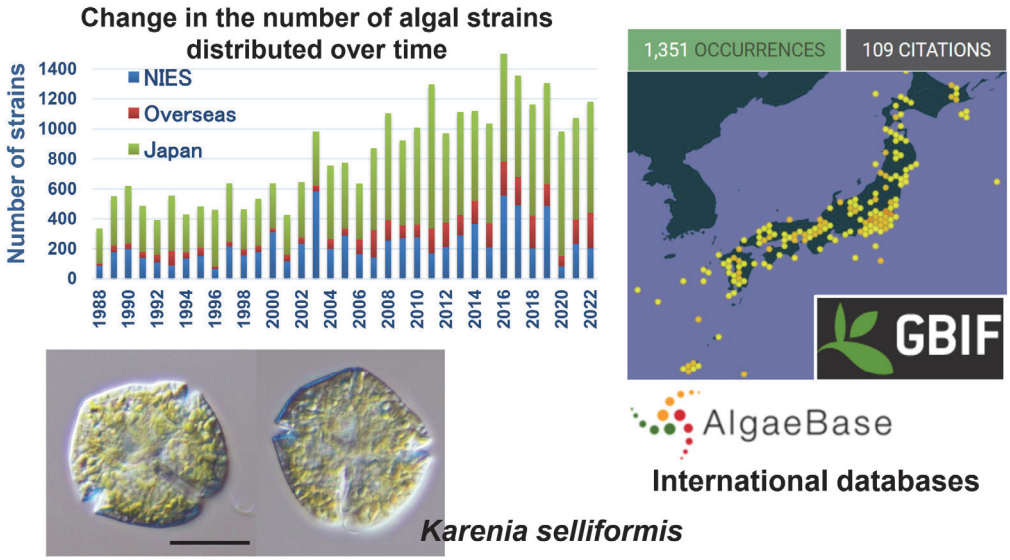


Fig. 3 Microbial Culture Collection activities, showing numbers of algal strains distributed, light micrographs of *Karenia selliformis* with 10 μm scale bar, and international databases. In the GBIF, occurrence data on 1351 strains have been registered and are currently cited in 109 references.

Social Systems Domain

The Social Systems Domain 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 Domain 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 Domain 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 2022, the Social Systems Domain conducted the following research activities as **Foresight and Advanced Basic Research** to improve the relationship between socioeconomic activities and the environment.

1.1 Bias correction of global reanalysis data for impact assessments

Research on exposure to heat is one component of environmental impact assessments. Especially in recent years, more detailed spatial and temporal analysis is required when global-scale climate impact assessments are conducted. In this

context, reanalysis of a data set on temperature with 1-h resolution at a global scale was released and is now available. However, in general, the global reanalysis data set does not take anthropogenic heat emissions (i.e., the urban heat island phenomenon) into account; therefore, it cannot be used directly for environmental impact assessment. Especially in urban areas, this may cause bias in the results of environmental impact assessments. Therefore, we compared and verified the global reanalysis data on temperature against the corresponding data from meteorological stations on each grid. We then evaluated the degree of bias and examined a method to correct for the bias. Examples of results for the degree of temperature bias between the reanalysis data and temperature data at weather stations in Tsukuba and Tokyo from 2000 to 2010 are shown in Figure 1. Positive values for the degree of bias indicate that the actual temperature data at the weather stations were higher than the global-scale reanalysis data.

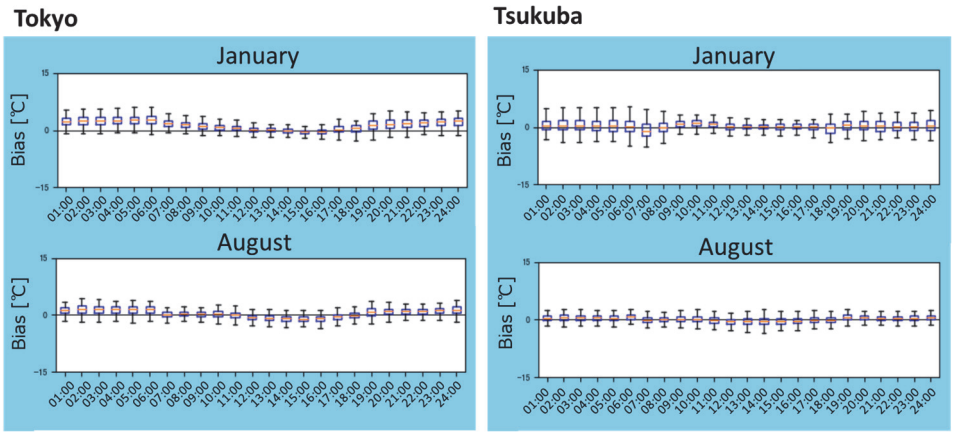


Fig. 1 Degree of temperature bias between the global reanalysis data and temperature data at weather stations in the corresponding grid

1.2 Energy demand monitoring system at an urban scale

Since 2015 we have been installing multiple energy demand monitoring systems that can observe electricity demand at the device level in some residences in Bogor, Indonesia. This study aimed to use the monitoring data to estimate the time-series and equipment ownership ratio of electricity consumption by households in the entire city. However, the number of households monitored was small, and therefore the system was unlikely to be regarded as representative. Therefore, we used questionnaire data to mimic monitoring data, and we increased the number of samples to estimate the energy demand characteristics of the entire city via spatial interpolation. In addition, we developed a reinforcement learning system for discrete time–electricity demand estimation systems for unmonitored households. Questionnaires were distributed to approximately 600 households, including those that were monitored. From the results of the questionnaire, we created a model by reinforcement learning to probabilistically estimate the electricity consumption of the unmonitored households from the electricity consumption of the monitored households. We then obtained an estimated spatial interpolation of the energy demand characteristics of all households in Bogor by using a spatial statistics

method. On the basis of this analysis, we developed an hourly energy demand prediction model that could be automatically improved by adding new data from the reinforced learning framework. Figure 2 shows the results of our estimation of the electricity consumption and electricity consumption patterns of each household on the basis of the questionnaire and the electricity consumption observed by the monitoring.

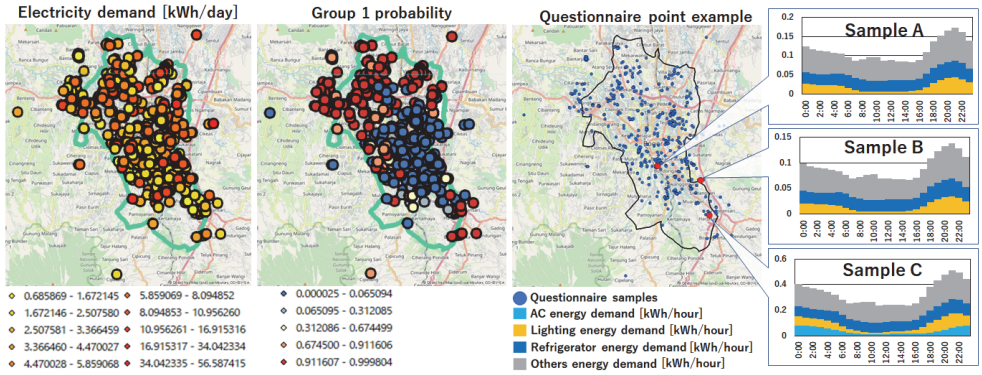


Fig. 2 Energy consumption of Bogor City, Indonesia, estimated by using monitoring and questionnaire data fusion

1.3 Analysis of electricity consumption patterns at NIES

As society accelerates the transition to carbon neutral, NIES is expected to reduce greenhouse gas emissions from its activities. This study used monitoring data to analyze the characteristics of electricity consumption at NIES and their relationship with research activities. Together with the Facility Management Office of the General Affairs Division of NIES, we collected hourly electricity consumption data through a whole year from a total of 445 points at NIES's Tsukuba Headquarters. The data collected for each electrical substation area were shared with researchers and staff through information exchange meetings (12 in total). Through the meetings, we discussed with researchers and staff the reasons for changes in electricity consumption patterns. We found that electricity consumption varied substantially (by tens of kilowatt hours) because of the replacement of data processing systems and supercomputer systems and the operation of experimental equipment. NIES has several facilities and items of equipment that use large amounts of electricity, and adjustment of the operational timing of these facilities and equipment is important for suppressing peak electricity demand. The study also found that there was constant electricity consumption throughout the year in the operation of constant temperature and humidity rooms, and changing temperature or humidity settings, or both, in these rooms will be indispensable actions for achieving carbon-neutral research activities at NIES. In addition to performing these diagnostic activities, we tried to detect the impacts of electricity-saving actions by researchers and staff. We found that suspension of, or changes in, the operation of experimental equipment will reduce electricity consumption substantially (Fig. 3).

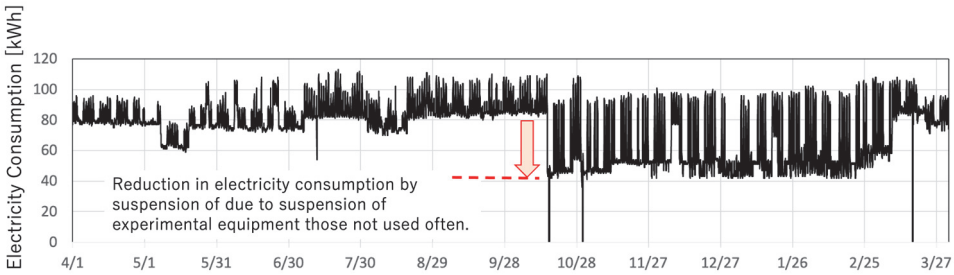


Fig. 3 Changes in electricity consumption through modification of the operation of experimental equipment

1.4 Research on impacts of working styles on society and the environment

NIES and Okamura Corporation conducted a joint analysis of the impact of telecommuting in urban areas (which has been adopted rapidly because of the COVID-19 epidemic) on energy consumption and CO_2 emissions. We used four points: 1) energy consumption at home due to telecommuting; 2) energy consumption in offices; 3) energy consumption associated with commuting; and 4) energy consumption associated with increased leisure time). An online survey of 4000 people who telecommuted was conducted, and the results were used to estimate the impact of telecommuting on energy consumption and CO_2 emissions. Our findings suggested that the current hybrid type of telecommuting (partly commuting and partly telecommuting) is not very effective in reducing office energy consumption, and that the implementation of telecommuting may even have led to increased energy consumption, especially in the case of public transport users. On the other hand, for those commuters who used passenger cars for commuting, we found that energy consumption could be significantly reduced by implementing telecommuting. We found that, to reduce energy consumption from hybrid telecommuting, in addition to examining how the office is used and how energy consumption is reduced at home during telecommuting, attention must also be paid to what activities are performed during the increased leisure time available because of the reduced commuting time.

1.5 Research on a framework for policy evaluation studies through a multifaceted review of the history and issues related to the social cost of carbon

The social cost of carbon (SCC) captures the social damage done by the additional emission of carbon dioxide—in other words, the social benefit of the additional mitigation of carbon dioxide emissions. Although SCC has become central to the academic and policy arena in the U.S., its presence in Europe seems less salient, and it is barely known in Japan. In this study, we reviewed recent research, debates, and discussions centered around SCC in the U.S. and Europe. We hope that this will provide useful information on how NIES and environmental policy in Japan should address SCC.

In FY 2022, we found that: 1) In the U.S., SCC is not necessarily applied to carbon pricing; instead, it is applied to decarbonizing policies and regulations—which is politically less challenging than carbon pricing. 2) SCC was introduced into U.S.

policy on a grand scale under the Obama administration. However, the estimates have been subject to political influence and have thus experienced a roller-coaster ride. 3) The challenges of SCC estimates include their consistency with net-zero-emission targets, variations in the estimates and scopes of damage, and the reflection of income distributions. 4) An alternative that is separate from the SCC approach is what is referred to as the target-consistent approach, whereby the most cost-effective cost of an additional mitigation is estimated under a given emission target. With these findings in mind, we suggest that we prepare for studying SCC estimates based on our own in-house models, and that we continue to keep abreast of the discussions and applications relevant to SCC in the international academic and policy communities.

2. Policy-Oriented Research

As **Policy-Oriented Research**, in FY 2022 we ran several online training workshops for policymakers and researchers, although during COVID-19 it was difficult to conduct large-scale training programs by accepting personnel from abroad. For policymakers in Asia, on 27 and 28 October 2022 we organized a training workshop on 1) Climate Policy and Models, 2) AIM (the Asia-Pacific Integrated Model) as a tool for assessing 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) at NIES. For researchers, we set up online training workshops for ExSS (Extended Snapshot Tool) in January 2023, AIM/Enduse (a technology selection model) in February to March 2023, and AIM/CGE (Computable General Equilibrium model; an economic model) in July to October 2022.

In FY 2022, Thailand submitted revised long-term strategies to the United Nations Framework Convention on Climate Change by using AIM results prepared by researchers in Thailand. Such contributions are the goal of Policy-Oriented Research in this Domain.

3. Intellectual Research Infrastructure Development

To design visions and roadmaps that will enable us to achieve a decarbonized society at the municipality scale, it is essential that we establish energy demand and supply information (energy balances) for municipalities. Such information will be used not only to design future visions and actions, but also to promote understanding of the current status of energy systems in each municipality. This study estimated municipal energy balances for all municipalities (1741) from 2013 to 2019 on the basis of prefectural energy balance information by referring to manuals produced by the Ministry of the Environment, Japan. Demand-side sectors classified into the industrial sector included agriculture, forestry, fisheries, mining and construction, food and beverages, textiles, and 11 other manufacturing

industries. The commercial sector included electricity, gas, heat supply, water supply, information and communications, and transportation and postal services. On the demand side, the residential sector included heating, cooling, and other uses, and the transportation sector included passenger cars, buses, and trucks. On the supply side, energy consumption was estimated in terms of coal, coal products, crude oil, light oil products (including gasoline and kerosene), heavy oil, LPG, natural gas, renewables and unused energy, electricity, and heat. We also used the estimated energy balance information to draw energy flow charts for municipalities. Figure 4 is an estimated energy flow chart for the city of Tsukuba, in Ibaraki Prefecture, as an example.

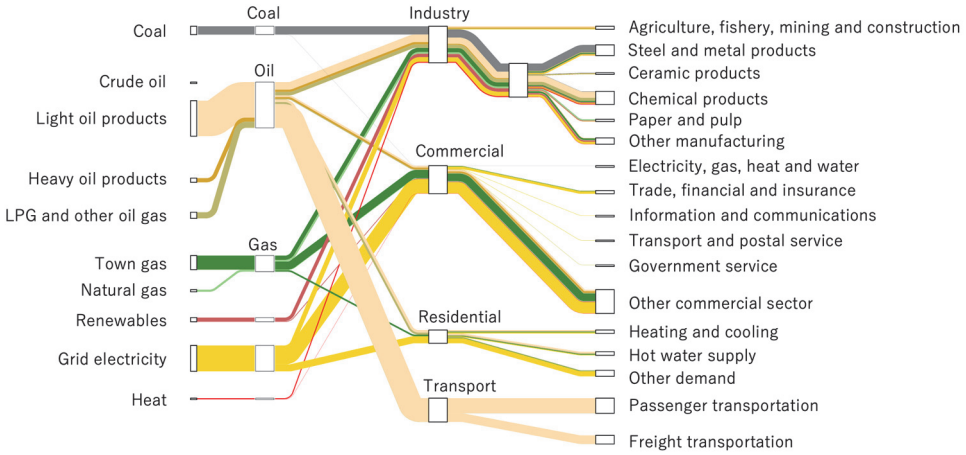


Fig. 4 Estimated energy flow chart for the city of Tsukuba, in Ibaraki Prefecture, in FY 2018

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). By 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

The nuclear power plant accident in Fukushima led to the pollution of forest ecosystems with ^{137}Cs in 2011. In this study, we simulated the spatiotemporal distribution of ^{137}Cs concentrations in the litter layer in the contaminated forest ecosystems in two decades from 2011. Litter layer contamination is one of the key environmental components of ^{137}Cs migration in the environment because of the high bioavailability of ^{137}Cs in the litter. Our simulations showed that ^{137}Cs deposition is the most important factor in the degree of contamination of the litter layer, but vegetation type (evergreen coniferous/deciduous broadleaf) and mean annual temperature are also important for changes over time. The forest floor under deciduous broadleaf trees had higher initial concentrations in the litter layer owing to direct initial deposition on the forest floor. Moreover, the concentrations remained higher than those under evergreen conifers after 10 years because of the redistribution of ^{137}Cs by vegetation. Areas with lower average annual temperatures and lower litter decomposition activity retained higher ^{137}Cs concentrations in the litter layer. The results of spatiotemporal distribution estimation by using the

radioecological model suggest that, in addition to ^{137}Cs deposition, elevation and vegetation distribution should also be considered in the long-term management of contaminated watersheds. This modeling should be informative in identifying hotspots of ^{137}Cs contamination on a long-term scale.

2. Policy-Oriented Research

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

This study aims to help with environmental recovery and creation in the affected areas following the FDNPP accident. In addition, it aims to provide knowledge that will contribute to the environmental policies implemented by municipalities in Fukushima Prefecture during times outside environmental disasters. Data on policy infrastructure, administrative plans formulated by municipalities, and local community stakeholders involved in environmental and reconstruction policies will be collected and analyzed to contribute to environmental recovery in areas affected by the FDNPP accident. On the basis of the above, recommendations for the formulation of environmental plans and environmental policies of municipalities will be made.

First, we conducted a study of the relationship between reconstruction policies, industrial base development projects, and decarbonization policies in 15 municipalities affected by the FDNPP accident. Specifically, we constructed and analyzed a database of master and disaster reconstruction plans; plans by policy area, facilities, and business location; and base development projects. In addition, the information on the status of industrial complexes, including the Fukushima Innovation Coast Framework, and the status of business locations was organized by using a geographic information system.

Secondly, with respect to the Fukushima Innovation Coast Framework, we began analyzing stakeholders' policy needs and their policy networks involved in the framework. We are currently conducting a questionnaire survey and social network analysis of the organizations involved in the Fukushima Innovation Coast Framework to clarify the structure of these policy networks and the challenges of network governance through collaboration among the various organizations.

Thirdly, we conducted a study to clarify the diversity of municipal governance structures in the areas affected by the FDNPP accident. We analyzed the principles and goals of reconstruction and the methods of public participation, as stated in the reconstruction plans of the eight affected municipalities that underwent full evacuation after the accident.

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

To refine the statistical model used to estimate the amount of disaster waste generation, we continued to collect and organized data on the amounts of disaster waste disposed of in past disasters, together with data on the scale of, and damage caused by, each disaster. We also collated data on regional characteristics related to the generation of disaster waste. For these purposes we used a series of desktop surveys. We obtained data for a total of 24 disasters and 277 municipalities. The data were then cross-checked with the database of general waste maintained by the Ministry of the Environment. The results showed that the values reported in the database of the Ministry of Environment tended to be smaller than those obtained from our desktop surveys.

To understand the mechanisms of how waste is generated through cleanup activities after disasters over time, we continued a basic survey of temporal trends in the number of activities of disaster relief volunteers who help with the cleanup of disaster-stricken houses.

For the manual sorting of disaster waste, a wearable line-of-sight camera was attached to workers who were engaged in manual sorting of PET bottles, glass bottles, and cans at an industrial waste treatment plant. Monitoring of the workers' gaze revealed that their line of sight was fixed within a certain range. We believe that this knowledge can be used to increase the efficiency of the work arrangement of multiple workers in a disaster context.

As part of the development of a technology that can rapidly measure asbestos from building materials and can be used in disaster contexts, we attempted to train an artificial intelligence model by using air samples from demolition sites.

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 engaged in efforts to support local governments and other organizations to help improve their disaster-response capabilities, even in times outside disaster.

In FY 2022, we supported the national and local governments in their efforts to develop human resources and disaster waste management plans, and we added content to the Disaster Waste Information Platform—especially practical support tools based on our research results.

In addition, we collaborated with the Ministry of the Environment and related organizations to continuously study and strengthen relationships regarding how to

provide support to disaster-affected areas in emergency situations and in normal times.

In particular, with a focus on how public information should be communicated to the public in times of disaster, meetings were held with officials from local governments to share information and discuss practical examples from each municipality. Although there are still many issues to be addressed regarding public relations during disasters, it is important to collect and organize good practices from case studies and share them with other local governments.

3. Intellectual Research Infrastructure Development

3.1 Estimated amount of radioactive cesium migrated with industrial waste in Fukushima Prefecture

We estimated the amount of radiocesium (r-Cs) that migrated from the intermediate treatment and disposal of construction and demolition waste by combining data on the material flows of construction and demolition waste transferred as industrial waste (in Fukushima Prefecture) and the density (measured as the air dose rate at each site) of the surface contamination of structures.

The amount of waste transferred was estimated from manifest data from Fukushima Prefecture between 2011 and 2015. The percentages of such items as wood waste and concrete waste discharged by type of demolition work were estimated from the names of the establishments in the manifest data and the blueprints of typical building structures. The amount of r-Cs that migrated from treatment and disposal of the waste was estimated from the air dose rate at the site of generation. The surface contamination density of structures (e.g., buildings, roads) was investigated, and the relationship with the air dose rate was determined for each component and each horizontal and vertical installation direction. Surface contamination densities on the exterior surfaces of buildings in “difficult-to-return” zones, where decontamination had not been completed, were measured for 2 years and 3 months, and the decrease in surface contamination density over time due to washing away by precipitation (i.e., the environmental attenuation) was determined in relation to the amounts of precipitation measured at the sites.

As a method of calculating the r-Cs concentration of outdoor and building exterior components, the weight ratio of the surface area exposed to the outside to the direction of installation was determined. This ratio was then multiplied by the surface contamination density according to the installation direction, as estimated from the air dose rate at the site of occurrence. The r-Cs concentration by site of generation and type of waste (obtained above) was then multiplied by the amount of r-Cs that migrated from the waste.

By using the method described above, we estimated the amount of r-Cs that

migrated from the treatment and disposal of concrete waste, asphalt concrete waste, plastic waste, and wood waste generated from construction and demolition work. The analysis showed that, in 2015, approximately 5.8 GBq of r-Cs was transferred from the treatment and disposal of concrete waste. For asphalt concrete waste, the amount was 498 GBq; for waste plastics, 45 GBq; and for wood waste, 41 GBq. The study showed that, in Fukushima Prefecture, most of the waste (with the exception of wood waste in 2011) has been intermediately processed and subsequently recycled.

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

After the FDNPP accident in Japan, freshwater ecosystems near the site remained contaminated by r-Cs. Clarifying r-Cs concentrations in aquatic insects is crucial, because fishes consume these insects and thus transfer r-Cs into freshwater ecosystems. As aquatic insects are usually measured for radioactivity in bulk samples of several tens of insects, variations in the r-Cs concentration among individuals are not captured. In this study, we investigated the variability in ^{137}Cs activity concentrations in individual aquatic insects, namely detritivorous caddisfly (*Stenopsyche marmorata*) and carnivorous dobsonfly (*Protohermes grandis*) larvae, from the Ota River, Fukushima. Four of the 46 caddisfly larvae showed sporadically higher radioactivity, whereas no such outliers were observed in 45 dobsonfly larvae. Autoradiography and scanning electron microscopy analyses confirmed that these caddisfly larvae samples contained r-Cs-bearing microparticles (CsMPs), which are insoluble Cs-bearing silicate glass particles. CsMPs were also found in potential food sources of caddisfly larvae, such as periphyton and drifting particulate organic matter, indicating that the larvae may ingest CsMPs along with food particles of similar size (Fig. 1). Although the CsMP distribution and uptake by organisms in freshwater ecosystems is relatively unknown, our study demonstrates that CsMPs can be taken up by aquatic insects.

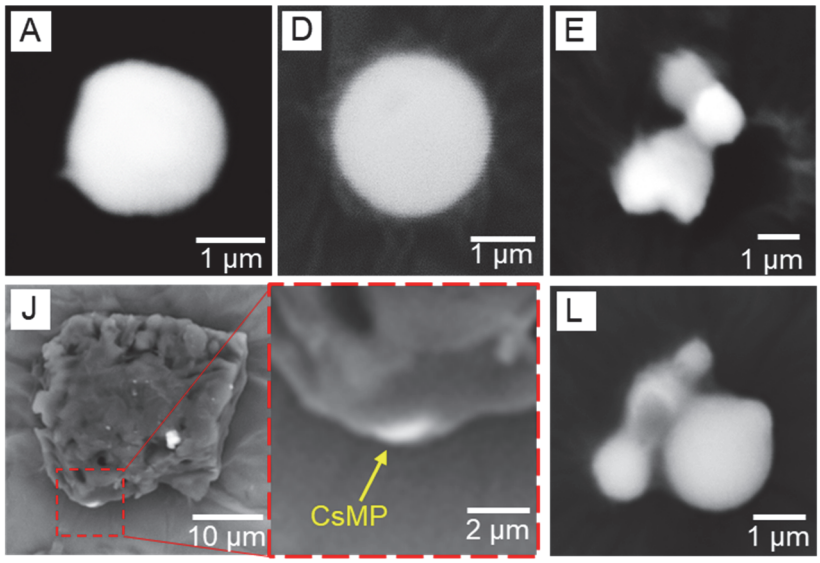


Fig. 1 Radiocesium-bearing microparticles (CsMPs) were isolated from caddisfly larvae (A), periphyton (D, E), coarse particulate organic matter (J), and suspended solids (L). CsMPs were placed on Kapton tapes for scanning electron microscopy–energy dispersive spectroscopy analyses. In the case of the CsMP in J, Cs was detected only in the white area of the large particle.

3.3 Biodiversity and ecosystem monitoring for regional collaboration

Although the evacuation order resulting from the 2011 FDNPP accident was lifted across a large area in 2017, a considerable part of the "difficult-to-return" zone remains. In this zone, anthropogenic activities have been restricted, and there is concern about the impacts on regional biodiversity and ecosystems of traditional anthropogenic activities such as farming. To reveal the status of biodiversity and ecosystems in and around the evacuation zone and share this information broadly, monitoring was conducted in FY 2022, following on from the previous year. Mammals were surveyed by using 46 camera traps set in forest areas. Birds, frogs, and insects were surveyed in 56 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 and spiders. As a result, we obtained movie files from the 46 mammal survey locations, along with sound files and insect samples from 55 of the bird, frog, and insect survey locations. A preliminary summary of the data on insects and spiders captured by 13 Malaise traps showed that the mean abundances of Coleoptera (beetles), Diptera (flies), and Hymenoptera (bees, wasps, and ants) were higher in the evacuation zone than in the ex-evacuation zone or the control zone (Fig. 2); these results were similar to last year's, although further statistical analyses are required for appropriate inference of the results. The preliminary results were shared with the elementary schools in which the traps were set.

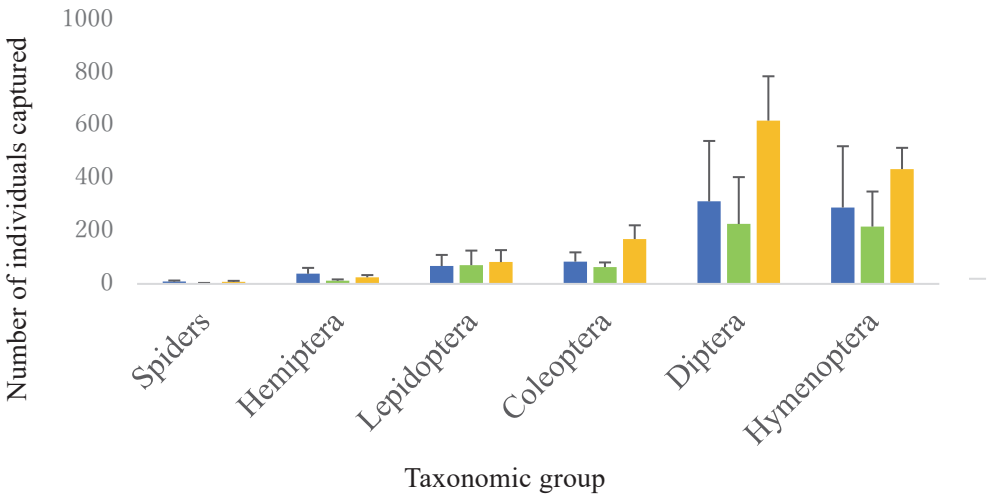


Fig. 2 Mean abundances and standard deviations of insects and spiders captured by the Malaise traps in and around the evacuation zone in 2022. Orange bars, evacuation zone; green bars, ex-evacuation zone; blue bars, area where no evacuation order has been announced.

In addition, continuing on from previous years, in 2022 we investigated the megabenthic community structure and environmental status along three latitudinal transects extending off the coastline in the north, central, and south regions of Fukushima Prefecture. Each transect was composed of three sites with different water depths (10, 20, and 30 m). When we combined these data with the data collected in previous years, we found decreases in the abundance and biomass of certain fishes, crustaceans, and echinoderms. Further research is needed to reveal the causal factors behind the changes in these megabenthic communities.

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 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 third issue of "FRECC+ Essence," a booklet re-edited from the web magazine, was published. For the purpose of learning and educating, and fostering the next generation of local human resources, we continued on from last year with the "Environmental Cafe Fukushima," a year-round dialogue forum, with eight members of the chemistry club at Fukushima Prefectural Asaka Reimei High School. At the end of FY 2022, we held a debriefing session on their activities. 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 build relationships with local stakeholders, we collaborated with a nonprofit organization in the city of Koriyama, in Fukushima Prefecture, that has been involved in activities to support disabled people affected by the Great East Japan Earthquake. The aim of the collaboration is to establish a "Mountain School" to consider how to create a diverse and rich symbiotic society based on lessons learned from the Fukushima experience. We also planned and implemented an environmental learning program for working adults and local high school students. One of the program's main initiatives is natural symbiosis in Satoyama and the use of local resources such as forest biomass.

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 2022.

1. Foresight and Advanced Basic Research

1.1 Application of non-targeted analysis using thermal desorption/comprehensive two-dimensional gas chromatography/time-of-flight mass spectrometry to accidental fires

So that we can gauge the health risks and biological effects of e-waste fires, it is of key importance to know what types and amounts of chemicals are released when these fires occur. In this study, we pumped between 6 and 24 L of air from an accidental fire at a recycling depot through a Tenax-TA sorbent tube and conducted comprehensive (non-targeted) analysis by thermal desorption/comprehensive two-dimensional gas chromatography/time-of-flight mass spectrometry (TD/GC×GC/ToFMS). Special focus was placed on the search for halogenated compounds. More than 5000 components were detected in the atmosphere around the fire; however, component separation was insufficient, despite the use of GC×GC. The number of organohalogen compounds retrieved increased by about 1.8-fold by refinement of the exact mass spectrum when we used mass defect filtering (MDF) software. Figure 1 shows two-dimensional total ion chromatograms and mass spectra as examples of the effect of MDF. After the MDF processing, 386 peaks were concluded to be halogenated compounds. The major substances retrieved included chlorinated (or chlorinated-brominated) dioxins, chlorinated (or brominated) phenols, benzene, and various other halogenated aromatic compounds. Direct comparison of the mass spectra was performed to investigate the potential for qualitative and quantitative comparison of the detected peaks without their

specific identification. The approximate quantitative values were summarized for each compound in the estimated substance group. Their ratios were estimated to be halogenated phenols: 13%; benzenes: 9.6%; dibenzo-*p*-dioxins: 9.6%; dibenzofurans: 8.4%; biphenyls: 7.4%; and toluenes: 6.4%.

In this case, the challenge was the large number of chemical substances emitted during the combustion process and the validity of their identification. In some cases, we considered it necessary to select a sampling method or pretreatment method that focused on the target substances. The measurement accuracy of the instruments (e.g., the measurement error of accurate mass) and the preparation of accurate mass spectral libraries are also important, because they greatly affect the accuracy of substance identification. It is also necessary to prepare a high-throughput substance search method for screening. Nevertheless, in cases such as accidents and disasters, where chemical risk information needs to be provided urgently, this method of adding simple post-data processing to rapid, high-throughput, comprehensive analytical data obtained by direct analysis without preprocessing and universal electron ionization–gas chromatography–mass spectrometry (EI-GC/MS) may prove useful.

Funding sources

This research was supported by the Environment Research and Technology Development Fund S-17-4(2) (JPMEERF18S11714) under the aegis of Japan's Ministry of the Environment.

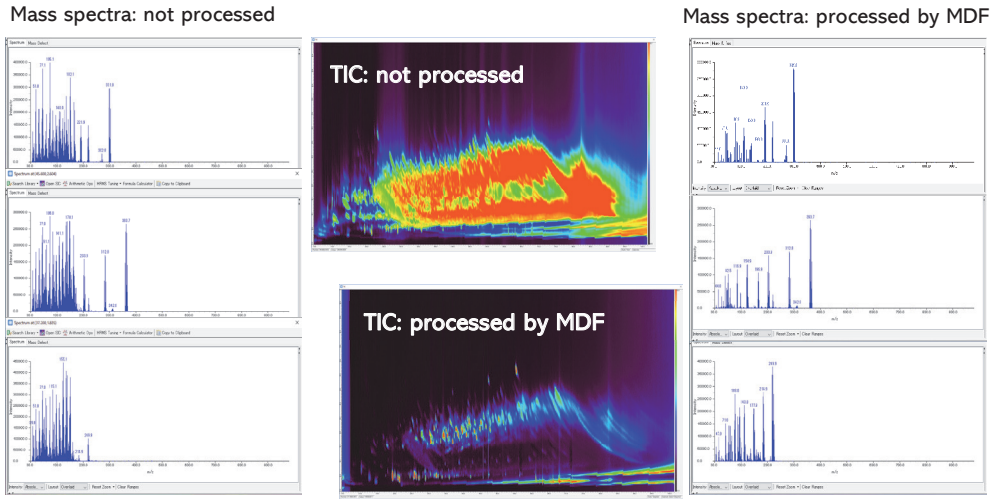


Fig. 1 Total ion chromatograms and examples of mass spectra processed and not processed by mass defect filtering (MDF) of air samples during a fire, as measured by GC×GC/ToFMS (Hashimoto et al. 2022)

Reference:

Hashimoto S., Takazawa Y., Ieda T., Omagari R., Nakajima D., Nakamura S., Suzuki N. (2022) Application of rapid air sampling and non-targeted analysis using thermal desorption comprehensive two-dimensional gas chromatography/time-of-flight mass spectrometry to accidental fire. *Chemosphere*, 303: 135021

2. Intellectual Research Infrastructure Development

2.1 Dual presaturation method for analyzing H_2O-rich samples by using quantitative ^1H nuclear magnetic resonance spectroscopy

Metabolomics is the comprehensive analysis of small-molecule metabolites included in biological samples such as urine, serum, and plasma in the presence of light water. ^1H nuclear-magnetic-resonance-based metabolomics can be used to survey metabolite patterns with minimum sample pretreatment, although suitable water-signal suppression is required to sufficiently reduce the large H_2O signal intensity. Water-signal suppression affects the trueness of the measured concentrations of analytes, but this impact has barely been discussed. Presaturation (pre-SAT) is a still widely used method of water-signal suppression. The accuracy of the pre-SAT method has been evaluated and dramatically improved at NIES. The improved method is a dual pre-SAT that can accurately quantify analytes, even near the suppressed water signal. The dual pre-SAT method consists of a conventional water pre-SAT and an extra dummy pre-SAT with a suitable offset for each analyte signal (Fig. 2). The proposed dual pre-SAT method accurately quantified glycine (Gly) and maleic acid (MA) in a 10 vol% D_2O/H_2O solution. The measured concentrations of Gly of 513.5 ± 8.9 mg kg^{-1} and MA of 512.2 ± 10.3 mg kg^{-1} corresponded to sample preparation values of Gly of 502.9 ± 1.7 mg kg^{-1} and MA of 506.7 ± 2.9 mg kg^{-1} (the number after "±" indicates the expanded uncertainty (k = 2)).

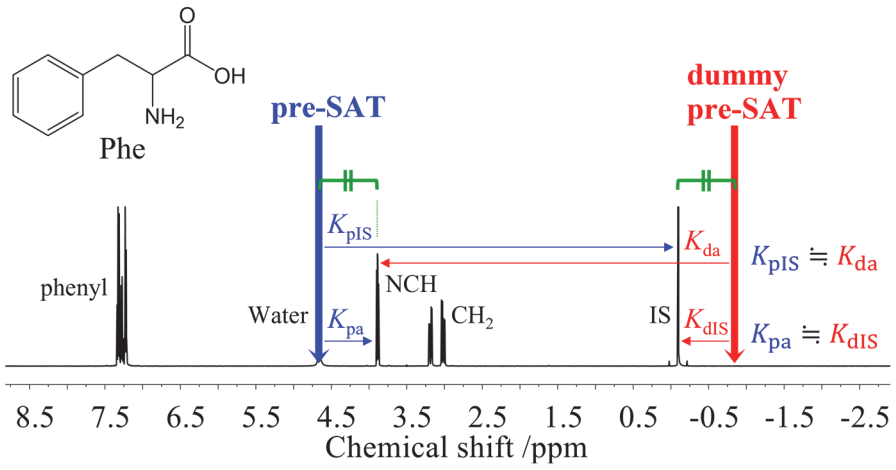


Fig. 2 Concept of the proposed dual pre-SAT method. The analyte is phenylalanine (Phe) and the internal standard (IS) is DSS-d_6. Coefficients K for the decreases in the signal areas caused by the water pre-SAT and the dummy pre-SAT are shown. The multiplied coefficients $K_{pIS}{\cdot}K_{dIS}$ for the total decrease in the IS signal area become equal to the multiplied coefficients $K_{pa}{\cdot}K_{da}$ for the total decrease in the NCH signal area of the analyte Phe. The multiplied coefficients are canceled out by obtaining both signal area ratios. (Reprinted with permission from Saito N. (2023), Fresh dual presaturation method for analyzing H_2O-rich samples using quantitative ^1H NMR. *Analytical Chemistry*, 95: 7855–7862. Copyright 2023 American Chemical Society)

Reference:

Saito N. (2023) Fresh dual presaturation method for analyzing H_2O-rich samples using quantitative ^1H NMR. *Analytical Chemistry*, 95: 7855–7862

Research Projects

Satellite Observation Project

The Satellite Observation Project contributes to improving scientific understanding of the global 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 2024. 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.

NIES's Satellite Observation Center (SOC) is responsible for implementing the Satellite Observation Project. Major achievements of the Satellite Observation Project in FY 2022 are as follows:

1. GOSAT

Operational data processing for GOSAT, which has been in space for more than 14 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 March 2023 (V02.90/91), CO_2 flux products up to October 2020 (V02.08), and CH_4 flux products up to September 2020 (V01.07) are freely available from GOSAT Data Archive Service (GDAS; https://data2.gosat.nies.go.jp), an online data distribution service. 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 CO_2 concentration data were used to evaluate the impact of the COVID-19 pandemic on the global carbon budget. The increase in the CO_2 concentration in the past 3 years (from January 2020 to January 2023) was 6.5 ppm, which was within the natural variability from 2010 to 2019 (7.0 ± 0.6 ppm) (Fig. 1). This means GOSAT did not detect any substantial impact of the COVID-19 pandemic on the global carbon budget.

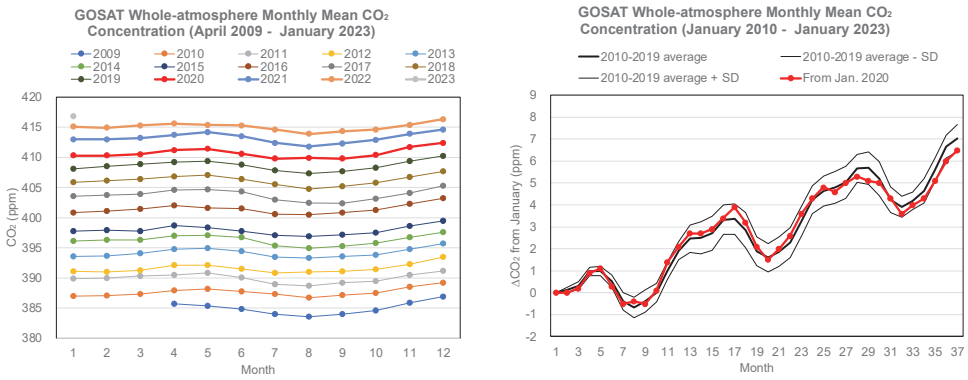


Fig. 1 (Left) GOSAT whole-atmosphere monthly mean CO_2 concentration from April 2009 to December 2022. (Right) Increase in GOSAT whole-atmosphere monthly mean CO_2 concentration over 3 years. The red bold line with closed circles indicates the CO_2 concentration during the COVID-19 pandemic.

GOSAT CH_4 concentration data and a high-resolution atmospheric transport and inverse analysis system were used to investigate methane emissions in China (Fig. 2).[1)] We found that the estimated CH_4 emissions varied in different regions of China in the period 2010–2018. The year-over-year increases in CH_4 emissions detected by the GOSAT observations in northeastern China were closely correlated with the changes in natural gas use in that region. In 2018, the estimated total natural gas emissions in this region were equivalent to 3.2% to 5.3% of the total regional natural gas consumption. These findings illustrate the urgent need for mitigation measures focused on reducing natural gas leaks from production, supply, and end-use facilities in the period of pipeline expansion in China so that the country can reach its carbon-neutral goal by 2060.

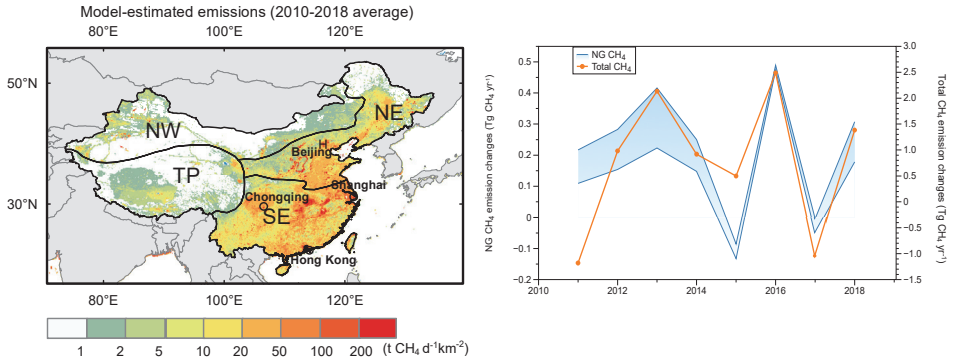


Fig. 2 (Left) Methane emission estimates for 2010–2018 in China. The four regions analyzed were northeastern China (NE), southeastern China (SE), northwestern China (NW), and the Qinghai-Tibetan Plateau (TP). (Right) Changes in estimated CH_4 emissions from natural gas (NG) (upper and lower range in blue) and model-estimated total CH_4 emissions (orange) in the NE region for the period 2010–2018.

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 L1B Product (V03.13), the CAI-2 L2 Cloud Discrimination Product (V01.05), and the FTS-2 SWIR L2 Column-averaged Dry-air Mole Fraction Product (V02.00) were released in FY 2022. One GOSAT-2 Science Team Meeting and one Data Release Review Meeting were held in FY 2022 to discuss issues such as data quality, including validation analysis and release preparation of the above-mentioned products.

The new version of the FTS-2 SWIR Level 2 Column-averaged Dry-air Mole Fraction Product (V02.00), which is based on the improved data processing

algorithm developed in FY 2021, is being used in global CO_2 and CH_4 flux estimations. Figure 3 is an example of the GOSAT-2 Level 4A CO_2 Flux Product, together with the GOSAT Level 4A CO_2 Flux Product, in October 2019. A new inversion system is used for GOSAT-2 data processing to achieve higher spatial resolution (≈ 2.5 × 2.5 degrees) than that of GOSAT. Subtle spatial variations that are not visible on the GOSAT map are shown on the GOSAT-2 map. GOSAT-2 Level 4 products will be released to the public in FY 2023.

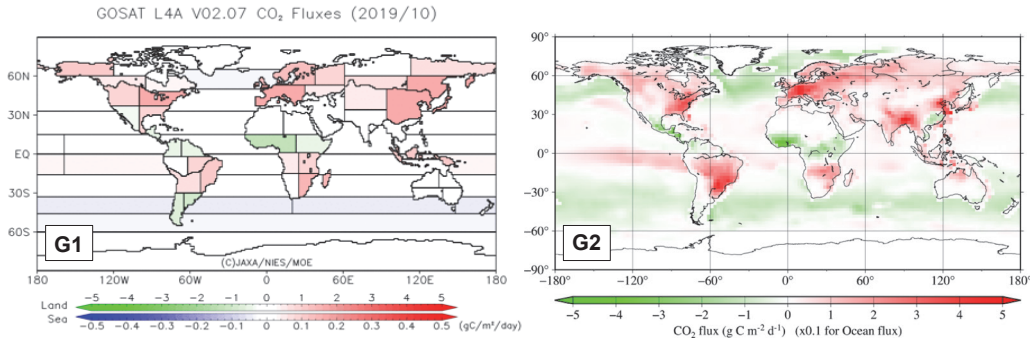


Fig. 3 Maps of Level 4A CO_2 flux products in October 2019 derived from (Left) GOSAT and (Right) GOSAT-2 data

3. GOSAT-GW

In FY 2022, manufacturing and testing of the Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3) and related ground systems, including NIES's GOSAT third-generation Data Processing/operating System (G3DPS) and the GOSAT-GW Nitrogen dioxide (NO_2) Data Processing System (GNDPS), were conducted by JAXA, NIES, and their contractors. The procurement contract for G3DPS hardware was concluded, and installation of the system at the University of Tsukuba is ongoing. Revisions of the TANSO-3 Validation Plan and the TANSO-3 Validation Implementation Plan were discussed in FY 2022. Procurement and installation of the ground-based observation instruments for validation of the TANSO-3 products are ongoing (Table 1 and Fig. 4).

Table 1 Ground-based observation sites in Japan for validation of TANSO-3 Products. These sites will also participate in the Total Carbon Column Observing Network (TCCON), the Collaborative Carbon Column Observing Network (COCCON), or the Pandora Global Network (PGN), which are global networks of ground-based observation sites.

	CO_2/CH_4		NO_2
	TCCON	COCCON	PGN
Hokkaido	ONGOING(Rikubetsu)		ONGOING (Sapporo)
Tsukuba	ONGOING	ONGOING	ONGOING
Tokyo - Downtown		IN PREP.	IN PREP.
Tokyo - Suburb			ONGOING
Yokosuka		IN PREP.	ONGOING
Nagoya			ONGOING
Kobe			ONGOING
Kyushu	ONGOING (Saga)		ONGOING (Fukuoka)

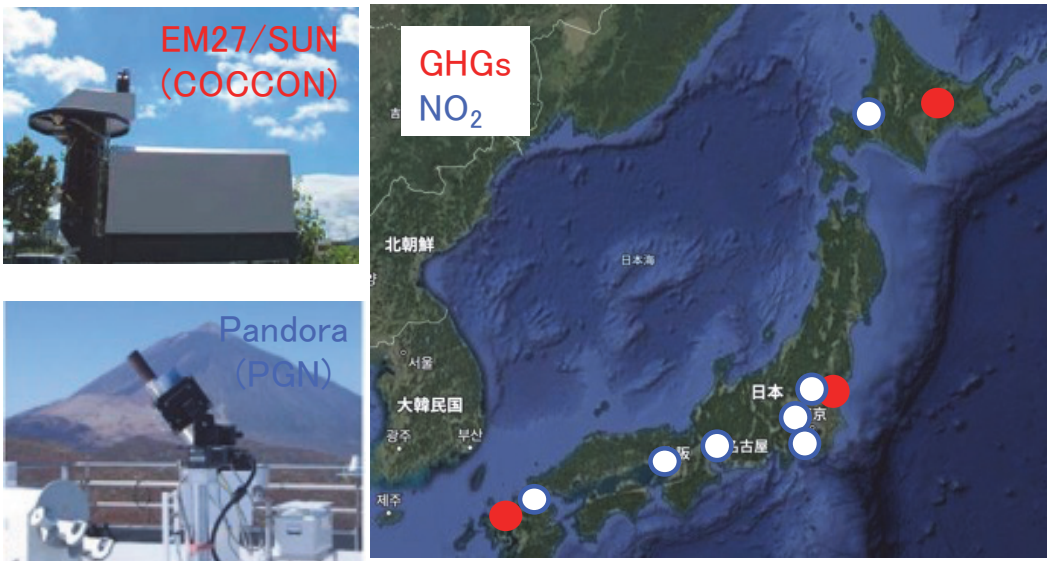


Fig. 4 (Upper left) Portable Fourier transform spectrometer (EM27) used in the Collaborative Carbon Column Observing Network (COCCON). (Lower left) Pandora spectrometer used in the Pandora Global Network (PGN). (Right) The locations of ground-based observation sites in Japan for validation of TANSO-3 products.

4. Collaboration with Other Organizations

Research Announcements on the GOSAT Series have been issued three times jointly by MOE, JAXA, and NIES since 2018 to solicit research proposals covering GOSAT and GOSAT-2 from around the world. Those proposals that are evaluated as appropriate by the GOSAT Series Research Announcement Selection and Evaluation Committee are adopted to conclude joint research agreements. Currently, a total of 45 joint studies are in progress.

In response to the agreements concluded with the U.S. National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), le Centre national d'études spatiales (CNES), and the German Aerospace Center, das Deutsches Zentrum für Luft- und Raumfahrt (DLR), several informal meetings were held virtualy.

5. Hosting of Meetings

NIES, with support from MOE and JAXA, hosted the 18th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-18) in July 2022. It was a hybrid meeting held from Tsukuba using online meeting rooms and poster session platform, with about 300 participants and 110 presentations in eight sessions covering topics ranging from the introduction of satellite missions to contributions to the Global Stocktake led by the United Nations Framework Convention on Climate Change (UNFCCC). The proposal from European scientists to host the next meeting in Paris in July 2023 was widely welcomed and approved.

6. Participation in International Events

In November 2022, SOC participated in the 27th session of the Conference of the Parties (COP27) to UNFCCC in Sharm el-Sheikh, Egypt by means of an official hybrid-style side event, an official exhibit, an on-site seminar at the Japan Pavilion, and participation in a Virtual Japan Pavilion. The official side event, "New Generation of Greenhouse Gas Remote Sensing Satellites for Contribution to the Paris Agreement" (Fig. 5) was jointly hosted by NIES and the Universities Space Research Association (USRA), chaired by Tsuneo Matsunaga (NIES) and Tomohiro Oda (USRA). The objectives of this event were to showcase advancements in space-based carbon observations, as well as the emission-monitoring capabilities expected from the next generation satellites. Another objective was to discuss the use of Earth Observations in deriving "actionable" information to monitor and guide climate mitigation efforts in support of the Paris Agreement. Four invited speakers from the US and Europe, along with a slide presentation from China, provided important viewpoints and valuable insights to the discussions at this event.

Fig. 5 The UNFCCC COP27 official side event, "New Generation of Greenhouse Gas Remote Sensing Satellites for Contribution to the Paris Agreement," was held in hybrid format.

7. Press Releases

SOC issued the following press release in FY 2022:
"Model Analysis of Atmospheric Observations Reveals Methane Leakage in North China—findings based on Greenhouse gases Observing SATellite "IBUKI" (GOSAT) observations" (November 2022).
See: https://www.nies.go.jp/whatsnew/20221128-1-e/20221128-1-e.html and https://www.eurekalert.org/news-releases/975078.

Reference:

1) Wang, F., Maksyutov, S., Janardanan, R. et al. (2022) Atmospheric observations suggest methane emissions in north-eastern China growing with natural gas use. *Scientific Reports* 12: 18587. https://doi.org/10.1038/s41598-022-19462-4

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 Centres 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

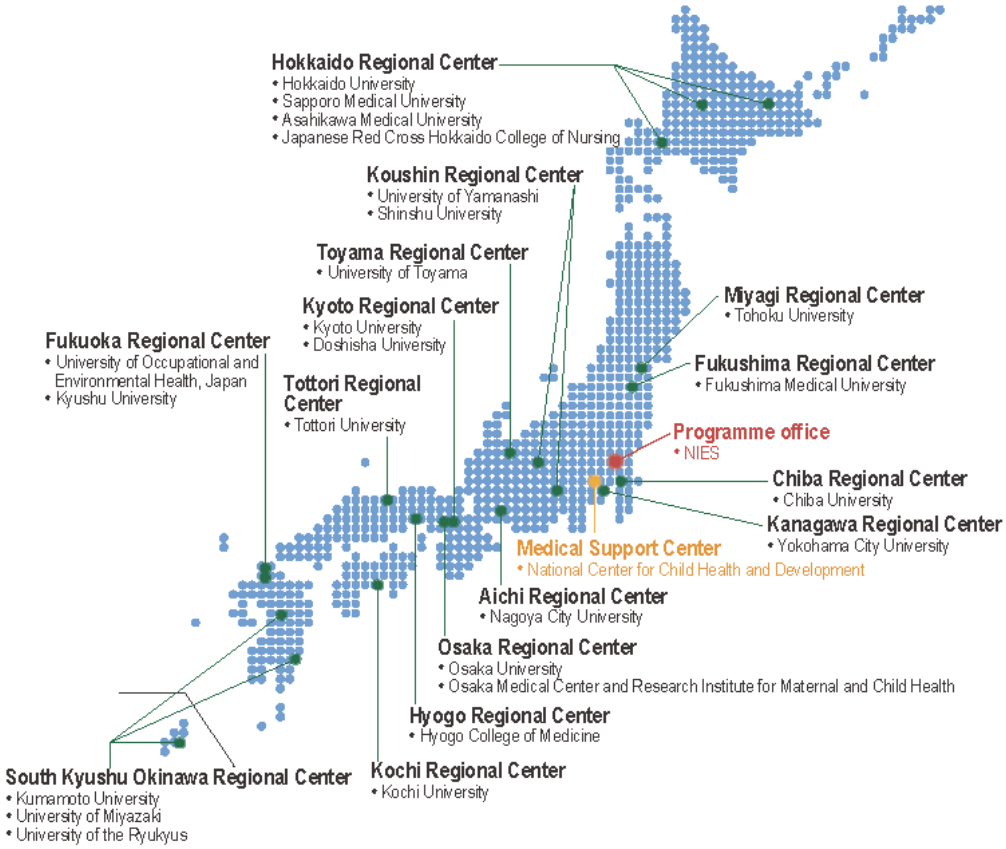
We started recruiting participants in January 2011, and recruitment continued until March 2014, when the number of participating mothers had reached 103 099. Recruited participants were pregnant women and their partners (when accessible). JECS began to collect data when the mothers were pregnant and planned to follow their children until they reached 13 years of age. The study protocol has now been updated to keep following the children until they reach at least 40 years. 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 2022

The children participating in the Main Study reached the ages of 8 to 11 years in FY 2022. We continued to administer questionnaires to the participants to collect a wide range of information on the children's health and development and their exposure to environmental factors. We analyzed 5000 maternal urine samples for organophosphate pesticides, insect repellents, and organophosphate flame retardants. As part of the Sub-Cohort study, approximately 1400 eight-year-old participants were tested developmentally and examined by a pediatrician, and blood and urine samples were 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 2022 are described below.

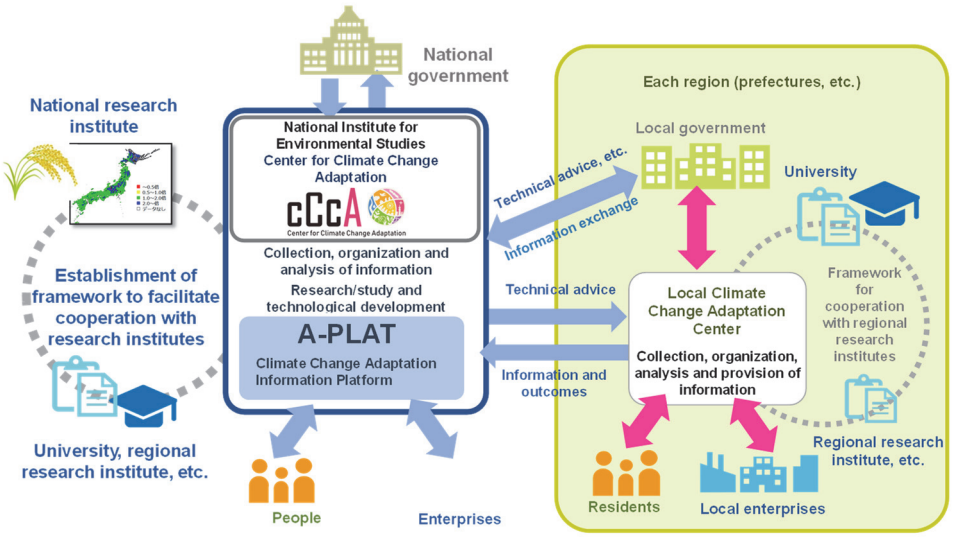


Fig. 1 Role of the Center for Climate Change Adaptation

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 to local councils, 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 7500 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:

- Three training courses were held in 2022, and a discussion meeting was held in October 2022 with the aim of sharing knowledge with local administrators to formulate regional climate change adaptation policies (Fig. 2).
- In February 2023, a symposium was held on the theme of climate change adaptation, with the participation of related research institutions and LCCACs to share relevant research and discuss possible collaboration.
- In October 2022, NIES, with MOE, organized a “Symposium on Promoting the Use of Climate Change Risk Information.” Companies, local administrators, researchers, and financial institutions attended the symposium to deepen their understanding and accelerate the private sector’s adaptation activities.

Fig. 2 LCCAC discussion meeting in 2022

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 (Fig. 3). The following measures were taken to enhance the dissemination of information on adaptation in Japan and abroad:

- Information on the initiatives and events of ministries, national research institutes, local government, LCCACs, and companies was expanded.
- Ten indicators of climate change impact projections were presented in WebGIS format.
- Web pages featuring the 27th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP27) and phenological monitoring were released.
- Information was also disseminated through the smartphone application "Minna-no Adaptation (Adaptation for Everyone) A-PLAT+," as well as through Twitter, Facebook, Instagram, and LinkedIn.

The number of page views was 1.12 million. In addition, the number of social networking systems (Twitter, Facebook, and LinkedIn) feeds reached 2258, substantially exceeding the target.

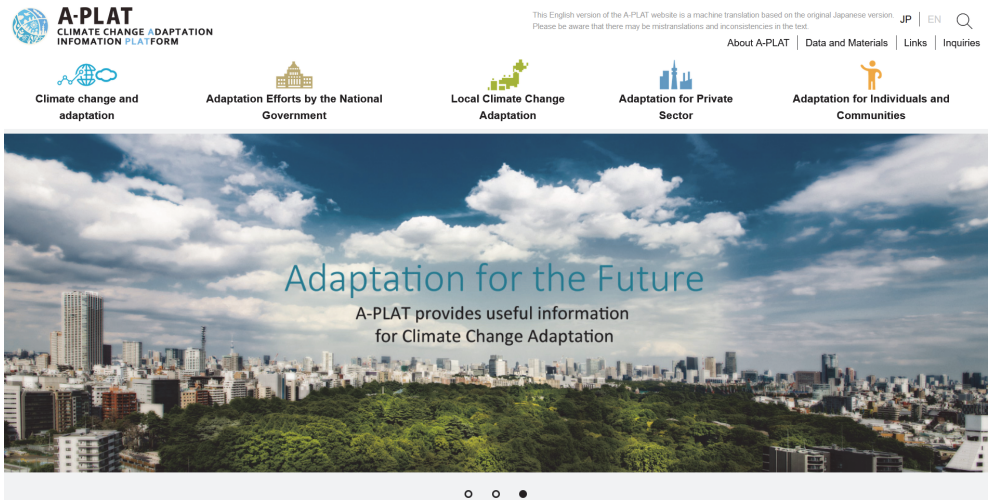


Fig. 3 Home page of the English version of the A-PLAT website (https://adaptation-platform.nies.go.jp/en/)

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). In addition to redesigning the web pages, we added a new "Adaptation Planning" page to organize the adaptation planning process and information (Fig. 4).

NIES, in collaboration with MOE and the Institute for Global Environmental Strategies (IGES), released a joint press release regarding the development of framework and strategy documents for AP-PLAT.

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 to Asia-Pacific region. We also organized an international workshop on information platforms for adaptation at COP 27. Through these activities, the needs and issues related to the promotion of adaptation in the Asia-Pacific region were organized and analyzed.

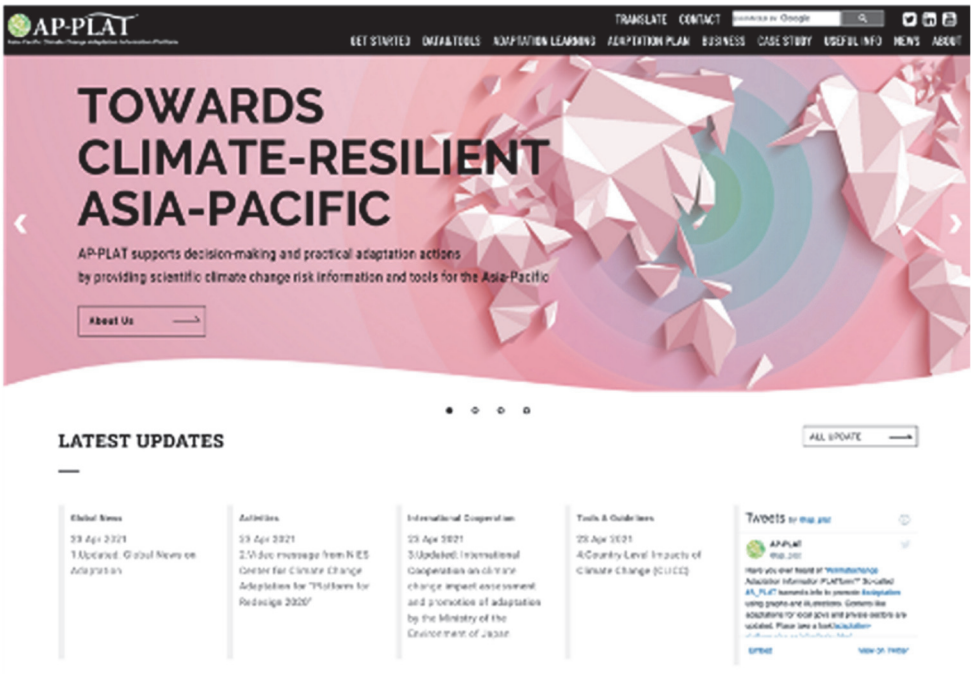


Fig. 4 English-version home page of the AP-PLAT website (https://ap-plat.nies.go.jp/)

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 MOE, we helped to revise a manual for the development of Local Climate Change Adaptation Plans 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. 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.

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.

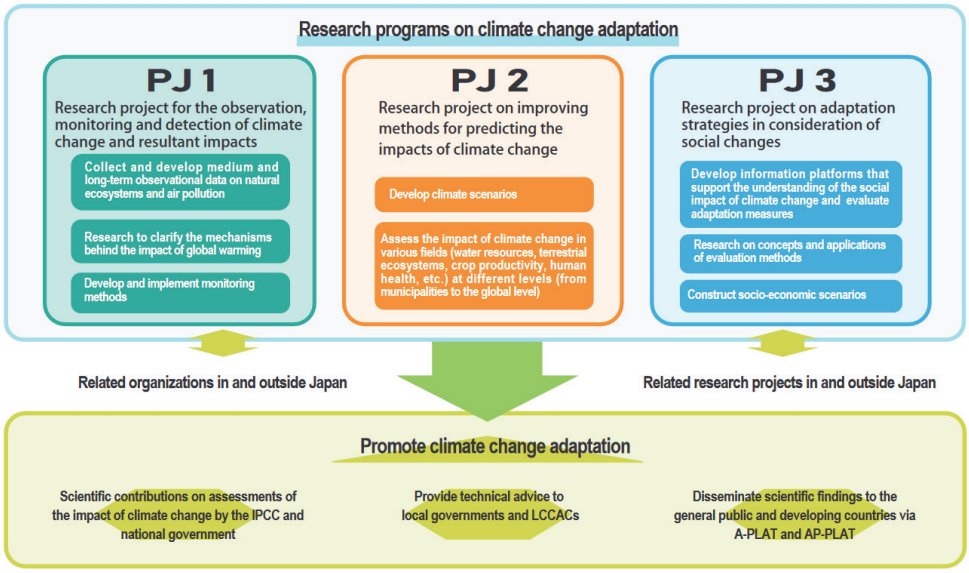


Fig. 5 Structure of three research projects

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

As part of our terrestrial ecosystem research (PJ1-3a), beech and red oak forests were resurveyed. Comparisons between the past and present vegetation suggested that there were effects of global warming on the vegetation structure. In a study targeting lake ecosystems (PJ1-3b), factors affecting lake transparency were analyzed by using long-term data on Lake Biwa. The results suggested that extreme water-level draw-down was an important trigger of improved transparency. In a study of coral and seagrass communities (PJ1-3c), long-term survey data in Okinawa Prefecture were analyzed and the negative effects of seawater temperature on coral communities were detected. In research targeting coastal and closed sea areas (PJ1-3d), measurement and analysis of the change in size distribution of an endangered mud snail, *Batillaria multiformis*, were conducted as citizen science in the northern limit habitat (Mutsu Bay) of this species. The results suggested that high summer water temperatures accelerated the growth of the species (Fig. 6). In this sub-theme (PJ1-3d), the growth responses of two diatom species dominant in the Seto Inland Sea were compared under different nutrient (nitrogen) levels. In the

theme of examining ecosystem-based climate change adaptation (EbA) at the river basin scale (PJ1-4), we conducted EbA research in the Lake Inbanuma watershed related to disaster prevention, water resource management, and natural ecosystem conservation. In a study of health (PJ1-3e), we analyzed regional differences in the incidence of heatstroke by using the criterion of the "Heatstroke Alert" used in Japan. In a study of renewable energy (PJ1-3e), a method was developed to verify the accuracy of surface solar radiation in reanalysis data.

In a study of the Asia-Pacific region, we conducted experiments and analyses on the effects of ozone and water stress on paddy rice (PJ1-2a). In a health study (PJ1-2a), we analyzed temperature effects on young children in Malaysia. In a study of mangroves (PJ1-2b), we conducted multifaceted research on the growth of mangrove plants in relation to soil chemical properties and soil microorganisms. As part of these studies, we conducted a field survey in mangrove afforestation stands that have been planted for climate change adaptation in the Republic of Kiribati in the Pacific.

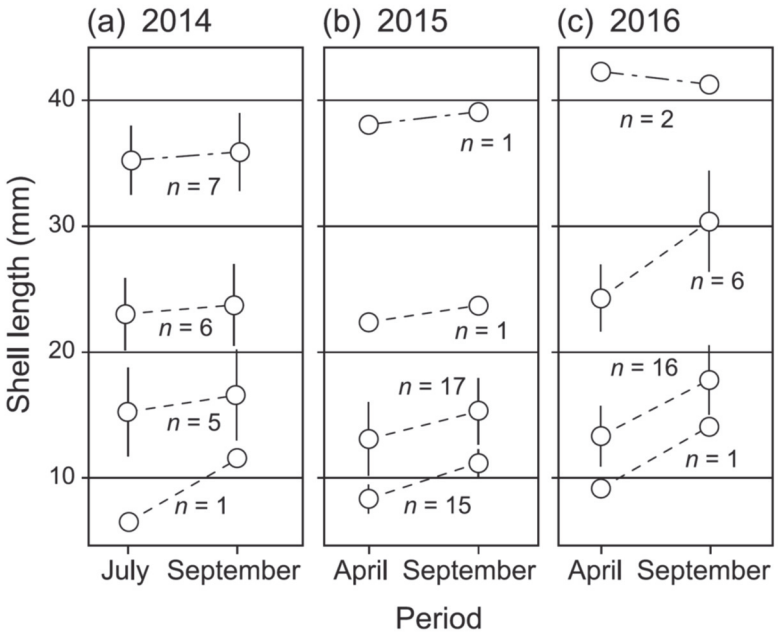


Fig. 6 Changes in shell length of *Batillaria multiformis* during spring–autumn 2014–2016 for four size classes (<10, 10–20, >20–30, and >30 mm). Growth was more pronounced in the summer of 2016, when there were more hours of sunlight and higher soil temperatures, than in the summers of 2014 and 2015, when there were relatively low temperatures.[1)]

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 health). In order to evaluate the distribution shifts of forest tall tree species across Japan, we devised a new method of analyzing differences in temperature distributions between juveniles (current regeneration habitat under a warmer climate) and adults (past regeneration habitat under a cooler climate) of the same species. The results showed that, among 302 researched species, juvenile trees tended to be distributed in colder

areas than the adult ones nationwide, implying the influence of global warming (Fig. 7). The juvenile and adult distribution differences tended to vary by species, forest type, and location. The mechanisms behind these differences were also investigated.

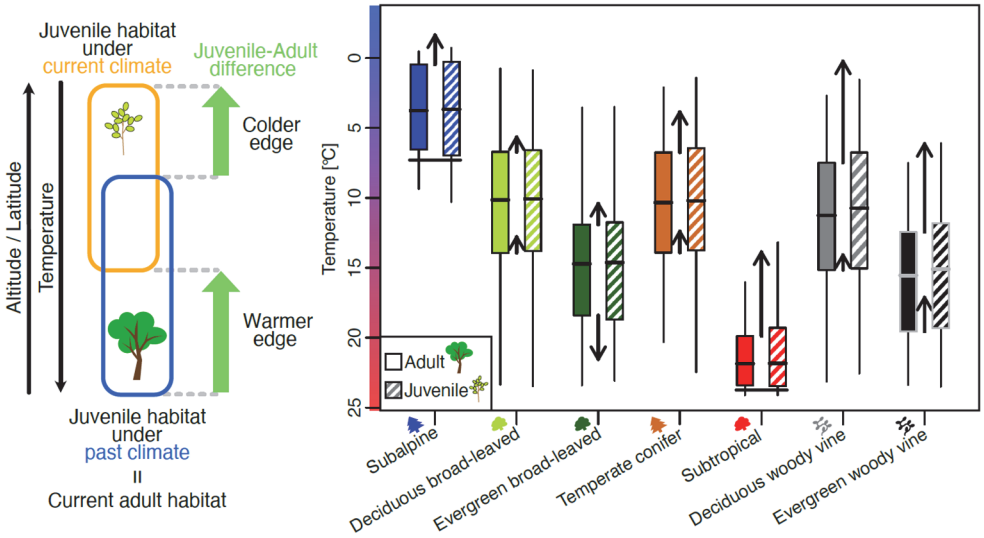


Fig. 7 Species distribution shifts assessment based on distribution differences between juvenile and adult trees. Arrows represent statistically significant directional shifts between juveniles and adults according to the size permutation results.

2.3 Adaptation strategies in consideration of social changes (PJ3)

We developed an integrated method of analyzing the geographical distribution of climate change impacts. On the basis of the projection results for Japan, eight homogeneous impact zones and five independent clusters were generated. Additionally, progress was made as planned on developing a model to evaluate the mutual impacts of food production and water resources; analyzing gaps in the use and management of coastal ecological resources in regions; formulating a climate change adaptation strategy considering uncertainty; evaluating the adaptive capacity of Local Climate Change Adaptation Centers; and analyzing the process of the local government response to flooding.

Reference:

Kanaya, G., Yamada, K., Itoh, H., Igarashi, T. (2022) Life-history traits of the endangered mud snail *Batillaria multiformis* in their northern limit population in Mutsu Bay, Japan. *Ecological Research*, 37(6): 753–767. doi:10.1111/1440-1703.12347

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, the 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 2022, 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 2023, the NIES library (Fig. 2) held74,558 books, 7487 journals (including electronic resources), and various other technical reports and reference materials. These materials can be searched by using OPAC (Online Public Access Catalog) and a link resolver via the Intranet. We have also introduced a web-scale discovery service, Primo (Ex Libris). It has the capacity to more easily connect researchers with the library's vast amount of information held in physical holdings, digital collections, and various repositories.

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

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

Fig. 2 The NIES library

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 as well as an institutional repository (see below).

As the government's 5-yearly Japanese Science and Technology Basic Plan calls for efforts to promote open science, a working group was established at NIES, and we examined the introduction of an archiving system (institutional repository) to be operated and constructed by NIES. As a result of the group's discussions we joined JPCORE (the Japan Open Access Repository Open Access Association), and in May 2022, we started to operate JAIRO Cloud, a cloud-based institutional repository-environment provision service. It is now possible to release articles and assign DOIs in response to requests from our researchers. In February 2023 the repository module was changed to WEKO3 to enable the registration of a variety of content types.

In addition, NIES is using the CHORUS Institution Dashboard Service to monitor and understand the status of our researchers' products and activities. On the basis of the monitoring results, a seminar was held at NIES in July 2022 to explain the current situation of open access. We are continuing discussions on the information infrastructure required to support the promotion of open science.

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 across the globe; descriptions of key environmental technologies; 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. A lending service is 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 easily understand the status of the environment. The system has been publicly available through the Internet since July 2010 and has since been updated as needed in response to user requests.

2.2 Tasks commissioned by MOE

In FY 2022, the Department performed the following task, as commissioned by MOE:

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

Inquiries:
International Coordination Office
Facsimile:＋81-29-851-2716
E-mail:international@nies.go.jp

National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki 305-8506, JAPAN
https://www.nies.go.jp/

NIES Publications
https://www.nies.go.jp/kanko/index-e.html

Editorial assistance: MAEDA Printing Co., Ltd.