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The Asia-Pacific Biodiversity Observation Network: 10-year achievements and new strategies to 2030

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Abstract

The Asia-Pacific Biodiversity Observation Network (APBON) was launched in 2009, in response to the establishment of the Biodiversity Observation Network under the Group on Earth Observations in 2008. APBON's mission is to increase exchange of knowledge and know-how between institutions and researchers concerning biodiversity science research in the Asia-Pacific (AP) region and thereby contribute to evidence-based decision-making and policy-making. Here we summarize APBON activities and achievements in its first 10 years. We review how APBON has developed networks, facilitated communication for sharing knowledge, and built capacity of researchers and stakeholders through workshops and publications as well as discuss the network plan. Key findings by APBON members include descriptions of species new to science, mapping tropical forest cover change, evaluating impacts of hydropower dams and climate change on fish species diversity in the Mekong, and mapping "Ecologically and Biologically Significant Areas" in the oceans. APBON has also contributed to data collection, sharing, analysis, and synthesis for regional and global biodiversity assessment. A highlight was contributing to the "Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services" regional report. New strategic plans target the development of national-level BONs and interdisciplinary research to address the data and knowledge gaps and increase data accessibility for users and for meeting societal demands. Strengthening networks in AP region and capacity building through APBON meetings will continue. By promoting monitoring and scientific research and facilitating the dialogue with scientists and policymakers, APBON will contribute to the implementation of conservation and sustainable use of biodiversity in the entire AP region.

KEYWORDS
capacity building, data sharing, ecosystem service, IPBES, master site

1 | INTRODUCTION

The Asia-Pacific (AP) region covers approximately 22% of the total global land area, with a range of climatic conditions, natural resources, and cultural diversities, and is home to two-thirds of the world's population (United Nations Economic and Social Commission for Asia and the Pacific, 2013). Despite the region's sizable ecosystems and large islands, inland wetlands, coral reefs, and various forest types, the region has undergone extensive land use transformation to agriculture and pastureland since the 1960s, and its aquatic ecosystems are threatened by overfishing, pollution, infrastructure development and invasive species. This development has been accompanied by a rapid loss of biodiversity. The main drivers of biodiversity loss include commodity-driven deforestation (such as plantations and forestry) in terrestrial and freshwater ecosystems (Curtis, Slay, Harris, Tyukavina, & Hansen, 2018; Fitzherbert et al., 2008; Hughes, 2017; Koh & Wilcove, 2008), dams in freshwater ecosystems (Dudgeon et al., 2006; Kano et al., 2016; Vörösmarty et al., 2010; Ziv, Baran, Nam, Rodríguez-Iturbe, & Levin, 2012), natural hazards (such as tsunamis and storms), climate change, land-based marine pollution, and overexploitation (including unregulated fishing and coastal development) in coastal-marine ecosystems (Burke, Reytar, Spalding, & Perry, 2011; IPBES, 2018a; Roberts et al., 2002). Thus, this is a prompting work toward achieving a more sustainable balance between development and conservation to be a highly urgent task in the region (Burke et al., 2011; IPBES, 2018a; Roberts et al., 2002). These circumstances call for interactions and partnerships of scientists and stakeholders that will integrate available information, appropriately document the state of biodiversity and its change that are being discovered, and promote the exchange and use of such information in biodiversity conservation and policy development. Asia is currently regarded by several scientists as the most biotically threatened part of the planet; to mediate this loss, further data are required to develop baselines on biodiversity and assay patterns of diversity and threat. Natural 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 (Lenzen et al., 2012; Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000). In the light of these urgencies, the establishment of an observational network covering the region and its broad activities from scientific research to producing integrated knowledge and capacity development are hence quite essential.

The Asia-Pacific Biodiversity Observation Network (APBON, Table S1) was established to enable a network of institutions and research groups in AP region that contribute to and utilize a knowledge resource base for decision-making and policy-making for the conservation of biodiversity and ecosystems (Figure 1). It was launched in 2009 in response to Biodiversity Observation Network under the Group on Earth Observations (GEO BON, Table S1) in 2008. At the initial phase, APBON held thematic working groups such as the terrestrial, freshwater, and marine ecosystems, which are the key elements in our region, and also correspond to the components of the GEO BON. Since the establishment, APBON aimed at promoting biodiversity monitoring and contributing to sound decision-making based on scientific knowledge. To achieve this, APBON facilitates the organization and periodically convenes a regional network of biodiversity observation institutions for maintaining a knowledge base that will support biodiversity conservation (also see APBON core value in SI text 1).

Here, we summarize our activities and achievements under the last work plan (Yahara et al., 2014). We review how APBON has been initiated and grown as a network;

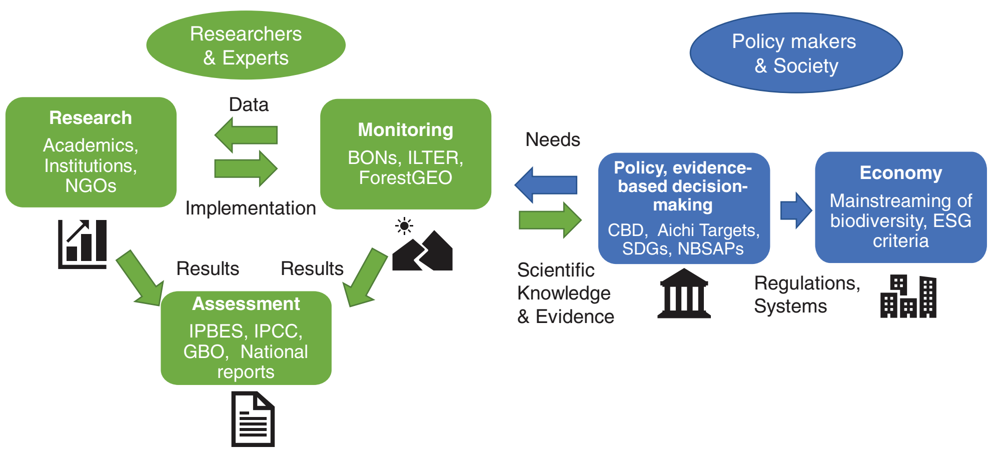

FIGURE 1 APBON promotes scientific activities including research, monitoring and assessments regarding to biodiversity and ecosystems. We also manage the platform to communicate among researchers, policymakers and stakeholders to promote data sharing and facilitate scientific knowledge delivery to stakeholders and identify societal needs for biodiversity observation. Those will contribute to facilitate and achieve the global goals of biodiversity and ecosystem conservation. The arrows indicate interactions between the communities. For further details on the acronyms, see Table S1 [Color figure can be viewed at wileyonlinelibrary.com]

we have facilitated the communication and interaction opportunities inter-/intra-researchers and stakeholders through workshops and publications. These observations and publications are also aimed at linking with the global network, particularly with the GEO BON, so as to connect the research needs and knowledge on the state and change in the biodiversity in our region with those of the global coordination and cooperation processes as the AP region possesses a unique characteristic. We also developed tools for data collection, sharing, analysis, and synthesis for further observations and capacity building. Contributions to performing assessments, such as Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, Table S1), which contributed to improving ecosystem management and sustainable use of biodiversity, are also highlighted. Further, we establish a new work plan of APBON, recognizing new needs of biodiversity observations and incorporating new approaches of biodiversity science.

2 | ACHIEVEMENT HIGHLIGHTS

2.1 | APBON from 2009 to 2019

Since APBON launched in 2009, we have held 11 APBON meetings and 12 Global Earth Observation System of Systems (GEOSS, Table S1) AP symposiums with contributors from more than 18 countries/areas by the end of 2019. According to our visions and missions (Yahara et al., 2014), we have also promoted collaborative projects, shared information gathered from various methods across the region and implemented collaborative work through five working groups (WGs) (cf. Reports of the past meetings, Biodiversity Center of Japan, 2020a).

Consequently, APBON has successfully developed a network of biodiversity scientists from many institutes in the AP region (Yahara et al., 2014). APBON has also contributed to networking biodiversity-related bodies and programs including the Convention on Biological Diversity (CBD, Table S1), Global Biodiversity Information Facility (GBIF, Table S1), International Union for Conservation of Nature (IUCN, Table S1), International Long-Term Ecological Research–East Asia-Pacific Regional Network (ILTER-EAP, Table S1) (Kim et al., 2018) and Asia Oceania Group on Earth Observations (AOGEO, Table S1). The multidisciplinary efforts in APBON also contributed toward developing a strategy for the Earth observation for biodiversity monitoring by connecting in situ and satellite observations (Secades, O'Connor, Brown, & Walpole, 2014) as well as to global agenda such as Sustainable Development Goals (SDGs, Table S1), Paris agreement and Sendai framework. APBON triggered the formation of national BONs: Japan Biodiversity Observation Network (JBON, Table S1) was simultaneously organized with APBON before CBD COP10. Korea Biodiversity Observation Network (KBON, Table S1), Chinese Biodiversity Observation Network (Sino-BON; Table S1) and China BON (Table S1) have been established as active national BONs.

From 2011 to 2015, a project on "Integrative Observations and Assessments of Asian Biodiversity" (hereafter, S9) was implemented in collaboration with many scientists of Asian countries, under the support of the Ministry of the Environment, Japan. Through the project and others, we had conducted our field biodiversity research and monitoring over East and South East (SE) Asia, and we have surveyed over 100 sites in 10 countries (Figure 2). Moreover, considering S9's financial support to observation projects, we discussed and agreed on the implementation plan of APBON for 2012–2015, at the fourth APBON workshop, which was held from December 2 to 3, 2011 (Yahara et al., 2014). The plan for 2012–2015 covered five major activities: (a) Editing and networking national biodiversity outlook, (b) Publication of additional APBON books, (c) Promotion of collaborative projects, (d) Development of shared database, and (e) Capacity building. Below, we first review our achievements of the third activity (also see Tables S2–S5), including our contribution to the IPBES AP regional assessment (IPBES, 2018a). Second, we review our achievements of the fourth and fifth activities in the data sharing section. Third, we review our progress in the first activity in the section on "Biodiversity observations in the national level."

2.2 | APBON achievements with reference to the IPBES regional assessment

IPBES aims to synthesize, review, assess and critically evaluate relevant information and knowledge on the contribution of biodiversity and ecosystem services to sustainability generated worldwide by governments, academia, scientific organizations, nongovernmental organizations and so on. IPBES has already published eight assessment reports until date (November, 2020), and these reports have been widely referred to and utilized by the society in decision-making, global environmental conventions, and the development of policy dialogues. Among the series of assessments, several APBON members were involved in and contributed to the IPBES Regional Assessment of Biodiversity and Ecosystem Services for Asia and Pacific (IPBES, 2018a). We have proposed the strategies to observe and assess the states and changes in the biodiversity in AP regions while reviewing the available references on various aspects of biodiversity in the AP regions in APBON's three volumes of books (Nakano, Yahara, & Nakashizuka, 2012, 2014,

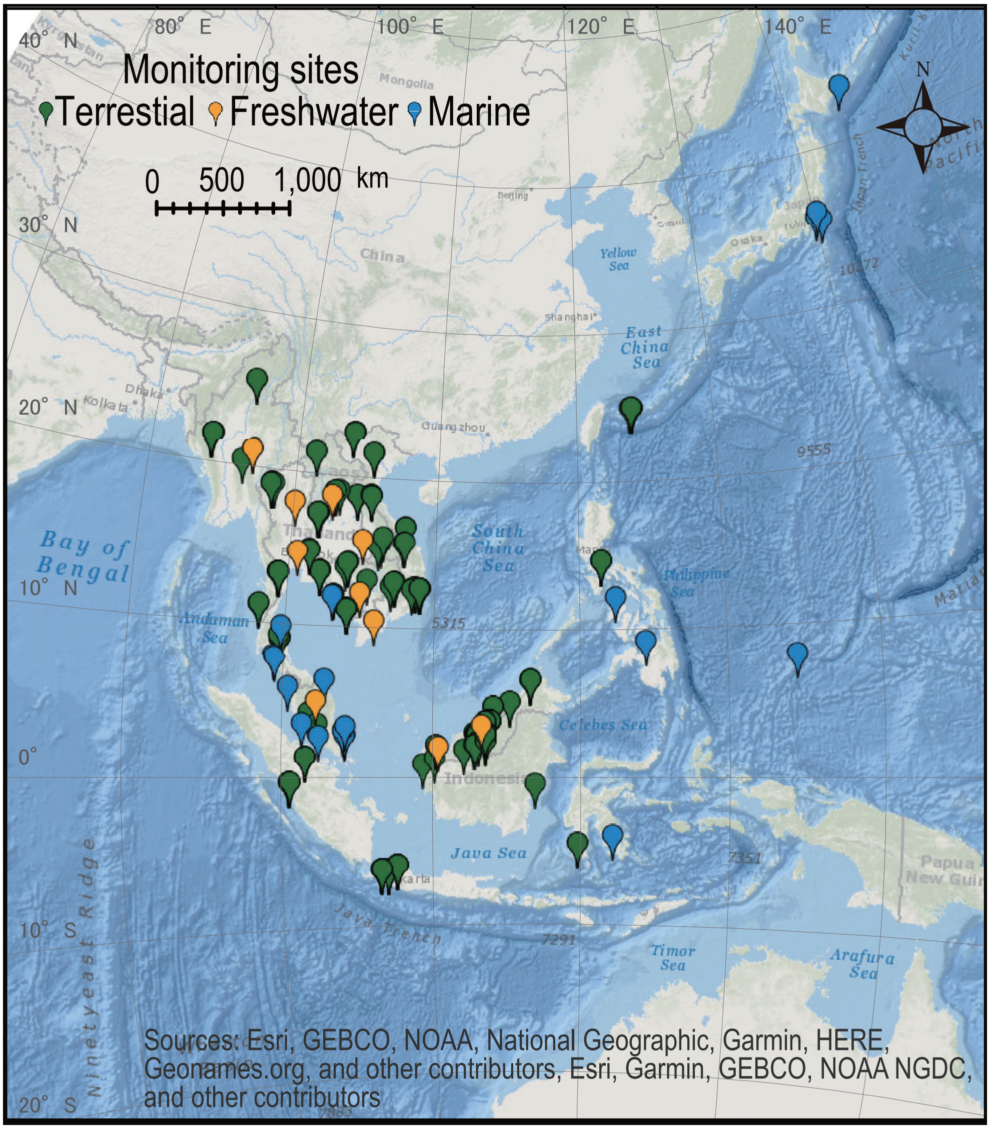

FIGURE 2 The location of the survey sites of the APBON members in terrestrial, freshwater, and marine areas in Asia-Pacific region. The terrestrial study sites were mostly forest area, which were established to survey plant species diversity and forest dynamics by the S9 project and individual research projects by APBON members. The freshwater sites were also established by the APBON members, supported by the S9 project and Nagao Natural Environmental Foundation Japan to monitor the impact on fish species diversity in the rivers and lakes, which were influenced by dams and the surrounding land-use patterns, and invasive species. The marine study sites mainly included seagrass and mangrove study site of the members of AP-MBON [Color figure can be viewed at wileyonlinelibrary.com]

2016), and these reviews provided precursors of "Chapter 3. Status, trends and future dynamics of biodiversity and ecosystems underpinning nature's contributions to people" in the assessment (IPBES, 2018a). Below, we summarize those key findings through our APBON activities and IPBES assessment and identify knowledge gaps to be addressed by further observation efforts in future.

First, forest loss has been extremely serious, especially in tropical regions in the world (Hansen et al., 2013). In case of SE Asia, deforestation is still ongoing in some countries including Indonesia (−0.68 M ha/year) and Myanmar (−0.54 M ha/year), but forest cover is increasing in some countries such as Philippines (0.24 M ha/year) and Vietnam (0.13 M ha/year) (FAO, 2015). Imai, Furukawa, Tsujino, Kitamura, and Yumoto (2018) analyzed drivers causing the losses or the gains of forest cover in SE Asia and found that major drivers changed between 1980s and 2000s; food and wood productions were major drivers in 1980, but only wood production remained to be a major driver of forest loss during 2000s. Consequently, in countries where wood production decreased, a trend of forest area shifted from a decreasing to an increasing stage, supporting the forest transition hypothesis (Meyfroidt & Lambin, 2011). This would be good news, but the increased forest cover may be mostly attributed to monoculture plantations. To obtain more accurate understanding on the biodiversity change with its drivers in tropical forests of SE Asia, repeated in situ observations in many locations are needed. The IPBES regional assessment on forest cover (IPBES, 2019a) was based on the statistics of FAO (2015) that include many discrepancies due to variable definitions of "forest" among countries, for example, tree crops are included in some cases. Standardized method and definition of forest cover over countries would be essential to conduct more reliable assessment of forests with high biodiversity and ecosystem services.

Second, forest loss in the tropical area of AP region threatens many native species. This threat is best documented for birds. Nishijima et al. (2016) assessed the effects of wood trade on bird extinction risks and showed that large wood importers including China, Japan and Korea are imposing large risks of bird species extinction in the forest of Indonesia, a major wood exporter. The IUCN Red List of Threatened Species includes 14,249 species assessed in AP region, among which 21% are threatened, which is like the global percentage of 23%. Most of assessed species are animals and only a small proportion of plant species have been assessed. Brummitt et al. (2015) assessed random global sample of 7,000 land plant species and estimated that 16–21% of plant species in AP region are threatened. However, this estimation is based on the assessment of only 1,520 species in SE Asia, and it is urgently needed to assess threat states of more plant species in tropical forests of AP region. On the other hand, taxonomy on plant species in tropical forests of AP region remain poorly studied. Promoting taxonomic studies of tropical forest trees is one of the most urgent needs in biodiversity observations in AP region.

Third, freshwater fish biodiversity is jeopardized by both climatic and anthropogenic factors globally. In AP region, the biodiversity is unexceptionally faced with various risks, of which hydropower dams are of particular note. Kano, Dudgeon, et al. (2016) elucidated the impacts of the hydropower dams and its synergistic negative effect with global warming on the freshwater fish biodiversity of the lower Mekong and neighboring areas (i.e., Indo-Burma Region), the world's largest freshwater capture fishery. Based on a scenario analysis with the >1,500 fish distribution data and information of >700 hydropower dams, the loss of the fish biodiversity by the dams is obvious. The loss is especially high in Lao PDR; the local fish species richness will be lost >30% (37–25 species/km^2) by further dam development. Cambodia will lose >20% local fish species richness (60–47 species/km^2). The dam impact has negative synergistic effects with global warming as the dams limit the ability of fishes to adapt to warming temperatures by shifting their ranges to occupy areas upstream. The dams' negative impact will be heightened 10–20% by such a synergistic mechanism.

Fourth, threats to coral reefs were evaluated by Yamano, Sugihara, and Nomura (2011) and Yara et al. (2012); they reported the evidence of northward range expansion of tropical corals in a temperate area, and projected the future impact of ocean acidification. Simultaneously, bleaching of corals was observed in several locations in tropical area because of high temperature especially in 1998. Hongo and Yamano (2013) revealed the impact of sedimentation on the recovery process after the bleaching as a case study; they suggested local land use stressor could be one of the manageable factors in local activity to reduce the effect of climate change on corals. These studies were evolved into more sophisticated statistical modeling research activities to detect the mechanisms for the range expansion and bleaching occurrence (Kumagai et al., 2018; Kumagai, Yamano, & Committee, 2018). There is also a contribution to mapping the AP scale distribution of coral reefs based on satellite data analysis (National Institute for Environmental Studies, 2008).

Fifth, distribution of over 4,000 records of marine species was updated in Ocean Biogeographic Information System (OBIS, Table S1) by the S9 project. Distribution of biodiversity and EBSAs (Ecologically Biologically Significant Area, Table S1) of East and SE Asian waters are evaluated by Yamakita, Sudo, Jintsu-Uchifune, Yamamoto, and Shirayama (2017). Although large areas of the EBSAs was already protected, several areas which were not in protected areas are detected such as Visayas, Kalimantan, Sulu Sea-Celebes Sea and those are also suggested as expert opinion in the EBSAs regional workshop. Other gaps between existing protected area showed lack of scientific data in several locations such as, Eastern Indonesia, Savua Marine National Park where noted as important area for migratory marine species, and several small islands which may be selected as protected areas because of its identity of the ecosystem.

Those researches successfully assessed the current status of biodiversity in AP region based on the analysis using large biodiversity data sets over the region. As we pointed out above, there are still knowledge gaps. However, it can be overcome through data accumulation, in situ field monitoring, harmonized methodologies and technological development. One of the solutions will be open data which represents a priority action for the region.

2.3 | Data sharing

The biodiversity and ecosystem services assessment in both national and global scales should be based on solid scientific data and knowledge as these are essential for policymakers to perform evidence-based decision-making (Figure 1). For example, national reports on information on the implementation of Aichi targets, which are required to submit to CBD, are drafted in collaboration with scientific experts in several AP countries; scientific experts cooperated with the process of the assessment on the status, changes, and services of biodiversity and effectiveness of the

TABLE 1 The data sharing systems and media in the APBON's network (also see Table S1)

Acronyms	Official name	Reference/websites	Category	Outline
	Ecological Research Data Paper	http://www.esj.ne.jp/er/datapaper.html	Data paper	The Ecological Research Data Paper is a peer-reviewed online journal that aims to collect excellent ecological research data and accompanying metadata available to the public
	Ecological Research Data Paper Archives	http://db.cger.nies.go.jp/JaLTER/ER_DataPapers/	Data paper archives	Electric data archives of the Data Papers above. Free access
GBIF	Global Biodiversity Information Facility	https://www.gbif.org/	Database/data depository	GBIF is an international network and research infrastructure funded by the world's governments and aimed at providing anyone and anywhere with open access to data about all types of life on Earth
ABCDNet	Asia Biodiversity Conservation and Database Network	http://www.abcdn.org	Network/program/database	ABCDNet is a biodiversity database for biodiversity conservation in Asia. ABCDNet includes species lists with 86,575 species and subspecies and 18,184 records from 33 Asia countries/areas of Birdlife, 59,278 species red list records from 15 Asia countries/areas and 450 websites collection, in collaboration with the Asia species Database, the Asia Species Red List Database, and biodiversity-related network resources
ffish.asia	Database for Freshwater Fish Biodiversity of Asia	https://ffish.asia/	Database/data depository	The "ffish.asia" is an open-access database of freshwater organisms in Asia. The comprehensive information about species occurrence, digital specimen, photos, 3D models, CT scanned data, DNA, and literature are accessible
OBIS	Ocean Biogeographic Information System	https://obis.org/	System/database	OBIS is a global, open-access data and information clearing-house on marine biodiversity for science, conservation, and sustainable development
BISMaL	Biological Information System for Marine Life	https://www.godac.jamstec.go.jp/bismal/e/	System/database	BISMaL is a web-based data system for biodiversity information, which also works as the OBIS node. It is managed by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

TABLE 1 (Continued)

Acronyms	Official name	Reference/websites	Category	Outline
DEIMS-SDR	Dynamic Ecological Information Management System—Site and dataset registry	https://deims.org	System/database	DEIMS-SDR is an information management system that allows users to discover long-term ecosystem research sites around the globe, along with the data gathered at those sites and the people and networks associated with them

implementation of strategies based on appropriate scientific observations and available scientific literatures. Along with national reports, some countries published the scientific overview of national biodiversity such as Japan Biodiversity Outlook (Japan Biodiversity Outlook Science Committee, 2016) and China's Biodiversity (State Environmental Protection Administration, 1998) (also see the section "Biodiversity observations in the national level"). These national-level reports provided key evidences to regional and global assessments such as ASEAN biodiversity outlook 2 (ASEAN Centre for Biodiversity, 2017), IPBES Assessment reports in both for global and regional perspectives (IPBES, 2018a, 2019a), and Global Biodiversity Outlook (Secretariat of the Convention on Biological Diversity, 2020).

Thus, improving data sharing has been a major challenge of APBON since 2009 (Nakano et al., 2012, 2014, 2016), encouraging that observed data are published as scientific papers or released on the web and shared to public. The data repository system, data paper and online database, is a promising way to make biodiversity data open and sharing. Both systems have been successfully developed and promoted in these 10 years. For example, data papers section of Ecological Research, the official English language journal of the Ecological Society of Japan, was launched in 2011 through collaboration with Japan Long-Term Ecological Research Network (JaLTER, Table S1) and JBON. Since then 77 data papers have been published in the section (as of October 2020) and data and metadata of those data papers have been accumulated in Ecological Research Data Paper Archives (Table 1, see recent special feature of data paper, Shin et al., 2020).

Online database, such as GBIF, OBIS and Asia Biodiversity Conservation and Database Network (ABCDNet), have made significant progress in information system development and number of registers (Table 1). APBON also developed the online database on freshwater fish diversity and distribution in Mainland SE Asia such as "ffish.asia" (Kano et al., 2013), which is an integrated database of species occurrence, digital specimen, photos, DNA and literature (Table 1). For marine biodiversity, data collected through APBON have been used to update the OBIS through the Biological Information System for Marine Life (BISMaL) (Table 1). In SE Asia, more than 61,800 records of occurrence of marine species, which were collected up until 2005, have been collated in the OBIS, covering 3,581 taxa. The ASEAN Center for Biodiversity (ACB, Table S1) is responsible for data contribution from ASEAN member states.

APBON's activities related to data sharing includes capacity building for data paper publication. In the past APBON meeting in Taipei, September 2016, a training course of data paper publication was held in collaboration with GBIF. This workshop resulted in publication of data papers including a paper on a dataset of fishes in Inle Lake, Myanmar (Kano et al., 2016). Further efforts for organizing training courses will be particularly promising in publishing forest plot data that are mostly maintained personally by many researchers. ACB conducts training workshops for Association of Southeast Asian Nations (ASEAN, Table S1) member states focused on the organization of their biodiversity information (also see the section "Capacity building"). Appropriate archiving of information ensures the interoperability of information and eases the preparation of syntheses, analyses, relevant models and other forms of knowledge necessary to understand biodiversity-related issues in the region. Some protected area managers have been trained in data archiving that resulted in several submissions to GBIF through ACB's Integrated Publishing Toolkit (IPT). The Picture Guides were also published for forest trees in Cambodia and Vietnam (4 and 1 volumes, respectively, Center for Asian Conservation Ecology Kyushu University (2017)), where information of flora had been still limited. These guides also include the local name of species for educative purpose for local people. APBON benefits from the database structures developed by GBIF and its membership have, in turn, shared these structures with their respective networks. Although this strategy has not resulted in an aggressive flow of biodiversity data to GBIF, the scientific community in the region has been made aware of the existence of such structures and some have started to volunteer their collections.

These global efforts have contributed to the achievement of the Aichi target 19, "Sharing information and knowledge"; and the recent global biodiversity outlook (Secretariat of the Convention on Biological Diversity, 2020) evaluated "on track" achievement of the target. In fact, "on track" and "exceeded" targets were only 7 out of the 60 targets, which could be contributed by the expansion of global database platforms as well as the networking platforms, including APBON.

3 | BIODIVERSITY OBSERVATIONS AT THE NATIONAL LEVEL

3.1 | Japan

JBON launched in 2009 is a voluntary network of researchers, NGOs and policymakers, and coordinates various research activities, observation networks, and databases on ecosystems and biodiversity, in order to enhance biodiversity observation activities in Japan. JBON collaborates with other related organizations/networks in Japan (e.g., JaLTER as described below), as well as international networks. The missions include (a) Coordination of research projects and facilitation of utilization of existing biodiversity data; (b) Management, monitoring, networking of various activities throughout the "Monitoring, Assessment, Political decision-making, and Enforcement of policy" cycl; (c) Contribution to policy-making related to biodiversity based on scientific information and (d) Participation to related organizations/networks such as APBON and GEO BON. One of the key contributions to international parties was coauthoring of CBD Technical Series "Earth Observation for Biodiversity Monitoring" (Secades et al., 2014) by the Remote Sensing WG.

The Monitoring Sites 1,000 is a long-term monitoring system run by the Ministry of the Environment of Japan since 2003. The monitoring sites cover over 1,000 selected sites including alpine ecosystems, forests, grasslands, Satoyama (traditional landscapes consist of various human dominated ecosystems), lakes, wetlands, coastal and island ecosystems all over Japan. Not only scientists, but also voluntary citizens take part/play roles in observations.

JaLTER was established in 2006, and conducts ecological research, including biodiversity observation. JaLTER consists of 20 core and 38 associate sites covering various ecosystems.

Based on these results on biodiversity observations, the Ministry of the Environment Japan published Biodiversity Outlook (JBO, Table S1), which aims to report the situation of biodiversity and ecosystem services in Japan. The first report (Japan Biodiversity Outlook Science Committee, 2010) reported mainly the drivers, pressures, states, and impacts of biodiversity and its change, with the responses to these changes and impacts for recent 50 years in Japan. The second reports reported rich geographic information on biodiversity and ecosystem services (Japan Biodiversity Outlook Science Committee, 2016), in which S9 made a great contribution. The third reports will focus on scenario analyses on biodiversity and ecosystem services and will be published in 2021.

3.2 | ASEAN

ACB is an intergovernmental institution established through an agreement among the ASEAN Member States (AMS) in 2005 for the purpose of facilitating cooperation and coordination among the members of the ASEAN and with the relevant national governments, regional and international organizations on the conservation and sustainable use of biological diversity and the fair and equitable sharing of benefits arising from the use of such biodiversity in the ASEAN region. Such a role is pursued in parallel to CBD, where AMS is encouraged to establish their national clearing-house mechanisms (CHMs) in support of the implementation of their National Biodiversity and Action Plans (NBSAPs). ACB participates in the Global Biodiversity Information Facility (GBIF) to provide the AMS with the capacity and option to share biodiversity data and apply them in advancing biodiversity conservation in the ASEAN region. Workshops and training courses are organized by ACB on the development and accumulation of interoperable databases on species, protected areas, and invasive alien species so as to promote the organized curation of national biodiversity observations. ACB has consistently participated in APBON since its inception in 2009 and has shared their experiences in capacity building and data sharing in APBON meetings and conferences.

Through the ASEAN-CHM, ACB provides access to various biodiversity-related information and encourages data sharing for the purposes of biodiversity conservation, decision-making, and policy development. The ASEAN Biodiversity Outlook (ASEAN Centre for Biodiversity, 2017), which is a periodic regional overview and the status of biodiversity in the ASEAN region, was published in collaboration with the ASEAN countries by using information derived from the national reports to the CBD and the data shared online.

3.3 | China

Biodiversity observations and data management efforts have been made in China, including Chinese Biodiversity

Observation Network (Sino-BON; founded by the Chinese Academy of Sciences) and China BON (sponsored by Ministry of Ecology and Environment of China).

Sino-BON was founded in 2014 by the Chinese Academy of Sciences and plays a leading role in biodiversity monitoring and research in China and beyond (Feng et al., 2019). Sino-BON covers 30 main sites and 60 affiliated sites over China, and includes 10 thematic subnetworks for collecting data on wide range of taxa. Sino-BON also has a synthesis center for methods and criteria, data management, and near-surface remote sensing (Ma, 2015). The Chinese Forest Biodiversity Monitoring Network (CForBio), which was established in 2004, is an important part of Sino-BON and the global forest biodiversity monitoring network (ForestGEO, Table S1). It covers major forest vegetation types in different climatic zones, and 20 permanent plots to study forest dynamics had been established by the end of 2019. Considerable advances have been achieved in the development of research and monitoring infrastructure. Sino-BON was in fully operational in 2016. National biodiversity observation data sharing platform of Sino-BON was set up with 17 general fields and extended fields, such as family, genus, species (incl. author), common name, locality, data, and coordinates, etc., and 142 thousand records are available for inquiry (also see SI text 2.1 Box 1, Sino-BON).

In addition to the efforts by Sino-BON, China BON also plays an important role in the in situ monitoring of biodiversity, such as mammals, birds, amphibians, and butterflies. As the monitoring activity of China BON, 749 target regions (counties) were selected and for the implementation of monitoring with 11,000 line transects and point transects. Further details for China BON can be found on the website of GEO BON (2020). Other data collection efforts include the ABCDNet and Mapping Asian plants, which aim to collate data from the entire Asian region either in point form or as checklists. There is also a national digital herbaria available to share digitized images of the National plant herbaria. Furthermore, numerous transects have been set up that provide data on several climate and environmental gradients, and National level initiatives, such as a pollinator initiative, are also ongoing under the auspices of the Chinese Academy of Sciences.

3.4 | South Korea

KBON is a network of researchers, citizen scientists, and policymakers in Korea, which coordinates various research activities, monitoring networks, and databases on biodiversity and ecosystems through biodiversity observation activities. This initiative is supported by the National Institute of Biological Resources (NIBR) under the Ministry of Environment, Republic of Korea. KBON collaborates with APBON and the National BONs in AP region. In addition, KBON contributes to the GEO BON.

The activities of KBON include such as species monitoring collaborated with citizen scientists, modeling and prediction of potential habitats of species, research on species/genetic diversity, and the promotion of the sharing of biodiversity information in South Korea. KBON is expanding and strengthening the participation of the citizen scientists and students using the mobile and web platform, the Naturing (NATURING Inc., 2020). The Naturing is one of the platforms on biodiversity informatics in South Korea, which promote the sharing of data and information on species and the discussions among members. Furthermore, by linking the outcomes of the observations, KBON contributed to the policy and decision-making for the conservation of biodiversity in South Korea (e.g., Korea's National Biodiversity Strategies and Action Plans).

3.5 | Thailand

The development of long-term ecological research and biodiversity observation in Thailand was started since the establishment of the Kok Ma Watershed Research Station in 1965. Currently, four sites (Huai Kha Khaeng, Khao Chong, Doi Inthanon and Khao Yai) are associated with the Forest Global Earth Observatory (ForestGEO), previously known as Center for Tropical Forest Science and two sites (Kok Ma Watershed Research Station and Sakaerat Environmental Research Station) are related with International Long-Term Ecological Research Network (ILTER, Table S1). Kasetsart University and Chinese Academy of Sciences are now establishing a 25-ha plot in peninsular Thailand. Besides them, there are more than 20 sites (1–4 ha plots) scattered across the country. Monitoring biodiversity and ecosystems, in particular forest dynamic becomes common research topics for most research sites such as tree diversity, mortality, recruitment, and stand growth monitoring (Dhanmanond & Sahunalu, 1995; Sahunalu, 2009a, 2009b). In addition, ecohydrology in montane forests is the main focus at the Kok Ma (Chaithong, Soralump, Pungsuwan, & Komori, 2017). Recently land use change effects on species distribution, ecosystem services (Trisurat, 2010; Trisurat & Duengkae, 2011), and plant and wildlife functional traits are also focused (Asanok et al., 2013). Research results from long-term biodiversity studies contributes to national research and decision-making such as carbon sequestration of the IPCC national report, watershed management and land use planning (Office of Natural Resources and Environmental Policy and Planning, 2010, 2015).

4 | NETWORKING AND PARTNERS

Based on the core networks of national BONs, including JBON, KBON, Sino-BON, and China BON, we have strived to network of networks and develop our partners. The developed networks and partners were summarized in Figure 3.

During the last 10–20 years in AP region, it has successfully progressed in biodiversity and ecosystem monitoring through establishing research organizations/networking platforms including APBON (biodiversity monitoring, since 2009), ILTER-EAP (ecosystems monitoring, since 1995) and AsiaFlux (the atmosphere–land surface interaction monitoring, since 1999). While, the Earth observation community recognized the importance to monitor and incorporate the data and knowledge into the Earth system science from plot, landscape, nation, region and to globe (GCOS, 2016; Rogers et al., 2017; Tang et al., 2016). Considering the actual linkage with broad science and local communities and the fact that biodiversity is largely interacted with the biogeochemical systems, observations of biodiversity should be advanced by coupling with micrometeorology (radiation, temperature, soil water, etc.), phenology, standing biomass of vegetation and net primary production, and ecohydrology (e.g., Kim et al., 2018). The growing needs (scientific, business, political, etc.) of those data and knowledge from Earth system science, and our scientific interests on the impacts of climate change on ecosystems along climate and geographical gradients in AP region, expect us to coordinate the existing observation networks and cooperate with satellite remote sensing and Earth system modeling communities.

Promoting networking with the other observation networks will improve information sharing of global observations. As much of the biodiversity observations are conducted at research sites, metadata of research sites and their catalog could be obtained in initial engagement. ILTER launched site registration and meta database of formal LTER sites from its member networks in the world, called "ILTER DEIMS (Umweltbundesamt GmbH, 2020)", the Dynamic Ecological Information Management System—Site and dataset registry (DEIMS-SDR, Table S1), is the unique place where one can find information about sites and datasets of networks dealing with ecological long-term observation and experimentation globally. Cooperation with ILTER will not only advance our field research on the changes of biodiversity, ecosystem structure and functions, but also enable us to catalog the information of observation sites from LTER networks and BONs at national, regional and global levels. Registering APBON research plots to the LTER networks through cooperation with LTER networks in the region (ILTER-EAP, see Table S1) would foster mutual collaborations for research and data sharing for integrated understanding and prediction of biodiversity and ecosystems.

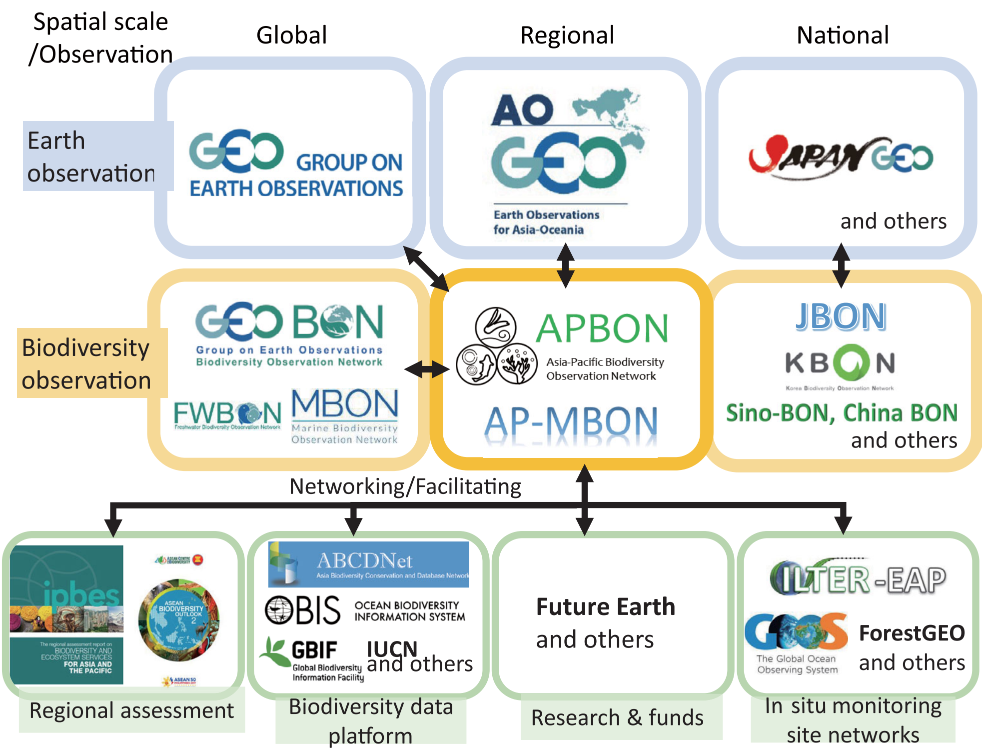

FIGURE 3 The core networks and partner organizations of APBON. There are wide-range organizations dedicated to the promotion of thematic or regional/global networks. We established close relations with these entities and shared the goals and worked together. The arrows indicate networking or facilitating between APBON and the groups or institutions. For further details on the acronyms, see Table S1 [Color figure can be viewed at wileyonlinelibrary.com]

APBON has also been engaged with global biodiversity networks, especially GEO BON. The secretariat of GEO BON was invited to APBON workshops during which we shared information on issues and progress and learned about the analytical process frameworks and tools for the evaluation of EBVs developed by GEO BON. We also participated in the GEO BON workshops that mostly focused on global-scale and thematic issues. Through these communications, APBON has been successfully developed our relationship with GEO BON. Furthermore, we have also been connected with the ecosystem and Earth observation communities to link local issues to global one and vice versa through the participation to GEOSS AP Symposium (which is now called as AOGEO Symposium), which is a regional initiative of the Group on Earth Observations (GEO, Table S1) in Asia and Oceania region. In the activities of AOGEO, APBON is cooperating with the other "task groups" of water cycle, carbon and greenhouse gas, ocean coast and marine, and food production (https://aogeo.net/en/) to address global agendas including SDGs. The Data Integration and Analysis System (DIAS, https://diasjp.net/) has been developed in Japan for regional application, and APBON is planning to contribute to this platform. GEO is developing a data and information system, GEOSS Portal (Table S1) to promote contribution of observation data or metadata from institutes conducting Earth observations for various areas by satellite, airborne, shipborne, and in situ systems. Connecting data and information systems of biodiversity observation to DIAS and GEOSS Portal is expected since in situ science of biodiversity and ecosystem services provides timely and invaluable information needed for sound decision-making at local, national, regional and global levels for sustainability of biodiversity and ecosystems under climate and societal changes.

Practical collaborations by these networking activities have been discussed, for example, sharing (a) research sites, (b) data observed by field survey and sensors and (c) integrated analysis to generate knowledge. In addition, (d) designing harmonized methodologies (e.g., EBVs) of observations is also a key to enhance the regional and global observations. To further develop these networking and collaborations, APBON's activities such as research projects, annual workshops, participation to AOGEO Symposium and GEO BON's meetings have to be continued.

4.1 | Networking of in situ biodiversity/ecosystem monitoring networks

4.1.1 | Terrestrial networks

Our core partners/networks include ILTER and ForestGEO, which are forest and terrestrial ecosystems and biodiversity monitoring organization at the research fields. The participants from those organizations to the past APBON workshops were fruitful to share the knowledge and discuss about current monitoring issues.

Furthermore, the in situ/satellite integration working group of JBON initiated a concept to link in situ and satellite observations from ecological viewpoints at the beginning of APBON (Muraoka et al., 2012; Yamano, Muraoka, Ishii, Suzuki, & Nasahara, 2014). Based on the "Satellite Ecology" concept (Muraoka & Koizumi, 2009), the working group paid efforts for monitoring phenology of terrestrial plant species and vegetation have been developed by combining traditional technique of plant ecology and automated monitoring systems including digital cameras by "Phenological Eyes Network (PEN)" (Nasahara & Nagai, 2015). Long-term historical phenological images in various ecosystems in Asia (Nagai et al., 2018) allows to evaluating the ecosystem structure and functions along the environmental gradient (e.g., latitude, annual mean air temperature). In addition, the integrated analysis of in situ and satellite observations made upscale evaluation of forest degradation in SE Asia (Nagai et al., 2014) and growing season in Japan and Northern Asia (Nagai, Saitoh, Nasahara, & Suzuki, 2015). Cooperation with LTER networks in the region also provides research opportunities on the consequences between biodiversity and ecosystem functions under spatial and temporal changes in climate and societal pressure on the nature (Kim et al., 2018). Carbon and nitrogen cycle, and phenology, are essential elements to bridge our further understandings on the ecosystems and their possible influence to societal benefits through ecosystem services.

4.1.2 | Freshwater networks

Freshwater fish monitoring in SE Asia has been based on in situ field activities conducted by Nagao Natural Environmental Foundation Japan (NEF). NEF collaborating with universities and research institutes of Thailand, Lao PDR, Cambodia and Vietnam, in which massive freshwater fish diversity of lower Mekong and Chao Phraya Basins was elucidated (Kano et al., 2013). In situ monitoring of SE Asia seems increasingly important as the hydropower dams, especially those constructed on Mekong mainstream, would significantly impact on biodiversity of fish and any other freshwater organisms (Kano, Musikasinthorn, et al., 2016). Broader and firmer networking is fundamental for monitoring their changes and impacts of future climate and society.

4.1.3 | Marine networks

There are multiple past and ongoing monitoring programs for marine biodiversity. The largest one was the

Census of Marine Life (CoML) program, which was conducted in 2000–2010 across various types of marine ecosystems, including the near shore areas of Asia and the Pacific, where there was a project conducted called Natural Geography in Shore Areas (NaGISA, Rigby, Iken, & Shirayama, 2007, Table S1). Current, ongoing monitoring programs include coastal and coral reef monitoring programs by Monitoring Sites 1,000, in which Japanese members of APBON are involved in both in situ observation and data management. Other monitoring programs include the Reef Life Survey (Edgar et al., 2017), Reef Check (Chelliah, Chen, Amri, Adzis, & Hyde, 2015), Seagrass Watch (McKenzie, Long, Coles, & Roder, 2000), SeagrassNet (Short et al., 2006), and other regional networks (Yaakub, Lean, Ooi, Buapet, & Unsworth, 2018), which have some monitoring sites in the coral triangle area. Some of these activities are now associated with the Marine Biodiversity Observation Network (MBON), which is one of the thematic programs of GEO BON.

Considering the current situation of many programs already running in AP marine regions, the marine activities of APBON should primarily focus on networking these programs to maximize complementarity. To achieve this objective efficiently and effectively, the marine group of APBON has established the Asia-Pacific MBON (AP-MBON, Table S1), which links the activities and communications of scientists participating in APBON and MBON. Among various missions of AP-MBON (discussed later), this program will facilitate the cataloging and linking of existing programs and research networks on marine biodiversity, and it will review and analyze existing, relevant datasets.

5 | NEW STRATEGIC PLANS: TO 2030 AND BEYOND

5.1 | Vision

The societal demands for the Earth observation have been increasing because of emerging environmental issues such as climate change and species extinction in both global and local scale. Our ecosystem and biodiversity monitoring activities as "Earth observation" and subsequent scientific analyses provide an essential data to understand the status, trends and projection of the future earth system including under climate and societal change. Through the high-quality observation of biodiversity change, APBON will strive to provide scientific evidence to develop sound assessments and facilitate policy-making.

For this purpose, besides our fundamental visions and missions (Yahara et al., 2014), we focus on promoting interdisciplinary research and problem-solving approaches with filling the knowledge gaps, which we have described previously, as summarized in Figure 4. We also recognized that the regional networks, such as APBON, play an essential role in taking an initiative to gather, explore, and

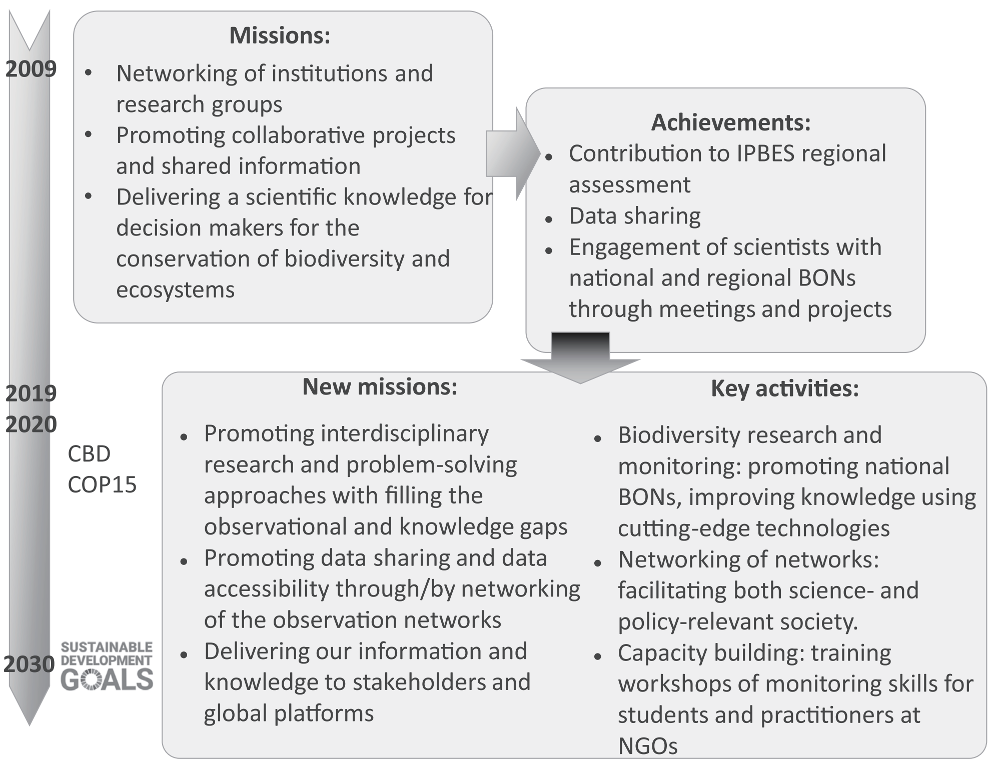

FIGURE 4 Summary of our missions and achievements in the first decade of APBON (2009–2019) and our new missions in the second decade beyond 2019. The 15th meeting of the Conference of the Parties (COP15) to the Convention on Biological Diversity (CBD) which will be held in 2021 and the UN Sustainable Development Goals to 2030 (SDGs) are benchmarks for our activity. For further details on the acronyms, see Table S1

prioritize local issues and practices and link these over regions, scientific communities and stakeholders. We cherish the bottom-up approaches and/or landscape-level approaches, which our members have used, as it matches with the scale of the biodiversity-issues and the goal setting to maximize the benefits to local people, regional ecosystems and biodiversity. It also offers more opportunities to work with scientists and local stakeholders and facilitate problem-solving corporation using the available knowledge. Another target is to promote data sharing and data accessibility through and by strengthening the networking of the observation networks in local to AP regional scale and deliver our information and knowledge to global platforms such as CBD, GEO BON, and global data platforms GBIF and OBIS. Thus, APBON plays a role as a "hub" to link the local, national, regional, and global needs of biodiversity observations, customizing observation designs (e.g., EBVs) and tools, and matching science-policy interface.

5.2 | Needs

Now, based on our achievements since 2009, we need to respond to the following new needs to the biodiversity observations. First, CBD Strategic Plan 2011–2020, including the Aichi Biodiversity Targets, will end the year, 2020, and a new strategic plan has just started discussing and will be determined in the forthcoming CBD COP15. This would be a good opportunity for us to participate in the CBD process and propose how we can contribute to conservation and sustainable use of biodiversity. In particular, we contributed the Beijing 2018 call on biodiversity for post-2020 decision-making (GEO BON, 2018) that states "we propose that the post-2020 targets explicitly include the development of sustained operational national biodiversity observation networks." We will make further efforts for developing national biodiversity observation networks in each member country and networking them in the AP region. Second, since 2012, regional and global assessments of IPBES have been made and many gaps of our knowledge for biodiversity status and trends have been identified (IPBES, 2018b, 2019b). Bridging those gaps by developing more extensive and integrated biodiversity observations are urgently needed. Third, GEO (2015) approved "GEO Strategic Plan 2016–2025: Implementing GEOSS," which defined eight Societal Benefit Areas (SBAs) including Biodiversity and Ecosystem Sustainability. Subsequently, "Biodiversity and Ecosystem Sustainability" SBA is selected as one of GEO Flagships and GEO BON is allowed to develop and implement near-operational services according to GEO priorities. In this context, APBON contributes to the production of data and knowledge so as to address the issues by promoting local, national, and regional activities. Fourth, in 2015, UN countries adopted the 2030 Agenda for Sustainable Development and its 17 SDGs that include two biodiversity-related goals, Goal 14: conserve and sustainably use the oceans, seas and marine resources, and Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss (UN, 2015). Future Earth, launched in 2013 by integrating three environmental change research programs including DIVERSITAS (Table S1) (Future Earth, 2013; Leemans, 2016). Fourth is playing a leading role in developing science supporting the achievement of SDGs. We need to contribute to the achievements of SDGs by providing adequate and defensible biodiversity data that help developing policy for conservation and sustainable use of biodiversity. Table S2 displays the mapping analysis of APBON's potential contributions to the GEO's engagement priory areas, namely SDGs, Paris Climate Agreement, and Sendai Framework of Disaster Risk Reduction, as a product at 12th AOGEO Symposium held in November 2019. The mapping outcomes provide an overview of how the biodiversity and ecosystem form the basis of our environment and natural resources and how these link to global agendas. In other words, our data and knowledge can contribute to broad items in global targets, which will be expected from global societies.

5.3 | Strategy

We have discussed on our future key activities in the past meetings. Here, we summarize the items into three sections: (a) biodiversity research and monitoring, (b) networking of networks and (c) capacity building. All the sections connect each other, and it would be leveraged effectively to launch the interdisciplinary projects and raise funds. We have restructured APBON management organization in 2019 (SI text 3), which aimed at more efficient management of APBON activities. We set three thematic working groups: Terrestrial, Freshwater and Marine.

5.3.1 | Biodiversity research and monitoring

(1) Monitoring states and changes of biodiversity.

The biodiversity loss in AP region is mainly driven by land use change, natural disasters, climate change, pollution, overexploitation of natural resources, and invasive alien species (IPBES, 2018a). Coupling those direct divers with related indirect drivers, we will continue to promote in situ monitoring biodiversity using our existing research sites (Figure 2) and/or expanding the sites and report the status and trends timely. We also make contributions for societal demand on biodiversity research. The more detailed research plan is summarized in SI text 2. Here, we describe the highlights of current and future activities in each working group according to the respective ecosystem.

Terrestrial: Monitoring efforts should address not only biodiversity and land-use change, but also people's perceptions, actions, and socioeconomic circumstances, as these are all intertwined. Socioeconomic development affects land-use change and also influences people's perception of their surrounding environment. Changes in perception and livelihoods can also result in changes in land use and utilization of ecosystem services (Takeuchi, Kobayashi, & Diway, 2020; Takeuchi, Soda, Samejima, & Diway, 2020). These societal changes as well as biodiversity change should be investigated at the same time to consider the best option for substantial landscape for biodiversity conservation. We also need to monitor the restoration of ecosystems because abandonment of deforestation area or agricultural land become increased in near future. As is the case of Japan, the abandon of traditional agricultural field (e.g., Satoyama) sometimes erodes biodiversity. This also requires a standardized reporting structure and method to ensure data is accessible and comparable both within and between sites and regions.

Long-term monitoring and reliable species identification are essential to detect the impacts of land use conversion and climate change on biodiversity and ecosystems. Maintaining monitoring sites is another challenging issue for the continuous observations and assessments in both monitoring developed areas and gap areas although solution could be different. For monitoring developed areas, it would be essential to enhance the utilization of the sites by not only scientific communities but also social communities; for example, some sites have tried to open the sites to public by sharing the data, opening infrastructure, and giving a lecture for environmental education to students and local people. The social use and demands would add the value of the monitoring sites, and as well as provide the fostering future generation to participate the monitoring. For gap areas, it might be firstly needed to fill the human-resource gap by increasing the understanding and awareness of biodiversity monitoring. In fact, some of our plots in SE Asia (e.g., Cambodia sites in Figure 2) have already been vanished because of the lack of understanding of monitoring. To fill the gap, capacity building for local counterparts is essential as few biodiversity-related scientists in the area (see also "Capacity building" below).

Freshwater:The freshwater environment is drastically changing. We recognize that observation strategies for the freshwater domain need to consider the complicated characteristics and dynamics of hydrological, chemical, ecological and societal systems. To monitor freshwater biodiversity and effectively detect major drivers, we classify the major drivers based on scale: large-scale drivers, such as habitat loss, oil palm plantations, and hydropower dams; and small-scale drivers, such as water pollution and invasive species. Large-scale drivers, especially hydropower dams (Kano, Dudgeon, et al., 2016) and plantations of oil palm and acacia (Kano et al., 2020; Kano et al., 2020) can have significant effects on freshwater biodiversity, and we should continue to monitor how these drivers are expanding in SE Asia and the associated effects on freshwater biodiversity. Moreover, climate change is a growing threat to freshwater biodiversity, although it is difficult to forecast concrete impacts. For example, we are planning to monitor the impact of the dams at Ubon Ratchathani, Thailand, and Stung Treng, Cambodia, the hotspots of the Lower Mekong River (SI text 2.2). These large-scale drivers would be able to be monitored remotely by satellite images and atmospheric data. In contrast, the effects of smaller scale drivers, such as water pollution, invasive alien species (Kano, Musikasinthorn, et al., 2016), and local habitat destruction, can only really be comprehended and monitored using field surveys (for example, Inle Lake and Upper Baleh River) (SI text 2.2). As the freshwater fishes are main food source in inland SE Asia: degradation of freshwater ecosystem services would bring the change of the life style of local peoples. Monitoring local markets would be a good way to know such a life style shift.

Marine: Collaborative efforts, that is, networking and integrating various activities, are key to the further development of marine biodiversity monitoring and analysis. In the region where AP-MBON focuses on, there are several ongoing and past research programs that are conducting long-term, broad-scale monitoring of marine biodiversity. Most of the research programs are targeting nearshore, conspicuous habitats such as coral reefs, mangrove, and seagrass beds. In the case of Marine BON (MBON, Table S1) in US, there is an activity to observe pole to pole transect so as to monitor the ecosystems in biogeographical scale. Networking and comparison of existing or past activities should be the first needs in our region. While, communication of scientists studying different marine taxa and ecosystems has still poorly developed, which precludes estimation and evaluation of marine biodiversity status across the entire marine ranges of AP region. Establishment of the network of networks led by AP-MBON should enable comprehensive analyses of temporal and spatial variation in marine biodiversity in our region by reviewing existing datasets in this area and by conducting up-to-date statistical analyses of their changes. Changes of past marine biodiversity should be readily evaluated in this region where marine ecosystem are rapidly changing with economic developments and global climate changes.

Conducting up-to-date statistical analyses of their changes from the past in marine biodiversity should be readily evaluated in this region where marine ecosystem is rapidly changing with economic developments and global climate changes. Moreover, AP-MBON intends to promote following research and outreaching activities such as; (a) Continuing monitoring of marine biodiversity in the AP region (including citizen science programs) in a globally-coordinated programs such as Reef Life Survey (Edgar et al., 2017), Reef Check (Chelliah et al., 2015), Seagrass Watch (McKenzie et al., 2000) and Global Ocean Observing System (GOOS), (b) Analyzing broad-scale, long-term changes in marine biodiversity in AP Region using global databases such as OBIS and GBIF; (c) Supporting design and adaptive governance of marine protected areas based on scientific data on marine biodiversity (Yamakita et al., 2015; Yamakita et al., 2017); (d) Analyzing values of ecosystem services, its trends, and its linkage to human society by social-ecological studies (Nakaoka et al., 2018); (e) Developing and apply cross cutting-edge technologies to marine biodiversity research such as meta-barcoding/environmental DNA (eDNA) (Miya et al., 2015), and remote sensing/GIS/Deep learning technologies (Yamakita, 2019; Yamakita, Sodeyama, Whanpetch, Watanabe, & Nakaoka, 2019); (f) Outreach of scientific outputs to various types of stakeholders of marine biodiversity and developing sustainable management plans via codesign, coproduction and codelivery (Yamakita, 2019; Yamakita et al., 2019).

(2) Filling gaps in data availability.

In AP region, data availability varies among taxa, time, space and levels of biodiversity partly because some countries lack human, institutional and financial resources to conduct the biodiversity observation (IPBES, 2018a). We will identify gap areas and cause of the gaps and fulfill the biodiversity research/monitoring activities through inviting focal people in those counties to our workshops and/or capacity building activities. Utilizing existing data and knowledge should provide us with an opportunity to estimate the states and trends of biodiversity with the current efforts and then to identify the observational designs and plans to be developed further in a targeted area.

Terrestrial: We have classified gaps into three categories; first one is the spatial gap, that is, observations in some geographical areas are not assessed nor networked. Plant diversity has been assessed throughout SE Asia (10 countries, 85 points, Figure 2). The main result of the project was identifying the biodiversity hotspot and recording many new species in the region. This project compensated the spatial gaps of plant species in the region, also provide picture guides of plants in local languages (Center for Asian Conservation Ecology Kyushu University, 2017). Linking with operational satellite remote sensing on forest biomass and land-use change should help fill the gaps of data and mechanistic understanding in broad-scale findings by satellites. Second is the temporal gap, which indicates many observations were made only at once. The long-term ecological plots play an important role in filling these gaps, and we have been networking with ILTER-EAP and ForestGEO. Applying mathematical and/or statistical models, maybe coupling with machine learning, is also useful to fill missing observations and past/future prediction. We will also approach and encourage participation of local scientists who are not networked to fill the spatial gaps. Third is the gap between natural and social sciences. As growing societal demand to solve the global/local environmental problems, sociological aspect of biodiversity issues is necessarily to find the strategic plans. This is not the direct gap of data availability; however, filling the data gap would also fill the science-policy gap eventually and could contribute sound decision-making.

Freshwater: Freshwater fish biodiversity information and data is inconsistent across the region; the basic information on species occurrence and taxonomists are relatively scarce in other countries where “ffish-asia” (Table 1) does not cover, for example, Myanmar and Papua New Guinea. Information on freshwater organisms other than fish, such as mollusks, crustacean, water plants seems to be still quite poorly documented in other countries of SE Asia. Capacity building of research on these organisms is necessary. Expanding the expert networks of AP region would be a key activity to fill the gap area and publish data at the database.

Marine: As in terrestrial ecosystems, large spatial and temporal gaps still remain in marine biodiversity data even for key/important species such as coral reefs, mangrove and seagrasses. Even though GIS-based maps are available for these species for example, by UNEP-WCMC, the data obtained in the past are not accurate in our region compared to those in developed regions like North America and Europe. Filling information gaps and updating old literature data are urgently needed. One proposed approach is to extract distribution of ecosystems from literatures including gray literature published in local languages (Fortes et al., 2018). We can also add/update spatial data on distribution of marine ecosystems and their status using recent technologies such as deep learning on remote sensing images. Extending the target areas for such activities is encouraged but obtaining research funds is a challenge. By this way, we would advance to evaluate status of marine ecosystems in any target areas of AP region.

(3) Increasing access to data.

Data accessibility is needed to serve societal needs timely and to promote to use for biodiversity analysis in a large-scale; the "accessible" open data also offers scientists with more opportunities to conduct meta-analysis on the global (Culina, Crowther, Ramakers, Gienapp, & Visser, 2018) and regional scales (Suzuki, Ishihara, & Hidaka, 2015). We will strengthen the partnership with the global biodiversity data base such as GBIF, OBIS and ABCDNet and also promote the members to publish data papers in scientific journals. Web-based platforms established in response to emerging need to adapt to climate change (Ministry of the Environment Government of Japan, 2020) could also be potential collaborators.

In order to optimize the use of observation information generated by the APBON, it was proposed recently to include visualization of information to advise decision-making and policy development in biodiversity conservation, and enhance visibility of this network to donor organization and development partners. The policy-relevant indicators such as EBVs, and Essential Ocean Variables (EOVs) would be used to evaluate the effectiveness of conservation policy (Navarro et al., 2017).

Terrestrial: Practically, the open data through GBIF, ABCDNet, and data papers (Table 1, Shin et al., 2020) have been promoted among APBON members. We recognize that data digitization and publication has been progressed as we have promoted in our past activities. We will continue to promote enhancing accessibility to the data, intending to be utilized by various disciplinary scientists as well as by nonexperts. To do so, the capacity building for handling these data will be necessarily. For training nonexperts, it would be effective to publish local picture guides with local language.

Freshwater: The open data through GBIF and data papers (Kano, Musikasinthorn, et al., 2016) has been promoted the members, as well as local database (Kano et al., 2013). However, these achievements are limited and considerable amount of data are likely buried in the local researchers' computers. The skills and motivation to publish data papers, as well as usage of open data, are still poor among the local researchers. Practical coursework for writing data papers would be necessary for the development of human resources. To promote the data sharing through public database or data papers annual APBON workshop is crucial as it also provides opportunities for capacity building as well as sharing open data principles.

Marine: Legacy data of the previous activities such as NaGISA have already been provided as the presence data of the species through OBIS. Furthermore, we contributed more than 49,000 data extracted from literatures (Yamakita et al., 2017). Digging data in local reports and updating new quantitative data on any aspects of marine biodiversity are encouraged as the next step, and collecting information from Japanese literature is in progress (Arita, Suzuki, Yamano, Yabe, & Kumagai, 2020; Kitano et al., 2020; Kumagai, Yamano, Fujii, & Yamanaka, 2016)). APBON includes members who are responsible members are responsible to the management of local OBIS node (such as BISMaL). Increasing communication between data managers and individual marine researchers should strongly been promoted to reach the accessibility to marine data not only for scientific research but also for capacity building which will facilitate more input to the databases.

We also expect to use the database for researches related to marine policies. This will enhance the awareness of the database to the public and stakeholders, which in turn enhances motivation to obtain, increase, and curate further data in the database. The databases will also be used to assess and evaluate multiple values and ecosystem services produced by marine biodiversity, such as fishery products, carbon storage, coastal protection and marine tourism related uses. For this purpose, wider array of data should be compiled to open-access databases, such as those data on compiled open-access databases, those data on social interviews and web questionnaire as examples.

(4) Improving knowledge on cutting-edge technologies.

Recent development of technologies such as drones, eDNA, remote sensing with powerful sensors and artificial intelligent enables us to monitor biodiversity and ecosystems in cost-effective and technical feasible manner. The 3D modeling and CT scanned data would also contribute to the development of morphology and taxonomy (see recent data in "ffish-asia"; Kano et al., 2013, Table 1). Image recognition and analysis is also essential for biodiversity monitoring by deep/machine learning (e.g., satellite map, Samasse, Hanan, Anchang, & Diallo, 2020; seagrass, Yamakita, 2019). In addition, data representation techniques such as online dashboard are also expected for more efficient use of the data. APBON will positively introduce and share cutting-edge technologies for efficient monitoring actives, and also discuss the methodology to solve our issues using those technologies.

Terrestrial: The difficulties in terrestrial biodiversity monitoring includes identification of species, large-scale monitoring, maintenance of the monitoring activities. The cutting-edge technologies would solve those problems; DNA-barcoding, eDNA and image recognition technology coping with UAVs would provide more effective tools to monitor species diversity in larger scale. Intensive linkage with satellite remote sensing such as synthetic aperture radar mounted on Advanced Land Observing Satellite (ALOS-2) and optical sensor mounted on Global Change Observation Mission—Climate (GCOM-C) satellites of Japan Aerospace Exploration Agency (JAXA) can enable upscaling of the site-level data on the ecosystem productivity or biomass to landscape, national and regional scales. In addition, mapping of the location and size of every tree will be feasible by combining satellite sensed data with a high spatial resolution and machine-learning (Hanan & Anchang, 2020). We will continue to make good progress in capacity building by providing training courses on those recent techniques.

Freshwater: Compared to terrestrial forest biodiversity, which biodiversity is apparent by visual observation, it is rather difficult to comprehend freshwater biodiversity properly. However, eDNA (e.g., Eva et al., 2016) can be a breakthrough method for freshwater biodiversity monitoring. The underwater drone may be also a powerful hardware for the monitoring (e.g., Meng, Hirayama, & Oyanagi, 2018).

Marine: Substantial progress has been made in the use of remote sensing techniques to monitor changes in key marine habitats, such as coral reefs, mangroves and seagrass beds. New technologies include both new sensors on satellites, which can cover broad-extents, and UAVs, which can cover smaller extents, but at very fine resolutions. Technologies to identify marine biodiversity from remote sensing technology have also been advancing. Currently, many studies are attempting to use deep-learning or other machine learning to classify key marine habitats (Yamakita et al., 2019). In addition to spatial study using various remote sensing techniques, high-resolution time-series data are now also available in the form of long-term recordings of acoustic data, such as for whales, and in the form of time-lapse camera images. However, synthetic summaries of these different technologies have not yet been made and are necessary to enable the selection and application of these new tools for the different purposes that are required by researchers and policymakers in the AP region. The AP-MBON should take leadership to link these new technologies to the objectives and needs of individual researchers and for capacity building.

As in terrestrial and freshwater ecosystems, eDNA can be a powerful tool to use for monitoring marine biodiversity for a variety of targets and purposes (e.g., Yamamoto et al., 2017). Some challenges still exist in applying this new technology to marine studies in the SE Asian and the Pacific regions. One is to create a DNA library for local marine species, some of which have not yet been identified to the species level by taxonomic studies. Another issue is the regulation of research in each county. Access and benefit-sharing (ABS) protocols for biological resources, including genetic resources, need to be established to enable collaborative research among bilateral and multilateral collaborations with appropriate compliance. In addition, there are not many existing domain knowledge, application, and marine survey techniques available for use in such collaborations. These need to be developed.

5.3.2 | Networking of networks

APBON has played a role as a networking platform and a facilitator among both science- and policy-relevant society. As increasing of social demand for the earth observation, we will continue to work to strengthen networks for observations and developing knowledge and ready-to-use information. Here, we summarize the challenges of high priority in networking of networks. In every APBON workshop, we set the agenda depending on the host country/area to reflect their needs, the outcomes of previous workshops, and AOGEO tasks to be addressed. We also invite guests that could contribute to both biodiversity and social science. Such networking outside of APBON also contributes to fresh collaborations with different areas and the identification of societal and scientific needs to fill existing gaps.

(1) Promotion of developing regional or national observation networks in biodiversity information gap areas.

The establishment of APBON and its role as a platform of collaborative research, data sharing, and capacity building has initiated some national BONs in our region through the sharing of vision and transferring of observational designs and know-how, as well as networking among biodiversity scientists. Thus APBON has been promoting a national level monitoring network, and has successfully networked with JBON, KBON, Sino-BON, China BON and other relevant biodiversity observational institution (see the section "Biodiversity observations in the national level"). With these experiences, APBON can support some critical know-how on the national BON design and implementation processes and monitoring tools, especially for some countries in the AP region, which are still under the challenge of building biodiversity monitoring initiatives. Initiating monitoring networks in national level would be one of the solutions to fill the geographical biodiversity observation information. Thus, we strive to network the existing national level observation networks with stakeholders of gap countries through collaborative research and APBON meetings. Those national level platforms play essential roles as domestic research hubs and data accumulation hubs. Those also support for national assessment and sound policy-making and implementation of National Biodiversity Strategies and Action Plans.

(2) Fostering interdisciplinary observations.

The growing complexity of the ecosystem structure and functions under climate and land use changes requires interdisciplinary understandings on the processes and entire system, and accurate estimates of the changing functions. Revealing the current status and predicting the future conditions of terrestrial, freshwater, coastal and marine ecosystems and their functions and services are of urgent issues that scientific communities need to tackle.

To foster interdisciplinary observations, assessment and prediction on biodiversity and ecosystem functions in changing environments and societies, collaborations of existing research networks from different thematic and technological domains are crucial (Muraoka et al., 2012). To facilitate the coordination toward concerted in situ observation networks, a new project should be initiated to (a) observe and review the findings from each plot, network and contributing research group by mapping the information by focusing on key aspects of ecosystem structure and functions such as phenology and carbon cycle; (b) catalog these findings by referring to EBVs, EOVs and Essential Climate Variables from biological perspective by considering the ecosystem integrity of the components (Haase et al., 2018); (c) analyze observation gaps in thematic and geographical means and (d) design ideal and cost-effective observation system for operational and long-term monitoring in the region. Multidisciplinary observation platforms would realize the plan of long-term and collaborative observations and analysis (Mirtl et al., 2018; Muraoka, Saitoh, & Nagai, 2015).

In next step, APBON will reach out to the academia and think-tank organizations such as East Asian Federation of Ecological Societies, related academic societies in each country, the Association for Tropical Biology and Conservation (ATBC) Asian chapter, and International Association for Ecology (INTECOL, Table S1) to further develop the observation activities and to expand the utilization of data and knowledge in the AP region for cooperative actions toward sustainability of biodiversity and ecosystems.

(3) Science-policy and science-society networks.

As we described in the section "Data sharing" above, scientific data and knowledge are essential for evidence-based decision-making and, in fact, it has been used in various-scale assessments. While, through the process of these assessments, we recognize that the available scientific evidences, especially on observed and future trend in nature-society interaction, are still scares. Some national reports of CBD described data deficiency to evaluate, and this would be partly because of poor data accessibility and/or poor data delivery to the reporters. It is therefore an urgent need to fulfill the existing observation gaps as well as to develop observation-knowledge production-information chain by fostering network not only between biodiversity research communities but also between various scientific communities focusing on our environment as well as stakeholders including decision-making processes. APBON recognizes such importance and we are working or planning to engage global observation networks and policy-relevant platforms.

Thus, we will also promote to utilize the research outcomes for policy-making through addressing the indicators of status and changes in biodiversity and its services, and also by developing the visualization tools as below. As our users would be various kinds of stakeholders globally and locally (SI text 4), to increase the accessibility of research outcome for the users, we will enhance developing user-friendly systems and tools which meet the society demands (SI text 5). Outreach activities and social communication also become more important for increasing social awareness and understanding of biodiversity and ecosystems, and for planning actionable plans for sound decision-making with the environmental issues related to biodiversity including sustainable use of resources (water, carbon, etc.).

5.3.3 | Capacity building

Capacity building and development are key to describe the state and changes of biodiversity in our region consist of dynamic climate and geographical environments, various societies and cultures, economic growth, and type of ecosystems. Rapid development of technologies is also an opportunity for biodiversity observation and assessment in the changing environment. Among the numerous skills, the cores are collecting specimen, survey skill in the field, GIS to integrate the data, camera traps for plants, birds and other animals. APBON should work as the capacity development platform in the region, as well as to deliver the lessons learned and know-how to the other regions which have observational gaps by setting opportunities in the APBON workshops and collaborating with our partners such as ESABII, ACB, and ForestGEO (Figure 3).

SE Asia has been paid less attention by researchers from the West, and many schemes aimed at building regional capacity lure capable students to the West where in many cases they stay after graduation; leading to a brain drain of some of the brightest young minds in the region. As one of the reasons of knowledge gaps owes to limitation of skill in biodiversity monitoring, data handling, writing papers, and so forth. Capacity building would play an important role in fulfilling the gaps. APBON will continue to make an effort to fulfilling the gaps, working with APBON members, the members of regional ecological societies, and various universities that manage diverse training workshops (see SI text 6). For example, East and SE Asia Biodiversity Information Initiative (ESABII, Table S1) was established to enhance taxonomical expertise of human resources for decision-making in conservation and sustainable use of biodiversity in 2009. ESABII has provided capacity-building workshops in taxonomy and contributed to the development of an information system on biodiversity so as to contribute to the promotion of biodiversity conservation. These activities successfully bridge the gap in regional capacity, which will also contribute to the achievement of the goal of CBD.

5.4 | APBON workshops

The APBON workshop aims to review and share the achievements of APBON participants' activities and to make work plans specific to regions and subjects through the concrete collaborations of the APBON members. Usually, we first discuss in each working group and then conclude all discussions by the whole group. We also strive to deliver capacity-building opportunities to learn cutting-edge biodiversity observation skills and regional-specific issues and policies. For example, at the 11th workshop in Kuala Lumpur, we conducted lectures on how genome-wide analysis technologies can be utilized for understanding genetic and/or species diversity and to learn Malaysia's national issues and policies on biodiversity and conservation (see the time frame and details cf. the time frame and the report of the workshop, Biodiversity Center of Japan, 2020b).

Achieving capacity building using APBON network is expected. Capacity building will be from citizen, government and researches. Communication with national agency is also encouraged. Considering this area helping to communication of local languages are also important. Not only translation of picture guides and methodological information but also use of easy understanding images such as pictures, info graphics and cartoons are also encouraged.

6 | CONCLUSION

6.1 | Priority for 2030

During the past 10 years since the establishment of APBON, critical knowledge on biodiversity includes such as (a) species-rich AP tropical region still hold many unknown species, which indicate we still underestimate the species diversity, (b) high developmental pressure changes biodiversity and ecosystems rapidly, while forest area has been increasing in some countries in SE Asia and (c) biodiversity contributes to human well-being in both local and regional scale; however, ecosystem services and "nature's contributions to people" are still under evaluated especially in gap areas. Thus, APBON needs to further develop the observations, assessment and prediction of the state and changes for understanding biodiversity and its benefit for making sound biodiversity conservation strategy. Furthermore, some countries, such as Philippines and Vietnam, showed this national-scale trend shift from a shrinking to an expanding stage of forest area. This would be due to some societal change, for example, increasing of GDP (forest transition hypothesis). Understanding the background mechanism of deforestation trends would be crucial for the conservation.

Many of our ongoing research projects and future plans (see the section of "Biodiversity research and monitoring" and SI text 2) employ a transdisciplinary approach, that is, stakeholder involvement to the project, which would answer the issues above partly. This approach would enable us to reveal the social mechanisms to impact the biodiversity and how biodiversity issues link or interact with other social and environmental issues. This coproduction process of scientists and stakeholders promotes mutual understanding and would be essential for achieving the project's goal. We would also expect the comprehensive understanding of biological and social consequences of biodiversity through the transdisciplinary projects.

APBON in its next decade needs to understand how a society in harmony with nature can be achieved under climate change and globalization. To do so, we will study not only biodiversity and ecosystem functions but how the ecosystems link to a local/global society by sociological aspects. Another emerging high-priority issue is biodiversity responses to the COVID-19 pandemic; our society has been affected by the pandemic in every way. As this situation also affects biodiversity, and conservation management, and related politics, we should monitor how the pandemic social circumstances, such as social lockdown and less human impact on nature, affect biodiversity. In addition, this pandemic also reminded us that biodiversity could bring a negative impact on our society on a global scale. AP region holds high-risk areas in emerging/existing zoonoses where are high biodiversity including vectors, high land-use change, and frequent contacts with human, wildlife and livestock (Jones et al., 2008). The region also holds various ways of use of biodiversity based on high cultural diversity. To figure out the sustainable and adequate use of biodiversity with preventing pandemics in AP region, we might need to assess the region-specific potential factors of pandemics as the direct and indirect drivers such as biodiversity use and global transportation varies among regions and countries.

IPBES (2019a) indicated that the indirect drivers, such as rapid human population growth, unsustainable production, and consumption and associated technological development, would have a negative impact on the biodiversity and ecosystem services in the future. To undermine the impact, key social interventions (sensu leverage points in IPBES, 2019a, 2019b) should be identified to prioritize the actions and practices for conservation. It would increase the importance of multidisciplinary and transdisciplinary studies to solve those issues especially incorporating with sociological and/or economic approach. These types of research and activities would also provide us with insights into the pathways of societal/environmental transformative change to manage biodiversity and ecosystem resources sustainably and a vision for a society in harmony with nature post COVID-19.

6.2 | Master site concept

To setup the multidisciplinary study, a "master site" or a "super site" plan has been discussed in APBON (Muraoka et al., 2012). The master site would be an in situ study site, where multidisciplinary activities are overlapping and some criteria such as accessibility, data accumulation and available facilities are satisfied. For example, simultaneous measurements of tree growth, phenology, carbon cycle (CO_2 exchange between the atmosphere and ecosystems) could be a key set of observations at forest master sites, and they may be scaled up with relevant satellite remote sensing. A model case can be seen at the "Takayama site," which is a forest research site located on a mountainous landscape in central Japan. Simultaneous measurements of the canopy phenology, photosynthesis, and spectral reflectance allow us to translate the information of ecological structure and functions to spectral information gained by in situ spectral radiometer and airborne remote sensing, followed by application to the satellite data for upscaling (Muraoka et al., 2012; Muraoka et al., 2015). We further review various monitoring activities in AP region to exploring potential for the site. As for marine ecosystems, CBD developed seven criteria for selecting EBSAs, including uniqueness and rarity, special importance for life-history stages of species, importance for threatened, endangered or declining species and/or habitats, vulnerability, fragility, sensitivity and slow recovery, biological productivity, biological diversity and naturalness (Clark et al., 2014; Yamakita et al., 2017). Those criteria are also useful for selecting a "master site" for monitoring of terrestrial biodiversity.

To collaborate with sociology, UNESCO Man and the Biosphere Reserves (MAB, Table S1), which emphasizes the importance of harmonizing nature and culture interaction, could also be a target to study. MAB sites consider well-being for local community more important, not only biodiversity and ecosystem conservation. It provides a link between biodiversity and SDGs and thus monitoring biodiversity under MAB is of particular importance for our network activity. This is a model system to achieve "a society in harmony with nature," which is one of the goals of CBD. By linking with those MAB site networks and biodiversity networks, we will understand diverse Asian traditional concepts of nature as well as societal roles of biodiversity and ecosystems, which will provide a hint for the new solution to global issues.

6.3 | Dialogue with policymakers in AP region

Conservation and sustainable use of biodiversity is not a national challenge but an agenda for all humanity. It is needed to be implemented by various frameworks such as bilateral or multilateral programs and initiatives, as well as biodiversity-related environmental global agreements such as Aichi Biodiversity Targets and SDGs. Furthermore, the transformative changes in the production and consumption of resources would be a key to achieve the conservation goals in biodiversity and ecosystem service (IPBES, 2019a). To meet these global societal goals and agendas, science-policy dialogue would be necessary to codesign the vision and strategies for the goals and targets based on the best available scientific knowledge. For its success, human resource developments for policymakers and experts or research and development are essential as well.

Regional cooperation plays an important role especially in AP region because of the habitation of migratory species and connectivity of habitat. Additionally, major biodiversity threats such as land use change and deforestation in tropical region are driven by global trade of crops and timber. Those are transboundary biodiversity issues; not only resource countries but consuming countries are involved. APBON aims to play a leading role in finding the solution through our activities by promoting international collaboration using transdisciplinary approach based on the comprehensive data and knowledge that cut across the scales through local, national, and regional observations. Such comprehensive knowledge could be generated from master sites plan and its application to other general observation plots in the countries and region would be delivered through science-policy dialogue. Building win-win relationships among all AP countries in biodiversity issues can be achieved only through mutual communication and dialogues. By using our networks, we will promote fruitful discussion and information sharing for conservation and sustainable use of biodiversity including all countries in AP region. Through the scientific knowledge-based and inclusive dialogue with policymakers of AP countries, APBON will keep implementing conservation and sustainable use of biodiversity in the entire AP region.

6.4 | Further networking and engagements

APBON welcomes scientists, institutions, data and knowledge users to cooperate for biodiversity and ecosystem sustainability. Interested readers of this APBON work plan 2020–2030 could contact with the corresponding authors of this article (Y. Takeuchi and H. Muraoka).

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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