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著者	Tanabe Shin-ichi, Nakamura Koji, Toda Masanori
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Beyond the DIWPA-IBOY: Monitoring Network and Strategies to Assess Human Impacts on Biodiversity in the Pan-Japan Sea Area

Shin-ichi TANABE AND Koji NAKAMURA
Institute of Nature and Environmental Technology, Kanazawa University, Kanazawa, Ishikawa 920-1192, JAPAN
Masanori J. TODA
Institute of Low Temperature Science, Hokkaido University, Sapporo, Hokkaido 090-0819, JAPAN

Abstract – The DIWPA-IBOY project is one of international projects that have been aimed to promote and encourage understanding of actual status and spatial and temporal trends of biodiversity in natural systems and the measures required for the conservation of biodiversity, the actions of which are underpinned by the Convention on Biological Diversity. A newly started project, the 21-century COE program in the Pan-Japan Sea Area, can be benefited greatly by utilizing some products of the DIWPA-IBOY. First, no effort is needed to establish newly an international network for monitoring biodiversity in the Pan-Japan Sea Area, because of the existing network for the DIWPA-IBOY. Second, biodiversity information on faunas and floras has been accumulated steadily through the DIWPA-IBOY activities, providing further potential for effects of human-induced environmental changes on biodiversity to be examined in detail in collaboration with environmental technology and measurement. Third, cost-effective monitoring designs can be generated based on the results obtained from the DIWPA-IBOY activities. Some preliminary results were presented for data of a limited taxon (light-trapped Lepidoptera) obtained at a DIWPA-IBOY core site, Tomakomai Experimental Forest (TOEF), Hokkaido University, in Japan that has finished one-year activities, including tentative analyses on the moth data to select a cost-effective design for the long-term monitoring.

I. Introduction

The earth's biodiversity is an irreplaceable biological resource essential to maintain the state of the global system within a physicochemical and life-resource-related threshold for human existence to be allowed. At present, the biological resource is being lost both qualitatively and quantitatively at a rapidly accelerating rate as a result of exponentially increasing human activities that have caused destruction, fragmentation, pollution and biological infection of natural habitats [1]. The loss of biodiversity has resulted in the degradation of functions and services that natural ecosystems intrinsically possess, which affect human life directly through supplies of goods such as food, fuels and medicines and indirectly through environmental conditions such as atmospheric chemistry, soil fertility and water quality [1].

The detailed information of biodiversity is critical to realize the conservation of natural ecosystems in sustainable ways. However, no sufficient knowledge for the status of biodiversity exists across the globe, therefore extremely limiting the ability for the society and policy-makers to make decisions for sustainable development and conservation [2]. To increase the availability of accurate biodiversity information, a large number of biodiversity projects are now occurring around the world, many of which have been triggered by an international program of biodiversity science, the International Biodiversity Observation Year (IBOY) [2]. The considerable efforts in these projects are devoted to elucidate actual status and spatial and temporal trends of biodiversity in natural systems. With well-accumulated information on biodiversity inventory, the IBOY can be the first step to assess comprehensively the degree of human impacts on biodiversity and ecosystem functions at both local and global scales.

For the Pan-Japan Sea Area, an international network for the inventory and monitoring of biodiversity has been established as an important subset of a large-scale network in the DIWPA-IBOY project (see below). The network includes several countries, such as Russia, Korea, China and Japan, located in the Pan-Japan Sea Area, most of which have finished the DIWPA-IBOY activities (e.g. trap sampling, sample sorting and specimen identification) for the respective faunas and floras. Thus, we are now ready to proceed to the second step at which effects of human-induced environmental changes on biodiversity are examined in detail through monitoring of both biodiversity and environmental conditions in collaboration with environmental technology and measurement. Table I summarizes the two international projects on biodiversity, the DIWPA-IBOY and the 21-century COE program in the Pan-Japan Sea Area, comparing some aspects of the projects.

Selection of adequate strategies will be essential for a long-tern monitoring to be realized in an efficient way, including cost-effective allocation of the effort that is often limited by insufficient resources (e.g. time, labor and money). For the COE program in the Pan-Japan Sea Area, the results obtained from the DIWPA-IBOY activities can be used to generate cost-effective monitoring designs, which can be context-sensitive for each participating site, depending on the observation capacity and the present availability of biodiversity information.

In this presentation, we at first introduce the framework and general activities of the DIWPA-IBOY, focusing mainly

TABLE I
Comparisons between two international biodiversity-oriented projects in relation to spatial scale covered, factors affecting biodiversity and purpose for monitoring biodiversity.

Project	Target area	Main factors affecting biodiversity and its temporal trends	Main purpose of biodiversity monitoring
DIWPA-IBOY	Large (Western Pacific and Asia)	Natural gradients (e.g. latitude, altitude, and mainland-island relationships)	To elusidate status and natural trends of biodiversity
The 21-century COE program in Pan-Japan Sea Area	Relatively small (Pan-Japan Sea Area)	Human impacts (e.g. air pollution, acid fallout, logging etc.)	To detect responses of biodiversity to human impacts

on the forest ecosystems (especially on the survey for the invertebrate faunas). Next, we present some preliminary results for a limited taxon (light-trapped Lepidoptera) obtained at a core site, Tomakomai Experimental Forest (TOEF), Hokkaido University, in Japan that has finished one-year activities, including tentative analyses on the moth data to select a cost-effective design for the long-term monitoring.

II. The DIWPA-IBOY project

The DIWPA-IBOY is one of international projects that have been aimed to promote and encourage understanding of the importance of and the measures required for the conservation of biodiversity, the actions of which are underpinned by the Convention on Biological Diversity. The ultimate goals of the DIWPA-IBOY are to elucidate 1) what biodiversity we have and where it is, 2) how biodiversity is changing, 3) what goods and services biodiversity provides and 4) how we can conserve biodiversity, primarily through inventory and monitoring of biodiversity. Targeted are plants, vertebrates and invertebrates in 1) forest, 2) freshwater, 3) coastal marine and 4) island ecosystems that are situated in the Western Pacific and Asian region. The project is still ongoing and will be continued also in the year 2003.

A. *The DIWPA-IBOY forest sites*

Now we have twenty-one strategic sites in total from a variety of participating regions/countries. These sites have been disseminated across the greenbelt stretching from the taiga of Siberia to eastern Australia without interruption by arid zones and major oceans (Fig. 1). As one of multiple purposes, the DIWPA-IBOY has contributed to establish an international network for the inventory and monitoring of biodiversity within at least the Western Pacific and Asian region.

On one hand, the inclusion of these sites into a framework of biodiversity research has made the following two important purposes attainable: 1) to represent major biogeographical regions and/or hotspots of biodiversity within the Western Pacific and Asian region and 2) to evaluate some large-scale environmental gradients related to latitudes, altitudes and mainland-island relationships. Thus, the nature of the DIWPA-IBOY lies in the large-scale networking of multiple sites distinct in the floras/faunas and the nearly simultaneous implementation of biodiversity surveys with standardized methodology (see below). As well as the inclusion of major higher taxa (plants, vertebrates and invertebrates) and ecosystems, this has also contributed to put the DIWPA-IBOY into a unique position among other biodiversity-oriented surveys, especially on forest ecosystems, over the world.

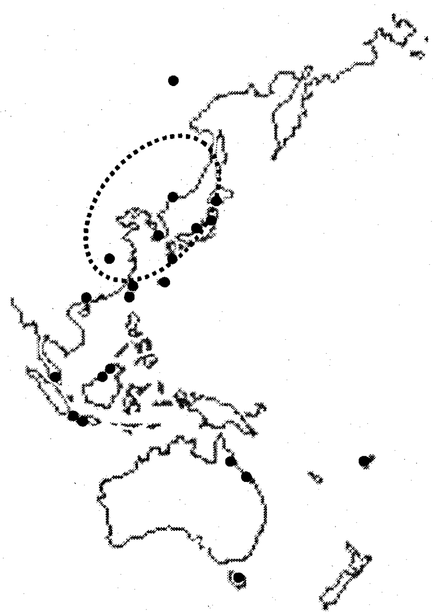

Fig. 1. DIWPA-IBOY sites for forest ecosystems. Dotted circle indicates the Pan-Japan Sea Area.

B. *Sampling strategies*

The DIWPA-IBOY aims at inventorying and monitoring at the network of sites and therefore requires to standardize the sampling methodology in order to allow and facilitate comparisons among sites and along the environmental gradients. A protocol manual for sampling methods and designs has been edited after the pilot studies in 2000 and 2001, and is now available for all targeted ecosystems as PDF files through the Internet from the DIWPA-IBOY website (http://diwpa.ecology.kyoto-u.ac.jp/index.htm) and as the printed version [3].

C. *Identification*

Despite more than 250 years of taxonomic research, there are still many identification-related problems for a faunal inventory, particularly of invertebrates, to be generated [4, 5]. Under the circumstances, we have developed a computer-aided identification system of invertebrate specimens, which can give technical supports for non-taxonomic specialists or parataxonomists to identify specimens, at least at the family level, using digital images of the specimens and the Internet. In the system, non-taxonomic specialists are responsible for the first-stage sorting, preparation (e.g. pinning and drying) and digital photography of the relevant specimens. The digital-imaged specimens are checked later for the taxonomic identity by expert taxonomists mainly through the exchange of the images using the Internet.

Thus, the systems allows 1) the specimens to be identified in the manners that is not resource-consuming (e.g. time and money) for both responsible sites and taxonomic experts and do not need the exchange of the specimens themselves, which sometimes results in problems for the specimens to be damaged or lost, or may be restricted within the countries to which the sites belong, and 2) the image to be integrated to generate a digital-photo library for the specimens that can support and facilitate multi-purpose use of the specimens (e.g. a reference collection in each site, training of taxonomy for students, staff and beginners and exhibition to the pubic), in which, for example each photograph of the prepared specimens is arranged according to the family to which the specimen belong. The library can be web-based and thus be the first step to generate a digital-photo encyclopedia of biodiversity over the Western Pacific and Asian region or virtually over the world.

D. *Database*

According to the nature for the DIWPA-IBOY to cover a number of regions/countries and various kinds of organisms, the database should be international and biodiversity-oriented in the true sense to integrate results of the project. There is a problem that is specific to such an internationally integrated database for biodiversity: there is a large difference in the completeness of faunal/floristic inventories among regions (e.g. temperate vs. tropical regions). In addition, it is also true that biodiversity information is greatly different in both quality and quantity among taxa, particularly of invertebrates (e.g. Coleoptera vs. Diptera). Under the circumstances, the invertebrate database for the DIWPA-IBOY forest research has been designed so that the taxonomic and ecological information at various taxonomic levels (e.g. order, family, genus, species) can co-exist and be dealt with in a single database at the same time. It is premised that 1) samples collected by various kinds of standardized methods are first identified and sorted at least at the order level, 2) after that, lower-level identification proceeds step by step from the order to the species level, and 3) the database continues to develop virtually until all samples or specimens are identified to species. The database is still under construction and will be available through the DIWPA-IBOY website in the near future.

III. Light-trapped moth assemblage in TOEF

A. *Arthropods as effective indicators of human impacts*

Arthropods are highly diverse components in various ecosystems, and occupy a tremendous variety of functional niches and microhabitats across a wide array of spatial and temporal scales. Although it is largely the mega fauna for policy- and decision-makers to focus on in evaluating and managing natural habitats, there has been a rapidly increased awareness of usefulness or importance for arthropods to be used in conservation planning as indicators for inventory and monitoring [6, 7, 8]. For example, arthropod indicators can 1) provide early warnings of human-induced environmental changes as a result of more rapid responses to the changes than do vertebrate indicators, which may not respond until too late for conservation and management, and 2) be used to evaluate the effects of further impacts on natural areas that no longer support vertebrate indicator species [8]. Thus, arthropods offer certain exceptional characteristics as indicator groups. For the COE project, the inventory information resulting from the DIWPA-IBOY activities can provide the basis for selecting indicator species or assemblages to monitor human impacts according to the sensitivity of arthropod groups or species to target environmental changes.

Moth assemblages are taxonomically well known and sufficiently diverse to include groups with different responses to the same stress, which can improve performance and effectiveness of monitoring [8]. As a result, moths have been one of preferred indicators for environmental changes [9], although their ecological functions in forest ecosystems are restricted largely to one category (almost all members in the order Lepidoptera are herbivorous). Inclusion of more functional groups is desirable for monitoring systems aiming to assess the ecosystem-level impacts of human-generated environmental changes.

B. *Sampling design and faunal description*

A total of 126 light-trap samples were collected from the two vegetation layers of the floor and the canopy at three plots within the 1 ha DIWPA-IBOY site in TOEF for three successive days around the new moon every month from April to October, 2001. Of a huge amount of trapped insect specimens, a total of 51,555 moth individuals have been identified to 920 species. As shown by a species accumulation curve attaining nearly an asymptote, this sample of moth assemblage is regarded as representing almost the total species richness that can be collected by the light trap in TOEF (Fig. 2).

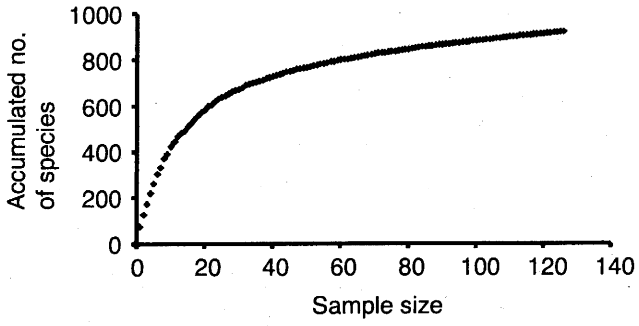

Fig. 2. Species accumulation curve for the light-trapped moth assemblage in Tomakomai Experimental Forest, Hokaido University, Japan.

C. *Cost-effective monitoring design*

Additive partitioning of diversity is a simple but useful approach to improve biological surveys by identifying the primary source(s) of the total species diversity in a region [10]. Total species diversity (*?*) in a pooled set of communities (or samples) can be partitioned into additive components within and among communities [11], corresponding α- and β- diversity [12, 13] or intra-trap and inter-trap diversity [14], where diversity is measured as species richness (*S*), or by using either the Simpson (1-*D*) or Shannon (*H'*) index. Of some dimensions (β-components) across which composition of a community changes, the dimension with the largest difference should be selected with priority for allocation of available monitoring effort.

β-diversity across each dimension. Table II shows the results of additive partitioning analyses for *S* and *H'*. The β-diversity was the largest between months in both *S* and *H'*, indicating that the diversity of the moth assemblage was due largely to differences between sampling months. As a result, if we want to save the sampling effort, we can reduce the number of sampling dates, plots and/or layers, but should repeat sampling several times in different seasons.

Fig. 3 shows seasonal patterns in the numbers of individuals and species of the light-trapped moth assemblage at the floor and the canopy. The seasonal patterns were similar, with peaks in July, regardless of layers and attributes (abundance and species richness) of the assemblage. The numbers of individuals and species were higher in the floor than in the canopy through the sampling period from April to October.

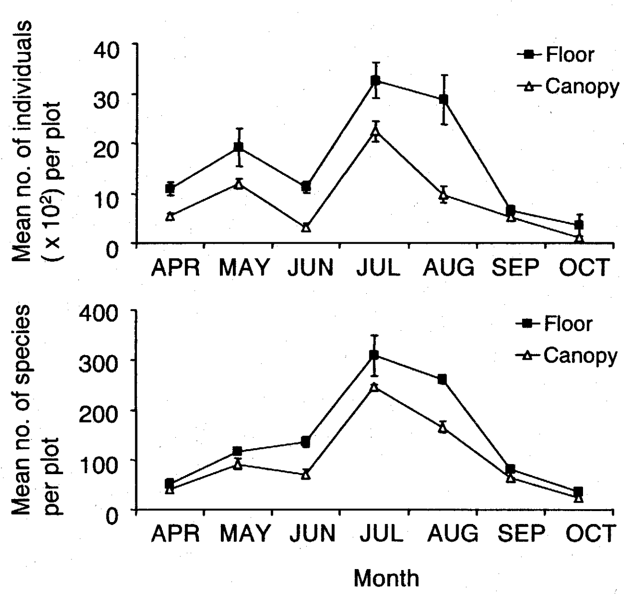

Fig. 3. Seasonal patterns in the mean numbers of individuals and species of the light-trapped moth assemblage across three plots at the floor and the canopy in TOEF. Vertical bars indicate the SDs.

TABLE II

Relative contributions of four dimensions, month, date, plot and layer, to the total diversity of light-trapped moth assemblage in TOEF, analyzed using additive partitioning methods for species richness (*S*) and Shannon index (*H'*).

Dimension (n)	Contribution to total species richness (*S* = 920)		Contribution to total diversity (*H'* = 5.52)	
	β-diversity	%	β-diversity	%
Month (7)	695.1	75.56	1.67	30.24
Date (3)	196.3	21.34	0.11	2.07
Plot (3)	177.7	19.31	0.05	0.89
Layer (2)	147.0	15.98	0.20	3.63

For the light-trapping design to collect the moth assemblage in TOEF, relative importance of four dimensions, month, date, plot and layer, can be evaluated by calculating

If available resources are severely limited and therefore allocation of the least effort to sampling is desirable to maintain monitoring activities for long-term, then one trap should be set on the ground in the evening of the new moon day in July. If more resources or effort is available, the sampling should be repeated in another month with most different faunal composition, and then expanded to more months in similar ways.

IV. Summary

The COE program aims to elucidate the effects of human-generated environmental changes on biodiversity and ecosystem functions in the Pan-Japan Sea Area and thus, can be regarded as being the next stage of the DIWPA-IBOY that has worked with such basic information as the actual status and spatial and temporal trends of biodiversity in natural ecosystems within the Western Pacific and Asian region.

The COE program can be benefited greatly by utilizing the existing network and information of faunal and floristic inventory resulting from the previous and/or ongoing activities in the DIWPA-IBOY project. Therefore, it is recommended to adopt the DIWPA-IBOY protocol for sampling methods and designs, at least in forest ecosystems, in the COE program to make biodiversity data comparable between the two projects. The DIWPA-IBOY database for forest biodiversity, which will be available soon, provides powerful tools for management of extensive and formidable data. That may solve one of difficulties with which biodiversity-oriented research often struggles, and can also contribute to the COE program.

Cost-effective monitoring in the COE project can be designed based on the inventory information obtained in the DIWPA-IBOY. The additive partitioning analysis of diversity is one of useful approaches to identify monitoring systems that match the resource availability and/or observation capacity in respective monitoring sites.

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