

Ecological Research Monographs



S. Nakano · T. Yahara  
T. Nakashizuka *Editors*

# The Biodiversity Observation Network in the Asia-Pacific Region

Toward Further Development of Monitoring

 Springer

# Ecological Research Monographs

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Shin-ichi Nakano • Tetsukazu Yahara  
Tohru Nakashizuka  
Editors

# The Biodiversity Observation Network in the Asia-Pacific Region

Toward Further Development of Monitoring

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ISSN 2191-0707

ISBN 978-4-431-54031-1

DOI 10.1007/978-4-431-54032-8

Springer Tokyo Heidelberg New York Dordrecht London

ISSN 2191-0715 (electronic)

ISBN 978-4-431-54032-8 (eBook)

Library of Congress Control Number: 2012941622

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*Cover illustration: Front cover: *Hepatica nobilis* var. *japonica*, an early spring flower, on Mt. Kakuda, Niigata Prefecture, Japan (photo by Tohru Nakashizuka). Back cover: Left: Tubeworm colony in deep-sea methane seepage in Sagami Bay, Japan (depth: 1000 m) (photo by Japan Agency for Marine-Earth Science and Technology (JAMSTEC)). Center: Japanese stag beetle, *Lucanus maculifemoratus*, collected on a mountain in Shiga Prefecture, Japan (photo by Shin-ichi Nakano). Right: Woman cleaning Mekong River catfish in a market in Laos (photo by Masami Daito).*

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# Preface

It has been commonly accepted that biological diversity is important for a functioning ecosystem that provides services essential for humans' well-being. Under the Convention on Biological Diversity (CBD), international efforts were made to achieve by 2010 a significant reduction in the current rate of biodiversity loss. The 2010 Biodiversity Target was not achieved, however, and biodiversity continues to be lost. At COP 10, the CBD adopted the new Strategic Plan for Biodiversity 2011–2020 and the Aichi Target to accelerate the support of worldwide biodiversity over the next decade.

The interface between science and policy are to be established as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Science is expected to play a leading role in the area of biodiversity, including characterizing the biodiversity of various areas, clarifying ecosystem services supplied to society, quantifying how rapidly biodiversity is being lost, and justifying needs and identifying possibilities for conservation and sustainable use of biodiversity. The Biodiversity Observation Network under the Group of Earth Observation (GEO-BON) was launched in 2008 to collect and analyze data on the status and trends of the world's biodiversity. However, the methodology to quantify biodiversity loss at the global, regional, and national scales remains underdeveloped. The development of integrative and predictive science to address global biodiversity change is urgently needed. DEVERSITAS, an international program of biodiversity science, is leading the task of developing networks of integrative and predictive biodiversity science. It includes the GEO BON.

In December 2009, scientists in the Asia-Pacific region successfully organized the Asia-Pacific Biodiversity Observation Network (AP BON) to establish a cooperative framework for conducting research and monitoring the ecosystem and its biodiversity. Also, the East and Southeast Asia Biodiversity Information Initiative (ESABII) was established to enhance the availability of biological information and taxonomic capacities. Having entered the "Asian Millennium," many Asian countries are now rapidly growing their economies and social infrastructures. This development, on the negative side, is causing a rapid loss of Asian biodiversity, giving us

an urgent mandate to work toward achieving a harmonious balance between development and conservation in the region.

We are publishing this book to provide a platform on which we can take a quantum step forward in advancing science that optimizes the synergy between development and biodiversity conservation in Asia. We hope that it will be informative for all people interested in biodiversity issues.

We are grateful to the Ministry of the Environment, Japan, for providing administrative and financial support. Also, we thank the authors for submitting their chapters, the part editors for their constructive criticisms of the manuscripts, the DIWPA office for formatting the submitted manuscripts, and the publisher Springer and its staff for their encouragement and assistance.

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# Contents

## Part I General Introduction

<b>Strategies to Observe and Assess Changes of Terrestrial Biodiversity in the Asia-Pacific Regions</b> .....	3
Tetsukazu Yahara, Munemitsu Akasaka, Hiroyuki Hirayama, Ryuji Ichihashi, Shuichiro Tagane, Hironori Toyama, and Ryo Tsujino	
<b>Biodiversity Outlook in the Southeast Asia: Challenges and Prospects for the Next Decade</b> .....	21
Rodrigo U. Fuentes, Rolando Inciong, and Leslie Ann Jose-Castillo	
<b>Economics and Economic Valuation of Ecosystems and Biodiversity in Japan</b> .....	27
Kentaro Yoshida and Kiichiro Hayashi	

## Part II Networks for Monitoring and Research on Biodiversity in the Asia-Pacific Region

<b>Plant Diversity in Two Philippine Long-Term Ecological Research Sites</b> .....	39
Victor B. Amoroso	
<b>Biodiversity Observation and Monitoring in Thailand</b> .....	53
Dokrak Marod and Utis Kutintara	
<b>Introduction to Ecological and Biodiversity Monitoring in China</b> .....	65
Haigen Xu, Hui Ding, and Jun Wu	
<b>Some Vegetation Types Studied with the Same Methodology in Indonesia</b> .....	71
Herwint Simbolon, Eizi Suzuki, and Ruliyana Susanti	



<b>Biodiversity Issues in Indonesia, with Special Reference to Biodiversity in Human-Dominated Landscapes</b> .....	93
Parikesit, Satoru Okubo, Teguh Husodo, Kazuhiko Takeuchi, and Dendi Muhamad	
<b>International Long-Term Ecological Research Network Activities in the East Asia-Pacific Region and Biodiversity Monitoring</b> .....	111
Eun-Shik Kim	
<b>Status of Biodiversity Loss in Lakes and Ponds in Japan</b> .....	133
Noriko Takamura	
<b>Fish Biodiversity Research in the Mekong Basin</b> .....	149
Eric Baran, Nith Chum, Michio Fukushima, Taber Hand, Kent G. Hortle, Tuantong Jutagate, and Bin Kang	
<b>Monitoring Fish Biodiversity in the Yangtze River, China</b> .....	165
Huanzhang Liu and Xin Gao	
<b>Fish Biodiversity Monitoring in Rivers of South Korea</b> .....	175
Ju-Duk Yoon, Min-Ho Jang, Hyun-Woo Kim, and Gea-Jae Joo	
<b>Part III Establishing a Biodiversity Database</b>	
<b>Data Discovery Mechanisms for Biodiversity Resources in the Asia-Pacific Region</b> .....	195
Utsugi Jinbo and Motomi Ito	
<b>ILTER and JaLTER: Their Missions and Linkage to Database Development in the Asia-Pacific Region</b> .....	205
Nobuhito Ohte, Masahiro Nakaoka, and Hideaki Shibata	
<b>Long-Term Monitoring of Natural Forests and Their Database (Forest Dynamics Database: Fddb) Constructed by the Forestry and Forest Products Research Institute, Japan</b> .....	217
Kaoru Niiyama, Masaaki Takyu, Satoko Kawarasaki, Mifuyu Ogawa, Tamotsu Sato, and Takashi Masaki	
<b>Current Status and Nationwide Database of the River and Floodplain Ecosystem in Japan</b> .....	229
Futoshi Nakamura	
<b>BISMaL: Biological Information System for Marine Life and Role for Biodiversity Research</b> .....	247
Hiroyuki Yamamoto, Katsuhiko Tanaka, Katsunori Fujikura, and Tadashi Maruyama	

**Part IV New Methods and Analyses for Biodiversity Studies**

**DNA Barcoding: A Novel Tool for Observation of Biodiversity** ..... 259  
 Toshihide Kato, Utsugi Jinbo, and Motomi Ito

**Development of a Threatened Species Portal  
 in the Asia-Pacific Region**..... 267  
 Osamu Kurashima, Utsugi Jinbo, and Motomi Ito

**Linking Remote Sensing and *In Situ* Ecosystem/Biodiversity  
 Observations by “Satellite Ecology”** ..... 277  
 Hiroyuki Muraoka, Reichiro Ishii, Shin Nagai, Rikie Suzuki,  
 Takeshi Motohka, Hibiki M. Noda, Mitsuru Hirota,  
 Kenlo N. Nasahara, Hiroyuki Oguma, and Kanako Muramatsu

**Long-Term Monitoring and Prediction of Ecosystem  
 Using Remote Sensing and the CLUE-S Model:  
 Sakaerat Environmental Research Station**..... 309  
 Yongyut Trisurat

**East and Southeast Asian Pteridophyte Flora  
 and DNA Barcoding** ..... 321  
 Atsushi Ebihara and Li-Yaung Kuo

**Spatially Explicit Models for Freshwater Fish  
 for Conservation Planning** ..... 329  
 Michio Fukushima

**Part V Biodiversity and Ecosystem Services**

**Sensing/Monitoring Networks on Carbon Balance  
 and Biodiversity in Tropical Peatland**..... 349  
 Mitsuru Osaki, Takashi Hirano, Gen Inoue, Toshihisa Honma,  
 Hidenori Takahashi, Wataru Takeuchi, Noriyuki Kobayashi, Muhammad Evri,  
 Takashi Kohyama, Akihiko Ito, Bambang Setiadi,  
 Hozuma Sekine, and Kazuyo Hirose

**Biodiversity Research for the Development of Indicator  
 Organisms in Environment-Preserving Agriculture**..... 375  
 Koichi Tanaka and Fumio Ihara

**Biodiversity of Inhabitants of Animals  
 and Vascular Plants in Korean Paddy Fields Ecosystem** ..... 387  
 Hea-Son Bang, Min-Su Han, Young-Eun Na, Myung-Hyun Kim,  
 Kee-Kyung Kang, Jeong-Tak Lee, and Deog-Bae Lee

**Biodiversity and Agrobiodiversity in Sri Lanka:  
 Village Tank Systems** ..... 403  
 Buddhi Marambe, Gamini Pushpakumara, and Pradeepa Silva

<b>Biodiversity of Freshwater Fish in Japan in Relation to Inland Fisheries</b> .....	431
Osamu Katano and Shin-ichiro S. Matsuzaki	
<b>Conservation and Restoration of Lakeshore Vegetation in Lake Kasumigaura, Japan</b> .....	445
Jun Nishihiro	
<b>Capacity Building for Fish Taxonomy in Southeast Asia</b> .....	459
Keiichi Matsuura	
<b>Index</b> .....	469

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**Part I**  
**General Introduction**

# Strategies to Observe and Assess Changes of Terrestrial Biodiversity in the Asia-Pacific Regions

Tetsukazu Yahara, Munemitsu Akasaka, Hiroyuki Hirayama, Ryuji Ichihashi, Shuichiro Tagane, Hironori Toyama, and Ryo Tsujino

## Introduction

Biodiversity loss is one of the most critical threats to global environments that has already transgressed planetary boundaries (Rockström et al. 2009). Indeed, nonlinear, often abrupt changes can drive unacceptable and irreversible deterioration. Rockström et al. (2009) claimed that earth's system cannot sustain the current rate of biodiversity loss without significant erosion of resilience. To halt this biodiversity loss, global efforts to achieve “by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national level,” called the 2010 biodiversity targets, have been made since the agreement by the world's governments in 2002. However, the latest data on the status and trends of biodiversity summarized in the third edition of Global Biodiversity Outlook (GBO-3) show that the target had not been met (Secretariat of the Convention on Biological Diversity 2010).

Reflecting the increasing needs to observe and document global biodiversity loss and its consequences, the GEO BON (Group on Earth Observations Biodiversity Observation Network) was organized in 2008 (Scholes et al. 2008), and its detail implementation plan was released (GEO BON 2010). GEO BON is trying to establish a coordinated global network that gathers and shares information on biodiversity and ecosystem services. Corresponding to GEO BON, its regional network in the Asia-Pacific region, AP-BON, was launched in 2009 under the support of the Ministry of Environment of Japan. Since then, a network of researchers, institutions, and organizations observing biodiversity and ecosystems in the Asia-Pacific region has been successfully developed by participants in three AP-BON

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workshops held in July and December 2009 and March 2010 and of two GEOSS-AP (Global Earth Observation System of Systems-Asia Pacific) symposia held in February 2009 and March 2010.

The time is right to work together to collect, exchange, analyze, and integrate biodiversity data to document the current status and changes of biodiversity and to contribute to global, national, and regional efforts for halting biodiversity loss. As was emphasized by Scholes et al. (2008), biodiversity data are not simply limited but are physically dispersed and unorganized. We urgently need to develop achievable strategies of networking biodiversity observations by which dispersed biodiversity data and isolated efforts to obtain new biodiversity data can be effectively organized.

In an effort to meet this need, let us consider how we can observe and assess terrestrial species loss in the Asia-Pacific region. First, we review previous efforts to document terrestrial species loss in the Asia-Pacific region and then consider new strategies for observing and assessing terrestrial species that can be hopefully employed in the AP-BON.

## **Current Knowledge of Terrestrial Species Loss in the Asia-Pacific Region**

First, let us review briefly how terrestrial species are being lost in the global scale. Some estimates of the rate of terrestrial species loss in the global scale suggest that those are at least 100 times higher than the background rate of species extinction (Leadley et al. 2010). An additional 9–52% of species are predicted to be extinct owing to climate change by 2050 (Thomas et al. 2004). van Vuuren et al. (2006) projected that the reduction of habitats by 2050 will result in a loss of global vascular plant diversity ranging from 7% to 24% relative to what existed in 1995. Malcolm et al. (2006) projected that climate change will result in 1–43% extinction of endemic plant and vertebrate species in biodiversity hotspots. The estimates vary largely owing to difference in future scenarios adopted, the approach to estimating extinction rates (He and Hubbell 2011), biological assumptions (e.g., presence of dispersal and of biome specificity), focal biomes, and/or focal taxon (Thomas et al. 2004; Malcolm et al. 2006; Van Vuuren et al. 2006). Future contraction of range size, which is potentially related to species extinction, and the dominant causes of the contraction are shown to differ among latitudinal zones (Jetz et al. 2007). For example, the future loss in the range size of birds by 2050 will be greater in middle to low latitudinal zones ( $\leq 30^\circ$ ) than in higher latitudinal zones. The main cause of the contraction is anthropogenic land use change (Jetz et al. 2007). In contrast, land cover conversions due to climate change are the dominant causes of the contraction in high latitudinal zones. These studies imply that the extinction rates at national and regional spatial scales, which are critically important for conservation planning at the corresponding scale, might not be derived easily from the global estimates. The extinction rates at national and regional scales need to be estimated by gathering fine-scaled information regarding patterns and trends of biodiversity.

Tropical Asia and tropical America are known as global centers of species richness of vascular plants (Kreft and Jetz 2007) and land vertebrates (Hoffmann et al. 2010). On the other hand, they are areas where forest loss is most rapid (Achard et al. 2002; Sodhi and Brook 2006; Hansen et al. 2008; Houghton 2008). Thus, it is suspected that species loss associated with forest loss is rapid in those areas. However, only a few syntheses have been made to document how rapidly species have been lost there. The best effort so far to document species loss is based on a decline in the Red List Index (RLI) of land vertebrates (Hoffmann et al. 2010), which shows that the increase in overall extinction risk is most marked in Southeast Asia. The RLI, however, is an aggregate measure based on scores calculated from the Red List categories of all assessed species, and its changes over time describe changes in the categories between assessments, not of population size and/or distribution ranges. Thus, to determine the rate of population decline and species loss, we need to quantify changes in population size and/or distribution ranges of species.

On the global scale, 7,100 populations of more than 2,300 species of mammals, birds, reptiles, amphibians, and fish are being monitored to calculate another aggregate measure called the Living Planet Index (LPI). Using the LPI, GBO-3 (2010) showed that the population of wild vertebrate species fell by an average of nearly one-third (31%) globally between 1970 and 2006, with the decline especially severe in the tropics (59%). Limited numbers of vertebrate species are being monitored in the tropical Asia-Pacific region, and thus trends of LPI may not accurately describe the population decline in the Asia-Pacific scale.

In the Asia-Pacific region, there have been numerous independent efforts to describe population decline or species extinction. These efforts are briefly summarized by Sodhi et al. (2004) and more fully reviewed by Sodhi and Brook (2006). They were subjected to a meta-analysis by Sodhi et al. (2009). Further efforts to document biodiversity loss have been made by Sodhi et al. (2010a, b). Sodhi et al. (2009) conducted a meta-analysis of 120 independent studies from Southeast Asia in which ecological attributes were recorded in pristine and nearby deforested/disturbed sites. The authors concluded that forest disturbance is the most detrimental factor regarding species richness in a wide range of taxa, and Southeast Asian biota are extremely sensitive to human-induced disturbances. As summarized in this meta-analysis, many studies showed population decline or local extinction by comparing natural forests with disturbed areas (e.g., secondary forests, agricultural areas, and urban areas). However, it is difficult to determine the rates of population decline and/or species extinction over time with such between-site comparisons.

To document the trends of biodiversity, we need to observe its state multiple times at the same site. Availability of such “time-series records” is limited in the Asia-Pacific region. The best documentations of species loss over time are for the biota of Singapore (Brook et al. 2003; Sodhi et al. 2004; Sodhi & Brook 2006). Brook et al. (2003) documented that at least 881 (28%) of 3,196 recorded species—including butterflies, fish, birds, and mammals—have been lost since The British establishment of Singapore on the Malaya Peninsula in 1819. For vascular plants,

Turner et al. (1994) documented that 594 (26%) of 2,277 species had become extinct. On a smaller scale, Turner et al. (1996) showed that 49% of 488 vascular plant species recorded during the 1890s were lost by 1994 from an isolated 4-ha fragment of rain forest in Singapore Botanical Gardens. Sodhi and Brook (2006) reviewed other case studies on the decline or loss of species in a particular area. More recent studies provided additional examples of species decline or loss at a particular site for birds (Trainor 2007; Maas et al. 2009; Sodhi et al. 2010a) and insects (odonates and butterflies) (Sodhi et al. 2010b). However, there are too few available data to estimate the rates of species loss in non-Singapore areas. Brook et al. (2003) extrapolated the taxon-specific species–area relations obtained from observations in Singapore to all of Southeast Asia. They then predicted an overall loss of 13–42% of regional populations due to the effects of deforestation in Southeast Asia (deforestation at 0.71% per year is assumed). However, prediction using the species–area relation may overestimate the rate of species extinction (He and Hubbell 2011). To obtain more reliable estimates of species loss rates in the Asia-Pacific region, we need to establish fixed study sites in each country and observe the biodiversity changes at the sites during an adequate time interval (GEO BON 2010).

In conclusion, our current knowledge of terrestrial species loss in the Asia-Pacific region remains limited. There is no doubt that the populations of many species are being lost there owing to rapid forest loss and other environmental deterioration, but the rate of this loss remains uncertain. This uncertainty is particularly serious for vascular plants, among which limited numbers of species have been assessed in the Asia-Pacific region under the International Union for Conservation of Nature (IUCN) Red List. In fact, more species than previously listed are expected to be threatened there.

## **How to Observe Status and Trends of Plant Species Diversity in the Asia-Pacific Region**

To develop adequate and effective conservation planning of terrestrial species (vascular plants in particular), we need to determine how many species are threatened for extinction and where and how rapidly those species are declining in the Asia-Pacific region. It is difficult to answer some of these questions. First, species richness in the Asia-Pacific region is so high that assessments of their extinction risks require tremendous efforts. Second, taxonomic information and distribution records are physically dispersed, and it is not always easy to synthesize them. Third, efforts to observe the presence and abundance of species on the ground have been isolated from remote-sensing efforts to document land-use changes on a large scale. There is a significant need for AP-BON to develop strategies to overcome these difficulties and promote observation and assessment of species diversity in the Asia-Pacific region. We propose the following three approaches, which we believe would effectively overcome the difficulties: plot-based approach,

specimen-based approach and area-based approach. Below, we focus on vascular plant species, but the approaches and strategies described below can be applied to any terrestrial organisms.

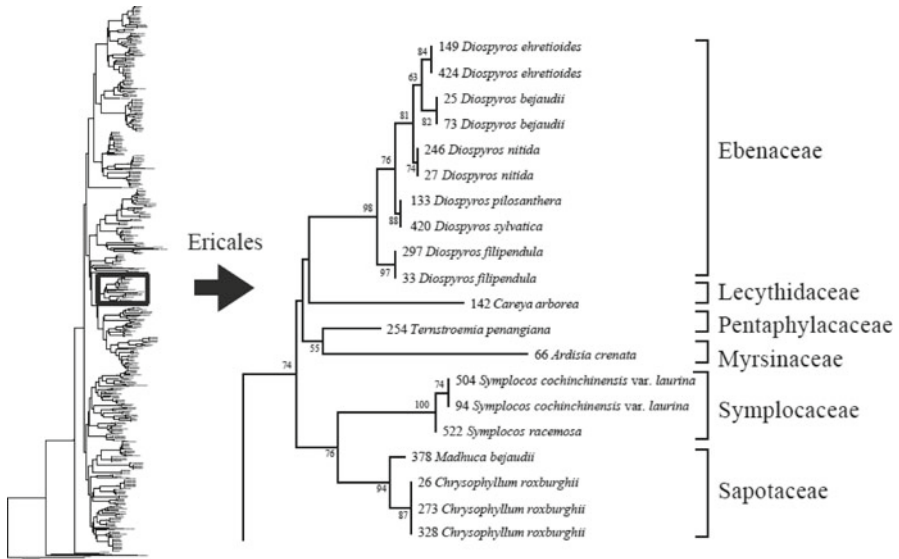
### ***Plot-Based Approach***

Permanent forest plots have been established in many countries as a fundamental data source of forest research. Inventory data obtained from those plots include not only the presence but also the abundance of tree species. If a plot was censused multiple times, we can determine changes of abundance in plot tree species. In some cases, plots once set up are lost under land-use change, providing information of local species loss. These time-series data are valuable for documenting where and how rapidly species are being lost.

A problem of using plot data is the identification of trees in the plot. Slik et al. (2009) synthesized inventory data of 46 Bornean plots located in a wide range of climatic, soil, and altitudinal gradients to determine the correlation of tree diversity with the environment. In this study, however, the data for the genus, not the species, were used because identification of species is often incomplete (see also Slik et al. 2003). Top et al. (2009) examined stand structure and tree species diversity using inventory data obtained from 540 plots in Kampong Thom Province, Cambodia. In that study, however, 88 species (36%) of the 243 total remained unidentified. These examples show that improved identification accuracy is needed to use plot data regarding the presence and abundance records of species.

Professional taxonomic skill and rich experience of identification have been required for accurate identification of tropical tree species. This situation, however, is changing owing to the accumulation of rich DNA sequence data in various plant groups. Now, by determining sequences of *rbcL* and *matK*, which are widely used as plant DNA bar codes (Kress et al. 2009), we can determine a family and usually a candidate genus of an unknown tree by using a homology search with a DNA database, even if the specimen is sterile (Fig. 1). We can then identify that tree at the species level using local flora, the taxonomic literature, and herbarium specimens. Some skills and practices are needed for this identification procedure, but it is much easier for most researchers to identify the species of a specimen for which the genus is known than to identify it when its genus is unknown. Using this approach, we successfully identified most unknown species of plot trees in Kampong Thom Province, Cambodia, where 36% of the plot trees remained unidentified in the report of Top et al. (2009) (Fig. 1). In addition, we showed that the list of Top et al. (2009) included a considerable number of misidentifications because (1) local people often misidentify species (even genus or family in some cases), and (2) local people often use the same name for different species.

We propose to promote a collaborative effort to sequence *rbcL* and *matK* of trees in many forest plots in Asia. If voucher specimens of plot trees are available, they can be used for DNA sequencing, although sequence success is often low if DNA



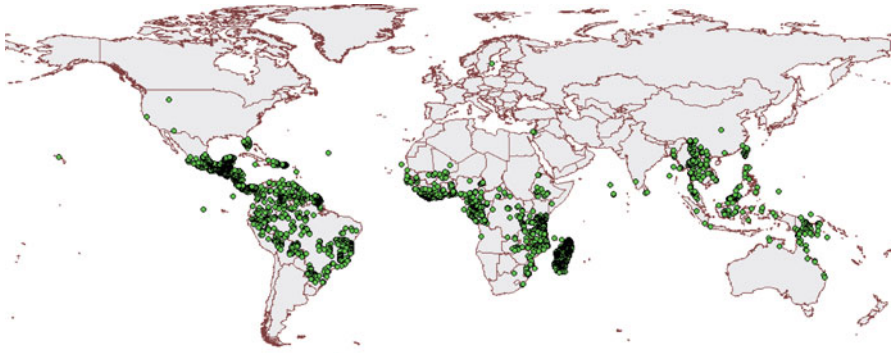
**Fig. 1** Phylogenetic (*rbcL*) trees of species growing in permanent sample plots of Kampong Thom and Kampong Chhnang Provinces, Cambodia. At right: phylogeny of species belonging to Ericales at an enlarged scale

molecules of specimens are too deteriorated. By accumulating DNA sequences linked with voucher specimens and their pictures, our ability to compare species' composition among Asian plots will be greatly improved.

### ***Specimen-Based Approach***

Records of the presence of plant species in particular localities have been accumulated in many herbaria since the time of Linnaeus. Those records obtained from herbarium specimens provide us indispensable data sources for documenting the distribution of plant species (Graham et al. 2004). It is only recently, however, that specimen records have been subjected to quantitative analyses using the methodology of distribution modeling (Guisan and Zimmermann 2000). In a pioneering study, Raes et al. (2009) used 44,106 specimen records from the digital database of the National Herbarium of The Netherlands to model distributions of 2,273 Bornean plant species belonging to 102 families, which have been taxonomically revised in Flora Malesiana from 1959 to 2007. After excluding nonsignificant models, 1,439 plant species were used to carry out a Borneo-wide, quantitative assessment of species richness and endemism at 5 arc-minute (approximately 10 × 10 km at the equator) spatial resolution. As a result, Sabah, northwestern Sarawak, and the high





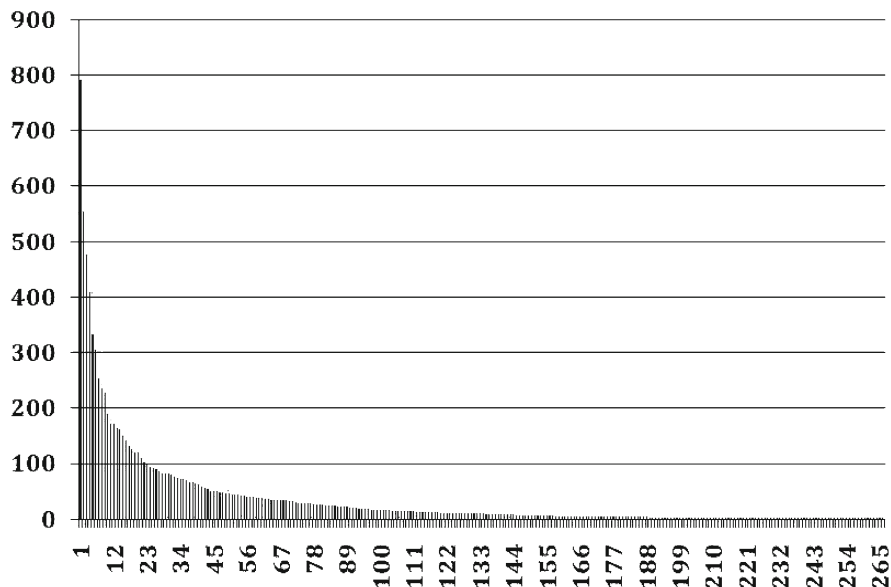
**Fig. 2** Geographic distribution of herbarium specimen records of *Dalbergia* (Fabaceae) that are available in the global biodiversity information facility (GBIF) database

mountains in East Kalimantan showed very high predicted values of species richness. The highest richness was found in a grid cell of Sabah, where 1,027 species were predicted to occur. The lowest predicted richness was found in a grid cell of West Kalimantan, where only six of the modeled species were predicted to be present.

Endemicity is determined using the weighted Endemism Index. To calculate this index, a species that occurs in only 2 grid cells has a weight of 1/2 in each of the two grids; another species that occurs in 10 grid cells has a weight of 1/10 in every grid cell where it is present; and so on. The weighted Endemism Index of a grid, determined by summing the weights of all of the species that occur in the grid, showed largely the same pattern as the richness pattern but were more concentrated around the mountains. To determine endemicity hotspots—areas with higher levels of endemicity than the expectation from species richness—the residuals of the richness-endemicity regression were mapped. As a result, Mt. Kinabalu and the Crocker Range Mountains in the north, the Meratus Mountains in the southeast, Sangkulirang Peninsula in the east, and the Müller Mountains of Central Kalimantan were identified as the endemicity hotspots. Among them, the latter two are not listed as “centers of plant diversity” (WWF and IUCN 1995).

The method employed by Raes et al. (2009) can be applied to any area where rich distribution records are available. Welzen et al. (2011) used it to discriminate four phytogeographic regions of Thailand and projected changes of plant distribution under a climate change scenario for 2050. Further efforts to model plant distributions are awaited in other areas of the Asia-Pacific region. It is desirable that AP-BON facilitate collaboration to promote these efforts.

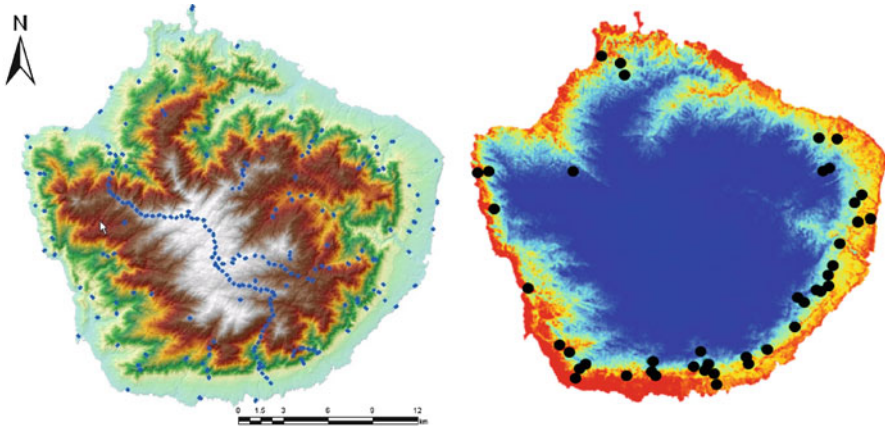
To develop distribution models, we need good distribution records. Fortunately, global efforts directed by the Global Biodiversity Information Facility (GBIF), an international organization that aims at creating a global database of biodiversity information, has successfully accumulated a huge number of distribution records digitized from herbarium specimens. As an example, Fig. 2 shows the distribution



**Fig. 3** Frequency distribution of the number of specimens per species of *Dalbergia* (Fabaceae). Species are arranged in the order of the number of specimens per species

map of *Dalbergia* (Fabaceae) drawn by using 8,894 distribution records downloaded from the GBIF portal. These distribution records accumulated in the GBIF database are useful for carrying out quantitative assessments of plant diversity in the Asia-Pacific region. However, the number of specimen records in the tropical Asia-Pacific region remains low despite the fact that many collection efforts have been made since the time of Linnaeus. There are numerous areas where few collection efforts, if any, have been made, and there are many species for which only a few specimens have been collected. We urgently need to identify the areas and species for which more collection efforts are required.

We should pay attention to the fact that large numbers of plant species are rare. Figure 3 shows the distribution of the number of specimens per species of *Dalbergia*. Among 266 species of *Dalbergia* for which at least 1 specimen record is available in the GBIF database, 135 species (51%) have  $\leq 10$  specimen records. It is difficult to develop statistically significant distribution models for species with so few distribution records. In the study of Raes et al. (2009), 834 species (37%) among the 2,273 total were excluded from the analysis because of the limited specimen records. On the other hand, rare species are more prone to extinction under land-use change, climate change, and other anthropogenic drivers of biodiversity loss. Therefore, in addition to the assessments of nonrare species by Raes et al. (2009) and Welzen et al. (2011), assessments of rare species are needed as a collaborative activity of AP-BON.



**Fig. 4** Locations of 270 transects in Yakushima (*left*) and observed and predicted distributions of *Calanthe triplicate*, a threatened orchid (*right*). Dots in the right-hand side show the observed distribution, and gradation shows differences in distribution probabilities

### *Area-Based Approach*

Although available data from forest plots and herbarium specimens provide invaluable information for assessing plant diversity, more data are needed to characterize spatial patterns and temporal trends of plant diversity, especially at a local scale. To develop a new protected area, for example, some detailed observations of the flora and vegetation are required. Webb (2005) used 15 transects to characterize vegetation and choose conservation zones in 2 wildlife sanctuary areas of the Cardamon Mountains, Cambodia. Few botanical surveys have been made in the Cardamon Mountains, and Webb (2005) could not use taxonomically identified distribution records. If specimens collected from many transects are accurately identified, we can employ various methods of distribution modeling (Guisan and Zimmermann 2000) to assess spatial patterns of plant diversity.

Figure 4 shows an example of transect surveys to describe spatial patterns of plant diversity in a particular area. Yakushima, Japan, is a small island with a circumference of 130 km with the highest peak of 1,936 m. It was selected as a World Natural Heritage site. The presence or absence of 656 plant species were recorded in 270 georeferenced transects, and an additional georeferences of threatened species habitats were recorded by GPS if they were occasionally found during the fieldwork. Using those distribution records, the distributions of plant species in Yakushima were modeled, including many threatened species (Fig. 4).

It is desirable to carry out similar field surveys in various areas of the Asia-Pacific region. To carry out such distribution surveys, it is hoped that an efficient sampling strategy can be designed by identifying the main environmental gradients

(Guisan and Zimmermann 2000; Margules and Sarkar 2007). If species richness is the focus, a proportional representation of all habitats is needed to ensure sampling as many species as possible. In addition, equal numbers of replicates per environmental combination are needed to examine the relation between species distribution and their environmental determinants (Guisan and Zimmermann 2000). In actual field surveys, however, accessibility to habitats often constrains systematic sampling designs.

### *Syntheses Towards Integrative Observations and Assessments*

Plot-based, specimen-based, and area-based approaches are mutually complementary. By integrating plot records, we can assess distributions of tree species without restricting target groups. However, forest plots cover only a tiny proportion of areas in the Asia-Pacific region. The area-based approach can cover wider areas, but we can still survey only a small proportion of the total Asia-Pacific region. This limitation can be overcome by using specimen records that cover the whole Asia-Pacific region, although there remain some areas where few collection efforts have been made. With the specimen-based approach, however, we need to select target taxonomic groups for an Asia-Pacific wide assessment because it is difficult to work on all species at once. Fabaceae is proposed as a target of global assessments because it is one of the largest plant families and includes many species that support the ecosystem function of nitrogen fixation. It encompasses many useful plants, many invasive alien plants, and species are extremely diversified in habitat preference, life forms, morphological and chemical traits, pollination systems, and interactions with herbivorous insects (Yahara 2010). In addition, Dipterocarpaceae and Fagaceae are hopeful targets for Asia-Pacific wide assessments of tree diversity. As for shrubs and herbs, Rubiaceae, Zingiberaceae, and ferns may be good candidates. It is desirable for AP-BON to promote collaborative assessments of these target groups as a first step of plant diversity assessments in the Asia-Pacific region.

To observe temporal changes of biodiversity and detect its deterioration, we must repeat observations at the same sites using standardized methods. From this viewpoint, GEO BON WG1 proposed “Biodiversity Observation Core Sites (BIOCORES),” and WG3 proposed “GEO BON observation nodes” (GEO BON 2010). The latter is aiming at utilizing existing research sites such as stations of International Long-Term Ecological Research (ILTER) for nodes of biodiversity observations or monitoring. According to GEO BON (2010), “many potential partners exist worldwide, although many of the potential partner organizations and sites (such as ILTER, NEON, BIOTA) have research as their primary orientation as opposed to monitoring. To initiate formation of a network of existing sites and attract new partners, GEO BON will create a “label” indicating membership in the network of GEO BON Observation Nodes.” On the other hand, it has been proposed to place BIOCORES in areas where biodiversity is seriously threatened. This is because “the aim of BIOCORES is to assess the processes, trends, and outcomes of

ongoing biodiversity loss during shorter terms than those of [long-term ecological research] ... and provide data useful for further conservation planning. It is desirable that monitoring and assessment activities in BIOCORES are integrated with conservation and adaptive management activities in the same area." These two proposals are complementary. It will be highly profitable to develop GEO BON Observation Nodes and BIOCORES in the Asia-Pacific region as a collaborative activity of AP-BON. Although many observation points are well established and networked for climate change, we do not have a network of biodiversity observation sites that enable us to monitor biodiversity changes effectively. Establishing that network is one of the most important and most urgent tasks of AP-BON and GEO BON.

## **Our Current Knowledge of Forest Loss in the Asia-Pacific Region**

Needless to say, deforestation is one of the most important drivers of biodiversity loss. In this section, we briefly review how forest loss is going on in the Asia-Pacific region. Global forest assessments such as those undertaken by the Food and Agriculture Organization (FAO) (FAO 2011) are designed to measure the area of and the trends in the extent of the world's forests. According to FAO statistics (FAO 2011), 31 Mha, or 9.54%, of the forest in South and Southeast Asia and 7.36 Mha, or 3.70%, of the forest in Oceania were lost between 1990 and 2010. Forest loss over these two decades was especially rapid in Cambodia (22.0%), Indonesia (20.3%), and Myanmar (19.0%) (FAO 2011). Whereas forest cover once comprised 73.33% of the land area of Cambodia in 1990, it has rapidly decline to 57.18% (FAO 2011). The mapped gross forest cover loss for Sumatra and Kalimantan in Indonesia was 2.86% of the land area, or 2.86 Mha, from 2000 to 2005, with the highest concentration having occurred in Riau and Kalimantan Tengah provinces (Broich et al. 2011).

In addition to FAO assessments that have been predominantly based on questionnaires and national reports on forest cover, satellite imagery data with 250–1,000-m resolution have been used to map the extent and distribution of a variety of forest types at the regional scale. The most recent analysis of deforestation rates in insular Southeast Asia, between 2000 and 2010, utilized 250-m spatial resolution land cover maps (Miettinen et al. 2011). The results revealed an overall 1.0% yearly decline in forest cover in insular Southeast Asia. In particular, peat swamp forests experienced the highest loss rates, at 2.2% per year, and lowland evergreen forests declined by 1.2% per year. Island-specific deforestation rates are the highest in Sumatra (2.7% per year) and Borneo (1.3% per year). These results basically agree with earlier analyses for Borneo (Langner et al. 2007), Indonesia (Hansen et al. 2008), Papua New Guinea (Shearman et al. 2009), and Sumatra (Laumonier et al. 2010). Forest area estimates by satellite imagery and FAO statistics, however, showed some gaps, partly because of the insufficient spatial resolution of satellite

imagery and the difficulty of determining forest vegetation (Stibig et al. 2004). We need to calibrate finer-scale estimates of forest loss to relate them to distribution models of species and to carry out extinction risk analyses.

Deforestation is due to complex factors. According to the meta-analysis of Geist and Lambin (2001, 2002), agricultural expansion is the main proximate pressure contributing to tropical deforestation, followed by wood extraction and infrastructural expansion. Agricultural expansion includes forest conversion for permanent cropping, cattle ranching, shifting cultivation, and colonization agriculture. Although shifting cultivation had once been considered the prime cause of tropical deforestation (Lanly 1982), it is now just one of variables of agricultural expansion, which causes deforestation (Geist and Lambin 2002). Tropical deforestation is best explained by a combination of agricultural expansion, wood extraction, and infrastructure expansion rather than by single variables.

In Asian tropical forests, commercial wood extraction, infrastructure expansion, and agricultural expansion (e.g., increasing farming of rubber, oil palm, coffee, and other cash crops) are the leading causes of deforestation (Geist and Lambin 2002; Fox and Vogler 2005; Gaveau et al. 2009; Feintrenie et al. 2010; Wicke et al. 2011). Interacting with these anthropogenic factors, forest fire is a major driving force of forest loss in insular Southeast Asia, particularly in Borneo (Langner et al. 2007; Langner and Siegert 2009). Over the 10 years from 1997 to 2006 in Borneo, 16.2 Mha of forest cover (21% of the land surface) were affected by fire (Langner and Siegert 2009). During El Niño years (1997–1998, 2002, 2006), fires occurred much more frequently in Borneo, and the fire-affected area was three times larger than during normal weather conditions. These fire events are linked to human activities described above because burning is the cheapest means of land preparation (Langner and Siegert 2009).

Among Southeast Asian countries, forest-covered areas in the Philippines, Thailand, and Vietnam are increasing, whereas those of Cambodia, Indonesia, Laos, Malaysia, and Myanmar are decreasing (FAO 2011). In the Philippines, forest area had decreased from about 70.0% of the land area in 1900 to 58.2% in 1941 and to 21.5% in 1988. The main causes of deforestation were intensive logging and agricultural expansion. After a logging boom from the 1950s to early 1970s, however, reforestation efforts were intensified under the threat of an imminent timber shortage. After that, forest cover increased from 22.0% in 1990 and to 24.8% in 2010 (FAO 2011). In addition to timber shortage, other forces—promotion of environmental stability, funding availability, emergence of people-oriented forestry programs—drove forest rehabilitation in the Philippines (Pulhin et al. 2006).

In Vietnam, forest area increased from 30.2% of the land area in 1990 to 42.2% in 2010 (FAO 2011). A major driving force of this forest transition was forestry policy; logging of natural forest was banned in 1993, and a reforestation program was launched in 1998. These successive forestry policies drove the forest increase in Vietnam (Mather 2007; Meyfroidt and Lambin 2009). On the other hand, wood imports have increased, and large quantities of illegal logs entered from Cambodia and Laos (Meyfroidt and Lambin 2009).