China-U.S. Scientific Engagement: Strengthening Collaborations for Sustainability and Biodiversity: Proceedings of a Workshop—in Brief (2022)

DETAILS

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Proceedings of a Workshop—in Brief

CHINA-U.S. SCIENTIFIC ENGAGEMENT: STRENGTHENING COLLABORATIONS FOR SUSTAINABILITY AND BIODIVERSITY

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Scientists in China and in the United States have addressed key topics related to sustainability in both formal and informal collaborations for many years. To further this engagement, the U.S. National Academies of Sciences, Engineering, and Medicine and the Chinese Academy of Sciences (CAS) are convening a series of three workshops. Each workshop will examine the state of sustainability research and practices; identify priority areas for scientific collaboration on specific challenges; and discuss opportunities for advancing policy actions and the potential for new technology development and deployment in China and the United States. The first workshop focused on sustainability and biodiversity, as an important area of sustainability research and practices. The next workshops are planned for 2023.

The first workshop, summarized below, took place July 27 to July 29, 2022. Participants gathered at National Academies headquarters in Washington, DC, and at a conference room in Beijing, as well as virtually, to discuss (1) strategies for a Post-2020 Global Framework; (2) biodiversity and implications for food; (3) biodiversity and health; (4) biodiversity and climate change; and (5) urbanization and biodiversity. The final session included a summary of main points from the workshop discussions, and is described in the section on Path Forward: Future Needs and Opportunities.

WELCOME AND OVERVIEW

The workshop began with opening remarks from National Academy of Sciences (NAS) President **Marcia McNutt** and CAS President **Jianguo Hou**. Dr. McNutt noted the opportunities for and long history of interaction between scientists in the two countries. "There is a strong desire and urgent need to collaborate on sustainability issues," she said and "a growing body of evidence has sounded the alarm that the biodiversity that sustains life on Earth is at risk." She stressed that U.S.-Chinese scientific collaborations and leadership will be critical to advising policy action and highlighting the value of preserving biodiversity. Dr. Hou pointed out the 2030 Agenda for Sustainable Development provides a shared blueprint forward, but biodiversity loss, climate change, public health crises, and food security challenge human survival and development. "Faced with unprecedented challenges, the international scientific community needs to work together to foster a more sustainable future from a scientific perspective," he said. He concluded by drawing on a Chinese saying: When people pull together, nothing is too heavy to be lifted.

Workshop co-chairs **Karen Seto** (Yale University) and **Yongguan Zhu** (CAS) shared background about previous meetings leading to the workshop series, including a U.S. NAS delegation visit to China led by NAS President Marcia McNutt in 2018, and a Chinese Academy of Sciences delegation visit to the United States in 2019, that included a joint workshop on urban sustainability.[1] In early 2022, the National Academies established a Subcommittee on U.S.-China Scientific Engagement to explore the opportunities for joint work in areas of global importance. Sustainability was selected as a focus because of the sustainability research going on in many universities as well as that many U.S. universities have satellite campuses in China focused on sustainability issues. Dr. Seto underscored that a key goal is to identify and discuss opportunities for advancing policy action that can support the United Nations Sustainable Development Goals (SDGs). Dr. Zhu reminded the workshop participants that sustainability is a common goal for all on Earth, not just in China and the United States, and that actions by both countries can have widespread positive impacts. He expressed hope that the workshop series will be a useful platform to advance the science and develop solutions, as well as to forge friendships and collaborations among the next generation of scientists.

FRAMING REMARKS

Peter Raven (Missouri Botanic Garden) shared that he was born in China in 1936, returned as part of a scientific delegation in 1978, and has encouraged long-term collaboration with Chinese botanists since then. He underscored the role of science as a universal form of communication. "For the biodiversity sciences," he stressed, "it is necessary for Chinese and American scientists to collaborate." He pointed out that while the two countries are about the same size, China is home to a much greater diversity of plant, terrestrial vertebrate, and butterfly species—essentially all well-known groups. On a global scale, according to Botanic Gardens Conservation International (BGCI) ThreatSearch, conservation assessments are now available for one-quarter of all known plant species. Among them, more than 20 percent are threatened with extinction over the next few decades.[2] "Climate change, closely related to the surge in population numbers and agricultural intensification, will clearly be the major source of extinction for all kinds of organisms in the coming decades, and it remains to be seen whether we humans can overcome our national greed rapidly enough and effectively enough to mitigate these effects on a major scale," he stated.

For the biodiversity sciences generally, Dr. Raven suggested five areas of cooperation between Chinese and U.S. scientists: (1) survey relatively well-known groups of organisms as rapidly and efficiently as possible; (2) for less-known groups, cooperatively develop survey methods to estimate the numbers and character of the variation of species; (3) select individual sites for intensive study in both countries to study and compare organisms in detail; (4) support development of legal strategies for preserving individual places in each country, with the results closely monitored and improved; and (5) make every effort possible to slow down and eventually halt the effects of global warming.

Fuwen Wei (Institute of Zoology, CAS) discussed China's effort to build a shared future for life on Earth, given that global biodiversity is at an unprecedented decline, according to data from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).[3] Conservation biology and its subdisciplines can offer solutions for a scientific perspective, he suggested. From a management perspective, he called attention to the Chinese government's concept of ecological civilization. He explained, "Ecological civilization focuses on pursuing and maintaining the unity of nature and man on the basis of sustainable development." It builds on ancient Taoist wisdom that addresses the interdependence of nature and man, as articulated by President Xi Jinping in May 2018. Ecological civilization is highly compatible with the SDGs, he said.[4]

[1] National Academies of Sciences, Engineering, and Medicine. 2020. *Advancing Urban Sustainability in China and the United States: Proceedings of a Workshop.* Washington, DC: The National Academies Press. https://doi.org/10.17226/25794.

[2] For more information, see https://tools.bgci.org/threat_search.php.

[3] IPBES. 2019. The global assessment report on Biodiversity and Ecosystem Services. https://ipbes.net/sites/default/files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf.

[4] For more information of this framework, see Wei et al. 2021. Ecological civilization: China's effort to build a shared future for all life on Earth. *National Science Review* 8(7). https://doi.org/10.1093/nsr/nwaa279.

China's efforts include afforestation, with more than 16 national landscape programs since 1978, as well as many regional and local projects. Significant progress has been made in scientific research in the study of biodiversity, with hundreds of scientists and dozens of research institutes, as well as the sharing of data and images online.[5] Ecological Conservation Redline areas account for 25 percent of China's land area, and China has launched three plans to prevent and control air, water, and soil pollution. A comprehensive "Gross Economic-Ecological Production Accounting" framework is in place to evaluate local governments. Dr. Wei suggested key directions for the future. First, define the relationship between nature and man, so that environment, society, and economy are considered as one, not separate. Second, make transformative changes to depart from business-as-usual. Third, implement bold conservation efforts to bend the curve of biodiversity loss. Fourth, take into account biodiversity adaptation and resilience. He concluded, "Be patient, promising, and confident."

Discussion

Dr. Seto asked about prioritizing the location of protected areas in both countries and globally, given growing demands on land. Dr. Wei noted it is important to pay attention not just to the quantity but also the quality of a protected area. Dr. Yongguan Zhu commented on the conflict between conservation and livelihoods. Reflecting on Dr. Wei's remarks, a participant called for ecosystem restoration and transformative change as a "whole package," not just in protected areas. Another participant said he was inspired by ecological civilization's consideration of culture and values in its paradigm.

PANEL I: STRATEGIES FOR POST-2020 GLOBAL BIODIVERSITY FRAMEWORK

Jianguo "Jack" Liu (Michigan State University) and **Keping Ma** (Institute of Botany, CAS) moderated the first panel to discuss how to measure progress on biodiversity protection, given the upcoming United National Biodiversity Conference (COP-15) will convene governments from around the world to agree on a new set of goals and targets for nature over the next decade.

Stuart Pimm (Duke University) discussed "30 by 30," in which countries pledge to protect 30 percent of their area by 2030. The United States, United Kingdom, China, and other countries have accepted this approach as a reasonable goal, but Dr. Pimm said it is important to look into the details in implementation.[6] He noted species are dying at 50–500 extinctions per 1 million species per year, an unprecedented rate.

He highlighted three studies looking at the role of protected areas globally, in China, and in the United States.[7] Most of the world's protected areas are in "wild" places with the least human impact, he said, and the question is how much these areas will benefit biodiversity. He urged a focus on species distribution. "What is hugely important is to look at protected areas for species with small geographic ranges," he said. Only protecting wild areas will not greatly increase biodiversity protection, he said. In China, biodiversity protection began in the mid-1980s with National Nature Reserves, and the numbers, acreage, and types of ecosystems protected have increased. He noted protecting panda habitat has protected other endemic species. In the United States, he continued, a lot of land is protected privately, but it is important to ensure that the "right 30 percent," in terms of biodiversity of endemic species, is protected.

Dr. Ma, also serving as presenter, said conservation planning and assessment need more data for use in COP-15, as well as for the Subsidiary Body on Scientific, Technical, and Technological Advice (SBSTTA-24), Open-Ended Working Group on the Post-2020 Global Biodiversity Framework, and other efforts. Moreover,

[5] For more information, see articles within Special Topic: Ecological Civilization—Insights into Humans and Nature, including Raven, H. P. 2021. Biodiversity science in China. *National Science Review* 8(7). https://doi.org/10.1093/nsr/nwab097; Primack, R. B. 2021. Biodiversity science blossoms in China. *National Science Review* 8(7). https://doi.org/10.1093/nsr/nwab058; and Brooks, T. M., and X. Zhang. 2021. Applied biodiversity science in China in the global context. *National Science Review* 8(7). https://doi.org/10.1093/nsr/nwab059.

[6] See Pimm et al. 1995. The future of biodiversity. *Science* 269(5222):347-350. DOI: 10.1126/science.269.5222.347; and Pimm et al. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. *Science* 344. DOI: 10.1126/science.1246752.

[7] The studies referenced by Dr. Pimm: Pimm et al. 2018. How to protect half of Earth to ensure it protects sufficient biodiversity. *Science Advances* 4(8). DOI: 10.1126/sciadv.aat2616; Li, B.V., and S. L Pimm. 2020. How China expanded its protected areas to conserve biodiversity. *Current Biology* 30(22):R1334-R1340. https://doi.org/10.1016/j.cub.2020.09.025; and Jenkins et al. 2015. U.S. protected lands mispatch biodiversity priorities. *Proceedings of the National Academy of Sciences of the United States of America* 112(16):5081-5086. https://doi.org/10.1073/pnas.1418034112.

he said, each part of the Global Biodiversity Framework, including the indirect drivers, direct drivers, targets, and goals is important and requires scientific input.[8]

According to Dr. Ma, the goal is to bend the curve of biodiversity loss by decreasing the rate of loss in the next 8 to 10 years, and then increase biodiversity toward the 2050 vision. Data are needed to define and assess progress, as well as identify priority areas at a global scale.[9] Dr. Ma described an approach he and colleagues developed for regional scalable priorities for national biodiversity conservation planning in Asia. Analyzing data, mostly from IUCN, for multiscale priorities for biodiversity and carbon sequestration, they saw a mismatch with existing protected areas when only one of these values is prioritized. They are looking for synergies to find joint priority areas, identified as "Cost-Effective Zones." Dr. Ma also highlighted an effort to map plants in Asia.

Zhiyun Ouyang (Research Center for Eco-Environmental Sciences, CAS) discussed integrating biodiversity and natural capital into policy innovation in China. How to coordinate protection and development to protect biodiversity and alleviate poverty is the key issue, he said. Beyond measuring Gross Domestic Product (GDP), Dr. Ouyang said evaluating ecosystem services can harmonize nature into policy innovation.

Dr. Ouyang described an assessment project in China to create an overall image of ecosystem status and map ecosystem services using remote sensing, ground survey sites, and modeling. The team mapped areas that are important for soil retention, sand storm prevention, water retention, flood mitigation, and other ecosystem services, and weighted the biophysical supply by the number of people affected.[10] This information can contribute to decisions about where to invest for natural capital, he suggested. He called for a "Gross Ecosystem Product" as a metric to measure the aggregated value of ecosystem goods and services supplied annually to people in a given region. Pilot GEP accounting is underway in five provinces, including Qinghai Province, a global hotspot for biodiversity.[11] Dr. Ouyang summarized that ecosystem service evaluation is a powerful and useful tool to support conservation policy making and innovation; China has made major efforts to integrate biodiversity and ecosystem services into policy and finance; and natural capital will play a unique role in national park system building, urban sustainability, and investment transformation for nature.

Discussion

In discussing the role of people in protected areas, Dr. Pimm clarified that protected areas can protect people and be drivers of rural economic development. Dr. Ma agreed that protected areas must benefit local people, otherwise they have no future. Dr. Pimm suggested the most cost-effective solution to tackle climate change is reforestation with native trees. Dr. Ma also urged adopting measures outside of protected areas, which might be easier to combine with a sustainable development approach, such as the proposal by the World Environment Forum to plant 1 trillion trees globally.[12]

PANEL II: BIODIVERSITY AND IMPLICATIONS FOR FOOD

Ashok Gadgil (University of California, Berkeley) and **Binbin Li** (Duke Kunshan University) served as moderators to discuss biodiversity and sustainable food systems, including urban and rural agriculture, food security, and complex social-ecological systems.

Jikun Huang (Peking University) said agricultural production has increased and poverty decreased in China, but challenges exist related to food security and environmental degradation. Strategies to support food security include Store Grains (Food) in Technology and Store Grains (Food) in Land; Grain for Green and other conservation programs; and the Green Agricultural

[8] For more information, see Revised figure 1. Theory of change of the framework in https://www.cbd.int/doc/c/2f74/dda0/270258bf5deaab47fbc43da4/wg2020-03-06-en.pdf.
[9] Yang, R., Y. Cao, S. Hou, Q Peng, X. Wang, F. Wang, T-H. Tseng, L. Yu, S. Carver, I. Convery, Z. Zhao, X. Shen, S. Li, Y. Zheng, H. Liu, P. Gong, and K. Ma. 2020. Cost-effective priorities for the expansion of global terrestrial protected areas Setting post-2020 global and national targets. *Science Advances* 6(37). https://www.science.org/doi/10.1126/sciadv.abc3436.
[10] Ouyang et al. 2016. Improvements in ecosystem services from investments in natural capital. *Science* 352(6292):1455-1459. DOI: 10.1126/science.aaf2295.
[11] For more information, see Ouyang et al. 2020. Using gross ecosystem project (GEP) to value nature in decision making. *Proceedings of the National Academy of Sciences* 117(25):14593-14601. https://doi.org/10.1073/pnas.1911439117.
[12] For more information, see https://www.1t.org.

Development Plan, 2021–2025.[13] To improve food security and agricultural sustainability in the future, political commitment is needed in three areas: institutional reforms, policy supports, and investments in agriculture (IPIs). With appropriate IPIs, Dr. Huang said, rapid and greener growth and food security can be achieved. Scientific evidence and policy dialogue can help determine the appropriate IPIs in each stage of development, the implications for biodiversity, and their implementation, he said.

Thomas Tomich (University of California, Davis) commented Dr. Huang's discussion of challenges and opportunities to link knowledge with action in China resonate as global challenges. He noted the *Annual Review of Environment and Resources*, an open-access journal that he co-edits with Dr. Gadgil, covers many topics raised in the workshop.[14] He called for a shift from a focus on agricultural plots to working landscapes and consideration of multifunctionality and multiple stakeholders. Complexities in mixed landscapes make it impossible to manage in top-down, administrative silos, he continued. Effective local voice and appropriate incentives are necessary, but not sufficient by themselves, to achieve local and higher-level goals. Major scientific challenges include taking multifunctionality seriously and understanding how to create a just balance to meet local and global commitments. As opportunities for collaboration between China and the United States, he suggested shifting the paradigm from plot levels to working landscapes as coupled social-ecological systems, and developing institutions and networks to train the next generation. He further suggested regional or national food systems assessments in China and the United States, with food as a lens to consider biodiversity.

Chao-Dong Zhu (Institute of Zoology, CAS) focused on bee diversity in China. Wild bees are the primary pollinators in many natural and cultivated ecosystems, and are important for food security. Bees are in decline, in part because of pesticide and fertilizer inputs, while there are fewer taxonomists to study them. Students and others are helping to collect data on solitary bees and construct interaction networks between host plants, bee larvae and parasitoids. A special committee on pollinator insects was established within the Entomological Society of China. They are setting up forums for knowledge transfer, capacity building and offering new online training courses on pollinator insects. Programs have also been established to survey and evaluate pollinators and services for both crops and forests in East China. Coordinated by Sino-BON, future collaborations include the Insect Diversity Monitoring Network to set up 14 monitoring sites across the country, a method to study and build a database, and mapping wild bee diversity in China and Southeast Asia. By protecting flowering plants and bees, we protect ourselves, Dr. Zhu concluded.

Ivette Perfecto (University of Michigan) shared perspective on biodiversity implications of food. She posited that industrial agriculture is not part of the solution, it is the problem. Global food systems are the largest cause of biodiversity loss and single most contributor to greenhouse gas emissions, play a major role in water issues, and have significant health impacts, as reported in the IPES (International Panel of Experts on Sustainable Food Systems) Report on the Food-Health Nexus.[15] Industrial agriculture has hidden costs of $12 trillion, compared to a market value of $10 trillion (a net loss of $2 trillion), and contributes to injustice and inequality between and within countries. She urged a focus on multi-functional, multi-benefit agriculture with small-scale farmers at the center. She noted small-scale farmers produce 30 to 70 percent of food eaten globally on approximately 25 percent of the land, and the diversity on their farms provides other ecosystem services.[16] A report by the United Nations Special Rapporteur on the Right to Food has shown that small-scale farmers using agroecology can double food production in 10 years while mitigating climate change, conserving biodiversity, and alleviating rural poverty.[17]

[13] For more information about these strategies, see Dr. Huang's presentation at https://www.nationalacademies.org/event/07-27-2022/china-us-scientific-engagement-on-sustainability-sustainability-and-biodiversity-workshop-i.
[14] For more information, see https://www.annualreviews.org/journal/energy.

[15] IPES. 2017. Unravelling the Food-Health Nexus: Addressing Practices, Political Economy, and Power Relations to Build Healthier Food Systems. https://ipes-food.org/_img/upload/files/Health_FullReport(1).pdf.
[16] Ricciardi et al. 2018. How much of the world's food do smallholders produce. *Global Food Security* 19:1970-1988.
[17] UN Special Rapporteur on the Right to Food. 2011. Agroecology and the Right to Food. http://www.srfood.org/en/report-agroecology-and-the-right-to-food.

Discussion

Dr. Perfecto acknowledged it is easy to talk about multifunctionality, but U.S. public institutions have not created capacity to take actions. To address this issue, a transdisciplinary perspective is needed to engage with communities in a holistic way. In China, there are different programs from Chinese Academy of Sciences and National Natural Science Foundation to support incoming scholars. Dr. Chao-Dong Zhu welcomed these programs to support postdoctoral researchers and young scientists from all countries, which can also enhance collaborations between CAS and the National Academies. Dr. Perfecto referred to the separation of nature and human as a challenge when it comes to action and policies. Another challenge is how to balance food production with other ecosystem services, and it would be useful to provide support to small-scale farmers to transition to agroecological systems that can have high productivity of diverse crops and help maintain biodiversity and mitigate climate change, Dr. Perfecto suggested. Dr. Chao-Dong Zhu observed that in China, a positive trend is that both farmers and governors recognize biodiversity and ecosystem functions are helpful in food production.

Dr. Seto asked about the role of urban agriculture. Dr. Ma said this is an emerging topic in China, and a new institute has been launched. Recognition of urban agriculture, especially in managing social shocks, is growing, and he said city designers and ecologists working together can produce greener cities. Dr. Tomich urged looking at different scales, from micro to regional. Studies in Davis, California, show the coordination of garden decision-making across households can significantly affect wild pollinator habitat. He added urban agriculture is important "because we are an urban species" and there are important cultural, aesthetic, and political implications. He also noted, at least in California, the distinction between urban and rural is becoming less meaningful because of the connectivity in what he referred to as "foodsheds." Data suggest climate change may reduce nutrients in some crops. Dr. Tomich added that there is some evidence that agricultural chemicals and breeding for yields may reduce nutrient density.

PANEL III: BIODIVERSITY AND HEALTH

Judith Wasserheit (University of Washington) and **Zhiyun Ouyang** (Research Center for Eco-Environmental Services, CAS) moderated this panel on the importance of biodiversity for health, including the complexity of soils, dynamics of disease systems that connect human and animal populations, and infectious diseases that impact wildlife conservation.

Diana Wall (Colorado State University) discussed soil biodiversity (microbes and animals) and health. She noted most research has focused on the impact of parasites, pests, pathogens, and viruses. A challenge is that human, plant, and animal health are studied as separate disciplines. An estimated 25 percent of terrestrial diversity is below ground, she said. Invertebrates have not been studied as much as microbes. Again, because of specialization, people are trained without knowing the connections, yet about 1.5 billion people are estimated to be infected by soil-borne diseases. She explained soil biodiversity is affected by poor land management and climate change, that can result in loss of soil ecosystem functioning and service provision (e.g., water infiltration, regulation of pests and pathogens, erosion control, nutrient release) with human health impacts. When translated to policy, she commented, soils are at the center of many global agendas, but life in soil is often ignored.

Several recent efforts to connect disciplines include the Global Soil Biodiversity Initiative,[18] International Network on Soil Biodiversity,[19] and Soil BON, of which she is co-lead.[20] The goal is to get soil biodiversity into other frameworks. Priorities include an independent body to support research and synthesis of soil biodiversity and health across specialties, monitoring soil-related policies and taking action, such as in Europe, where a Soil Health policy is being discussed, establishing a dashboard of soil and biodiversity indicators, and an evidence-based solutions platform. Bringing people and soil biodiversity data together are key for protection of soil ecosystem services, she concluded.

[18] See https://www.globalsoilbiodiversity.org.
[19] See https://www.fao.org/global-soil-partnership/resources/highlights/detail/en/c/1457777.
[20] See https://geobon.org/bons/thematic-bon/soil-bon.

Yi Shi (Institute of Microbiology, CAS) noted traditional studies based on isolation and characterization have provided limited understanding of microbes. Ongoing advances in sequencing technologies and analytic approaches are showing how microbes underpin health homeostasis and can create global public health impacts, including COVID-19. In determining why infectious diseases emerge and re-emerge, factors include climate and ecological change, as well as population mobility. He urged being more proactive, to include strengthening current surveillance and research; vaccine and drug development; multidisciplinary efforts, global network and platform; and policy and public support. His research looks at the diversity of virus genome and replication in nature to understand how they amplify, mutate, and cause diseases.

To Dr. Shi, "one world, one health" means understanding biodiversity and mutual interactions in different environments. It is a promising and frontier field for scientists with multidisciplinary backgrounds. As an example of this opportunity, CEEID (CAS-TWAS Centre of Excellence for Emerging Infectious Disease), established in 2018, takes advantage of several CAS research institutions.

Raina Plowright (Cornell University) explained four processes are needed to trigger a pandemic—infect, shed, spill, and spread (Figure 1). Each process is partially driven by environmental change. Increased stresses can lead to higher rates of infection, higher loads of pathogens, and higher likelihood of spillover. She shared several case studies, including Nipah virus in Bangladesh, which spills over from *Pteropus medius* bats to humans when bats contaminate date palm sap, and Hendra virus, which can be transmitted from bats to horses to humans. Hendra virus has become more prevalent in Australia when the forest that provides food in winter has been cleared. As a consequence, bats have transitioned to urban and agricultural areas to seek food. When remaining winter habitat flowers, spillover stops. Restoration and protection of this habitat could benefit human and livestock health while also having benefits for climate, biodiversity, and landscape health, she noted.

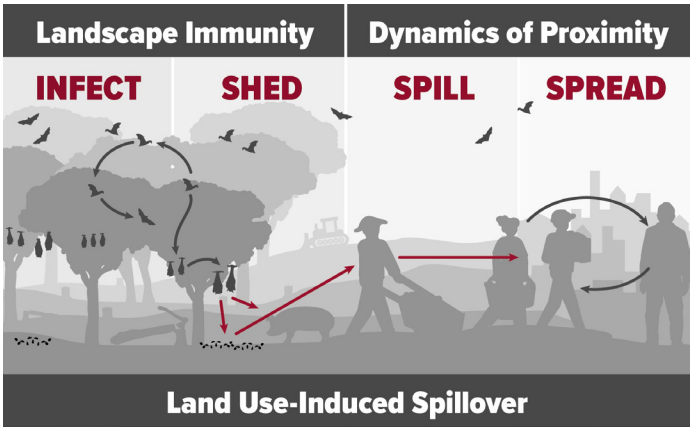

FIGURE 1 Four process trigger a pandemic. All are influenced by land use changes. SOURCE: Raina Plowright, presentation, July 28, 2022, based on Plowright et al. (2021), Reaser et al. (2022), and Eby et al. (Accepted).[21]

To prevent pandemics, she urged not only policies related to early detection and response, but also prevention by stopping spillovers. We need to understand the mechanisms, then can address problems very specifically, she said. However, even without understanding of a specific disease, she advocated for broader approaches, such as reducing fragmentation and not forcing wildlife into human habitats.

Binbin Li (Duke Kunshan University) pointed out that COVID-19 has directed attention to the synergy between biodiversity conservation and human welfare. This attention can be used to take action to promote biodiversity, she suggested, such as a ban on wildlife consumption.[22] Of 254 species traded in China, 69 have been identified to date as possible hosts or vectors. Impacts of climate change on biodiversity and health result from changing climatic conditions, landcover and land use changes, and species range shifts. It is important to understand how to predict and respond to them. Biodiversity creates co-benefits, she continued, noting the high overlap between natural disasters and biodiversity. An uncertain future requires better planning, she continued. The Sustainable Linear

[21] Plowright et al. 2021. Land use-induced spillover: a call to action to safeguard environmental, animal, and human health. *The LANCET Planetary Health* 5(4):E237-E245. https://doi.org/10.1016/S2542-5196(21)00031-0; Reaser et al. 2022. Fostering landscape immunity to protect human health: A science-based rationale for shifting conservation policy paradigms. *Conservation Letters* 15(3):e12869. https://doi.org/10.1111/conl.12869; and Eby et al. Rapid changes in bat ecology drive the emergence of a fatal zoonotic virus. *Accepted. Nature.*

[22] Xiao et al. 2021. Why do we need a wildlife consumption ban in China? *Current Biology* 31(4):R168-R172. https://doi.org/10.1016/j.cub.2020.12.036.

Infrastructure Route Planning Model is one useful tool. Looking at the chain from preemergence to spillover to emergence to localized transmission to epidemic to pandemic, the model shows that the best investment is to prevent a potential pandemic in the early stages. Dr. Li said it is time to convey the scientific evidence and also show how to calculate economic savings.

Discussion

Dr. Plowright said complex resilient systems can prevent zoonotic diseases. If wild animals have enough food to eat in complex environments, they are less likely to have intense contact with humans. Dr. Yongguan Zhu noted the tradeoffs. More exposure to wildlife means more of a chance of exposure to agents. Humans may be creating conditions for a spillover, such as trade of wildlife under great stress. Dr. Li added that another health consideration related to biodiversity is mental health. Nature protects mental health. Dr. Plowright stressed the importance of stopping spillovers upstream before they become raging pandemics. She called for a deeply transdisciplinary approach with extensive spatial and temporal analyses, not snapshots of one place at one point in time. Dr. Wasserheit noted surveillance systems can provide data as a cornerstone to improve health, but these systems are fragile in many countries and often are not able to pull together human, animal, vector, climate and other relevant data. Dr. Li pointed out there are approximately 1.7 million undiscovered viruses, but the capacity or resources to study all these viruses would be limited. Many scientists think that a more targeted approach to identify viruses that are most likely to spillover to cause disease in humans would be useful rather than a broad exploration of all detectable viruses.

PANEL IV: BIODIVERSITY AND CLIMATE CHANGE

Dr. Seto and Dr. Chao-Dong Zhu served as moderators of a panel to examine the impacts of climate change on biodiversity, including forest landscape restoration for climate change mitigation, carbon sequestration and biodiversity, how climatic change influences species distributions, and climate scenario development and evaluation.

Zhiheng Wang (Peking University) presented on Chinese plant diversity amidst global change. Climate and land use changes increase the extinction of species and reduce the effectiveness of protected areas. Few studies have taken place on this in Asia. Dr. Wang and his team examined plant distribution changes in the Gongga Mountains during two periods: 1950–1988, and 1988–2008. In last few decades, 64 percent of species moved upwards in the mountains, and 23 percent moved downward. The trend has varied in other parts of China, determined by the effect of climate change, climate adaptation, species properties, and mountain properties. If a species is more determined by precipitation, it tends to move upward; if more by temperature, it tends to move downward. Additionally, species move upward in cold and large mountains and downward in small and warm mountains. In many places, vegetation dynamics are changed more by restoration and other human activity than by temperature and precipitation. Looking ahead, models using different scenarios suggest a large number of the species evaluated will be threatened. The challenge is how to preserve the tree of life under future global change scenarios, because current protected areas are not doing this. He suggested using tools to identify priority areas for expansion by systematic conservation under future global change scenarios, and expressed hope for collaboration with U.S. scientists.

Julie Winkler (Michigan State University) suggested that climate change impacts, vulnerability and adaption (CCIVA) assessments are opportunities for international collaboration. Among other uses, collaboration can improve the availability and application of climate information, address uncertainty, and assess the potential of maladaptation. She noted observations and projections are used in both top-down and bottom-up strategies, and an ensemble of projects can be downscale for specific areas and provide an estimate of uncertainty. Of 135 biodiversity assessments conducted between 2006 and 2015, 63 percent used the WorldClim dataset.[23] Dr. Winkler said opportunities for international cooperation include the development of biologically relevant, readily available, easy-to-use climate datasets to complement WorldClim, especially for mountainous

[23] For more information, see https://www.worldclim.org.

regions and for remote areas. Climate datasets designed for biodiversity applications should include information on climate extremes. In terms of studying impact with response models, Maxent is the most commonly used, and it is rare to see use of more than one response. This is contrast to other fields, such as agriculture, where multiple models may be used and compared.

Dr. Winkler commented that while thousands of conservation strategies are implemented worldwide, such as protected areas and species introduction, their effectiveness when faced with climate change is not well studied. For example, she asked, can proactive modifications be made to enhance future conservation capacity? One idea is development of a decision-support framework, suggesting another opportunity for collaboration. In summary, she said, collaborative opportunities abound to utilize, improve on, and expand climate change assessments to increase their utility for proactive decision making in biodiversity and conservation.

Xiaojuan Liu (Institute of Botany, CAS) discussed the strength of functional trait effect on forest biodiversity-ecosystem functioning. Biodiversity loss affects ecosystem functioning, she commented. Two decades ago, scientists began to point to restoration ecology and conservation ecology as strategies. Forest restoration is among the most effective strategies for climate change mitigation, which the UN Decade on Ecosystem Restoration recognizes. But tree planting is not a simple solution. Species mixtures provide more ecosystems services than monocultures, for example. Figuring out which species to plant requires an understanding of morphological and physiological characteristics, both above and below ground. Two methods are the Community-Weighted Mean (CWM) and Functional Diversity (FD). Dr. Liu described a Biodiversity-Ecosystem Functioning Experiment, covering 50 hectares and a pool of 60 species. Planting more mixtures of species shows better survival and better interaction of functional traits and diversity than planting a single species. Integrating a temporal dimension is essential. Functional diversity becomes larger than CWM and leads to community stability. Its importance is increasing under rising temperatures and wetter conditions. Dr. Liu urged moving from monospecific to diverse planted forests to restore and maintain biodiversity, ecosystem functioning, and nature's contribution to people.[24] Although it may be some time before knowledge of plant functional diversity is deployed systematically, she said these studies provide a relevant ecological basis in this direction.

Hannah Fairbank (Global Environment Facility [GEF] Secretariat) shared an overview of the GEF-8 Strategy and Programming Directions. The GEF is the funding mechanism for five international environmental conventions. With input from the COPs, a new strategy is developed every four years, followed by criteria for funding.[25] GEF-8 kicked off on July 1, 2022, through 2026, with $5.33 billion pledged by 39 donor nations. It has focal areas with 11 integrated programs (IPs). The IPs are designed to advance systems transformation in urbanization, health, energy, food, and natural systems with targeted levers to get there. She invited participants to review the GEF strategies, IPs, and resources.

Discussion

Dr. Seto asked how to improve the utility of climate change assessments and models for conservation planning and restoration. Dr. Winkler suggested better involvement of stakeholder groups at the beginning. She also commented that existing research has not been used as it should for decision making. Ms. Fairbank shared that in 2019, the GEF Scientific and Technical Advisory Panel came out with guidance on climate risk screening, which is required at the concept level for activities to be financed. Dr. Wang commented that different data generate different outputs, and many people do not recognize the uncertainties that could affect decisions. It is important to make these uncertainties clear. In addition to climate data, data on species, vegetation, and community data also essential, as is sharing of these data, Dr. Wang added. Dr. Liu said for restoration, more current large-scale data are needed. The role of trees on

[24] Bongers et al. 2021. Functional diversity effects on productivity increase with age in a forest biodiversity experiment. *Nature Ecology & Evolution* 5:1594-1603. https://www.nature.com/articles/s41559-021-01564-3.
[25] See https://www.thegef.org.

agricultural lands was discussed as an opportunity for carbon storage and other benefits.

PANEL V: URBANIZATION AND BIODIVERSITY

Yongguan Zhu (CAS) and **Stewart Pickett** (Cary Institute of Ecosystem Studies) moderated the final session looking at how expansion of urban areas directly and indirectly impacts biodiversity and ecosystem services.

Steven Handel (Rutgers University) discussed the potential and challenges of restoring urban biodiversity, given that most of the world is urban and of urban character, and the percentage is growing. Most of the workshop presentations have focused on reserves and natural areas, he commented. The city as an environment is different from non-urban areas in terms of climate, air quality, soil, hydrology, habitat fragmentation, and disturbance. Heat islands raise the temperature several degrees hotter than surrounding areas, which stresses plants, animals, and microbes. A polluted atmosphere and dryer soils also characterize urban areas. The existing habitats are often a mosaic of parks, yards, gardens, and other human-managed sites. He called for using the matrix of new parcels to improve biodiversity. While these areas cannot go back to the ancient past, or even 50 or 100 years ago, there are ecological approaches and tools to improve urban biodiversity. Dr. Handel shared several case studies, including an experiment on a New York City landfill, a restored Brooklyn waterfront, a reclaimed air base in Southern California, and the Forest Park created for the Beijing 2008 Olympics. Despite the constraints in each, Dr. Handel pointed to opportunities using ecological processes to restore natural heritage, improve ecological services, minimize management needs and costs, improve biodiversity in surrounding areas, and add ecological resiliency for the future.

Weiqi Zhou (Beijing Ecosystem Research Station [BERS], CAS) discussed urban biodiversity, landscape patterns, and social variation in Beijing City. He concurred that protecting urban biodiversity is crucial to stem biodiversity loss, especially with 60 percent of the world population in urban areas. BERS has four field sites along an urban-rural gradient with on-site continuous monitoring, 300 long-term plots with urban core areas, and remote sensing to understand spatial patterns. Tree-by-tree surveys of each green patch within 87 residential areas from 39 zones were conducted. The 10 most common species account for 55.9 percent of all trees, with the choice dominated by high ornamental value but also high allergenic risk. He noted a lack of luxury effects (in which higher-income neighborhoods have more trees) in Beijing. Insect and bird diversity were also monitored. A cross-city comparative study of tree biodiversity in residential areas in eight Chinese cities is ongoing. Preliminary results show most tree species are selected for ornamental purposes, as in Beijing, and mixed results in terms of legacy and luxury effects. He also noted establishment of an integrated urban plant-insect-bird observatory to understand interactions, as well as a 20-hectacre, long-term plot in Shenzhen.

Robert McDonald (The Nature Conservancy) touched on three themes related to biodiversity in urban areas: direct impact, indirect impact, and urban nature-based solutions. He noted that a study requested by the Convention on Biological Diversity (CBD) called attention to the massive scope or urbanization and characterized urban growth as the third biggest cause of habitat loss.[26] It also reported on the effects on protected areas, carbon storage, and coastal resilience. A few key research gaps include the impact of urbanization on freshwater and marine biodiversity and also more research in Global South cities. Dr. McDonald noted that policy needs related to direct impacts of urban expansion on biodiversity include (1) the National Biodiversity Strategy Action Plans (NBSAPs) and urban plans to consider how to protect urban-adjacent biodiversity as key to the "30 by 30" global biodiversity targets, (2) the integration between UNFCCC (climate) and CBD agendas to promote synergies between planning for climate and biodiversity, and (3) empowering and capacitating subnational governments.

Indirect impacts, such as food consumption, have a greater impact on biodiversity than direct effects. The agricultural land to support cities is 36 times larger than the actual urban area, but there is little scientific study

[26] McDonald et al. 2018. Nature in the Urban Century: A Global Assessment of Where and How to Conserve Nature for Biodiversity and Human Wellbeing.

of this. Modeling and metrics are needed to connect decisions with these impacts, for example related to where to source food for schools. Policy needs include a need for urban (and corporate) commitments to net biodiversity loss that includes indirect effects, as well as strong urban-relevant commitments in the CBD and UNFCCC processes.[27]

Finally, urban nature-based solutions (NbS) for climate well-being are the main way that The Nature Conservancy engages with cities. Key research gaps include how cities can be both dense and green and how NbS can meet societal needs relative to other potential solutions. Financing, incentives, and best-practice governance systems are needed for planning, creating, and maintaining NbS, he added.

Jun Yang (Tsinghua University) stressed the need for generalizing urban biodiversity studies to develop better management strategies.[28] While a number of scientific studies on urban biodiversity are available, local leaders may not find them helpful to their day-to-day decisions. As scientists, we must share the problem, he asserted. Most studies focus on individual cities, and local practitioners have to guess what applies to their city.

One solution is to offer a synthesis, he suggested. For example, the relationships between urban landscape features and urban bird diversity can be generalized to help local practitioners with planning. Dr. Yang described an analysis on a global scale. Across 126 cities that satisfied the requirement of survey completeness, they found that for a city, no matter the biome or country or scale, the percentage of impervious surface has a negative impact, and the percentage of tree cover has a positive impact. They also looked at the association between different guilds of birds and landscape features. The result was largely the same with some variation. While a site-specific study is preferred, he commented, finding generality may be essential to more broadly integrate urban biodiversity conservation into municipal activities such as urban planning. He concluded that data from the U.S. Geological Survey and eBird were essential for his study. He suggested data sharing is a good beginning for Chinese and U.S. scientists to move forward together.

Discussion

A participant suggested a redefinition of urban space to include interconnections, such as those related to food consumption and infectious diseases. Understanding what will happen 20 to 30 years in the future, given the combined effects of climate change, was also raised. Dr. Handel urged that scientists build links with the design professions, especially landscape architects. He also noted different priorities for two kinds of cities—older cities that are being modified, especially in the United States and Europe, and newer cities being built, especially in Asia and Africa.

Dr. Wasserheit suggested that the plant-insect-bird observatory described by Dr. Zhou include a human dimension. For example, randomized controlled trials could look at the impact on humans of exercise according to CDC guidelines in nature-enriched settings of the plant-insect-bird observatory versus non-nature settings in the same urban area, she suggested. She also asked about any analogs in biodiversity process and outcome measures to those in health, for example the UN's "95-95-95" targets related to HIV prevention and treatment.[29]

PATH FORWARD: FUTURE NEEDS AND OPPORTUNITIES

Dr. Seto summarized some main points that she identified from speaker presentations and panel discussions. She offered four areas, cross-cutting across the topics discussed during the workshop, where gaps in science and policy may be helped by collaboration. The first is a better understanding of the impact of climate change on the distribution of species, and the implications for food and health. The second is to link

[27] McDonald et al. Urban Butterfly Effect: How Nations Can Accelerate the Contributions of Local Governments to Global Transformative Change. http://www.ubhub.org/pdfs/tube2022.pdf.
[28] See, for example, Kendal et al. 2017. A global comparison of the climactic niches of urban and native tree populations. *Global Ecology and Biogeography* 27:629–637. https://doi.org/10.1111/geb.12728; van Vleit, J. 2019. Direct and indirect urban expansion. *Nature Sustainability* 2:755–763. https://www.nature.com/articles/s41893-019-0340-0; and Simkin et al. 2022. Biodiversity impacts and conservation implications of urban land expansion projected to 2050. *Proceedings of the National Academy of Sciences of the United States of America* 119: e2117297119. https://doi.org/10.1073/pnas.2117297119.
[29] See www.unaids.org. These targets are that 95 percent of people living with HIV know their HIV status, 95 percent how know they are HIV-positive are accessing treatment, and 95 percent on treatment have suppressed viral loads.

restoration for forests and natural landscapes with urban ecosystems, given the impacts of climate change on ecosystems and ecological function. The third is more policy oriented: Given the unknown impacts of climate change on species distribution, how can we use climate change models, as well as uncertainty bands, to inform policy and especially the siting of protected areas? Reflecting on earlier presentations, siting more or larger wild areas will not necessarily protect more species, so how can models be improved to anticipate the distribution of species and where protected areas should go. Finally, she called for shared data. The long-standing archive of Landsat, in combination with satellites launched by China, the United States, and other countries, including the private sector, can be powerful when used jointly, but access to these data should be ensured. She also noted three different phases or pathways for collaboration. First are workshops and other efforts organized by CAS and the National Academies. Second are long-standing collaborations among individuals, which she suggested be strengthened, especially for emerging scholars. The third important pathway is between institutions across countries.

Dr. Tomich noted the role of climate change models in establishing protected areas. He urged widening to landscape approaches, rather than focusing on a few places, as well as coupling ecosystems with human well-being. He opined that linkages to outcomes for humans increase leverage in policy decisions. He also suggested downscaling global integrated assessments to national or regional levels. Transdisciplinarity can expand authentic stakeholder engagement, he added. Finally, he stressed the need to build capacity in the next generation of scholars.

To Dr. Yongguan Zhu, "The message is clear; we must collaborate." He suggested a permanent joint committee to organize, coordinate, and facilitate on issues of sustainability, and said he looked forward to in-person meetings to advance collaboration. He also urged collaborations between institutions, in addition to between individuals, to achieve sustainability goals.

Dr. Ma expressed confidence in the future of collaboration and noted that presenters proposed concrete ideas, such as identifying priority research areas and collaboration between CAS and the National Academies. He urged conveying highlights of the workshop to a larger audience, as well as more detailed summaries of the presentations in the five panels. Dr. Seto agreed panel summaries would be helpful and also suggested a forward-looking, perspective paper. She added that proposing priority research areas for collaboration needs to involve the entire community, which she believed would be welcomed by both CAS and the National Academies. Dr. Wasserheit added that the National Academy of Medicine (NAM) is interested in the connection between health and climate change, as articulated by NAM President Victor Dzau.

Dr. Jianguo "Jack" Liu suggested studying the interactions among countries to develop comparisons and examples. It is important to address the impact of China on the United States and vice versa, and the impact of both countries globally, he suggested. Dr. Perfecto built on this comment with an example. In China, the average size of a farm is smaller than in the United States. One potential project would be to study the impact of the size of farms on biodiversity, health, and climate change.

Dr. Li offered a proposal to involve emerging scholars by establishing small grants for joint collaborations. She noted that smaller grants would be more accessible for emerging scholars and lead to more collaborations and opportunities. Dr. Seto acknowledged there are many models for implementation but the important thing is to provide resources to junior scholars. She noted existing opportunities for meetings and networking, but senior scientists who already have established networks are often the recipients. Dr. Yongguan Zhu closed by offering hope that interactions between both academies will continue. He also agreed with the importance of involving scientists in both countries at all levels.

DISCLAIMER This Proceedings of a Workshop—in Brief was prepared by **Franklin Carrero-Martínez, Paula Whitacre,** and **Emi Kameyama** as a factual summary of what occurred at the workshop. The planning committee's role was limited to planning the workshop. The statements made are those of the rapporteurs or individual workshop participants and do not necessarily represent the views of all workshop participants; the planning committee; or the National Academies of Sciences, Engineering, and Medicine.

REVIEWERS To ensure that it meets institutional standards for quality and objectivity, this Proceedings of a Workshop—in Brief was reviewed in draft form by **Kamal Bawa** (NAS), University of Massachusetts at Boston; **Sandra Diaz** (NAS), National University of Cordoba; and **Chao-Dong Zhu,** Chinese Academy of Sciences. The review comments and draft manuscript remain confidential to protect the integrity of the process.

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