Environmental and Sustainability Indicators 5 (2020) 100017

Contents lists available at ScienceDirect

Environmental and Sustainability Indicators

journal homepage: www.journals.elsevier.com/environmental-and-sustainability-indicators/

Progress on national biodiversity indicator reporting and prospects for filling indicator gaps in Southeast Asia

Xuemei Han [a,1], Michael J. Gill [a], Healy Hamilton [a], Sheila G. Vergara [b], Bruce E. Young [a,*]

[a] NatureServe, 2550 South Clark Street, Suite 930, Arlington, VA, 22202, USA
[b] ASEAN Centre for Biodiversity, Domingo M. Lantican Avenue, Los Baños, Laguna, 4031, Philippines

ARTICLE INFO

Keywords:
Aichi targets
ASEAN
Convention on biological diversity
Indicator use
Monitoring progress

ABSTRACT

With tremendous biodiversity but increasing threats, Southeast Asia faces challenges in meeting its commitments to the Convention on Biological Diversity's 2020 Aichi Targets. The use of indicators to monitor, evaluate and guide conservation progress is increasingly urgent. We quantified indicator use by 10 Southeast Asian governments in the 4th and 5th national reports submitted to the Convention on Biological Diversity in 2010 and 2015. We found indicator use variable among nations but increasing. Use of quantitative trend indicators doubled from an average of 6–12. There was no change in the number of non-quantitative (mean of 2) or quantitative baseline indicators (those measured once; mean of 9). Indicators most frequently addressed habitat condition and extent, species diversity, protected areas, and agriculture (means of 2–6 indicators each). They were rarely used (mean < 1) to indicate trends in wildlife exploitation, information sharing, climate change, and invasive species. Species diversity indicators increased from the 4th to 5th reports, and there were marginal increases in indicators used for aquatic ecosystems. The results highlight a slow but noticeable increase in the use and quality of indicators in national biodiversity reporting in the region. However, for the region to accelerate progress towards agreed-upon targets of multilateral environmental agreements, a more relevant and diverse set of indicators will need to be employed. Paths to doing so include the use of disaggregated global indicators, increased regional coordination to improve the efficiency and quality of indicator generation, and increased efforts at growing national-level monitoring capacity.

1. Introduction

Southeast Asia is home to several biodiversity hotspots, each suffering rapid losses of biodiversity (Myers et al., 2000; Sodhi et al., 2004). Many species occur in Southeast Asia and nowhere else. At least 29,332 plant (approximately 10% of the global total) and 2276 vertebrate (approximately 8% of the global total) species are endemic to the region (Myers et al., 2000). Due to these high levels of endemism, conservation efforts within the region must succeed to avoid the loss of a significant portion of Earth's biodiversity. Prominent region-wide drivers of biodiversity loss include habitat destruction from anthropogenic land use change (Brooks et al., 2002; Cardillo et al., 2006; Lee and Jetz, 2008; Schipper et al., 2008; Sodhi et al., 2004, 2010a; Stuart et al., 2004; Wilcove and Koh, 2010), illegal wildlife trade (Nijman, 2010; Sodhi et al., 2004), and over-exploitation of native species (Schipper et al., 2008; Sodhi et al., 2004). Furthermore, climate change (Bickford et al., 2010; Lee and Jetz, 2008), invasive species (Peh, 2010), and pollution all pose additional and cumulative challenges to inland, coastal and marine biodiversity (ACB, 2017; Koh and Sodhi, 2010; Sodhi et al., 2004).

In response, and to fulfill obligations under the Convention on Biological Diversity (CBD) and other multilateral environmental agreements such as the United Nations Sustainable Development Goals and the Ramsar Convention on Wetlands, governments and civil society organizations are increasing investment in conservation in Southeast Asia. To understand the extent to which these efforts are having an impact, policy makers and conservation practitioners need access to reliable information on baseline biodiversity measures and indicators that measure progress in reducing pressures and improving conservation status (Butchart et al., 2010; Tittensor et al., 2014; Walpole et al., 2009). Indicators are also key to monitoring progress toward specific goals, such as the CBD's 2020 Aichi Targets (CBD, 2011). Many Southeast Asian governments either don't have adequate data to underpin indicator

* Corresponding author.
E-mail address: bruce_young@natureserve.org (B.E. Young).
[1] Present address: Fairfax County Department of Management and Budget, 12000 Government Center Parkway, Suite 561, VA 22035.

https://doi.org/10.1016/j.indic.2019.100017
Received 22 May 2019; Received in revised form 11 December 2019; Accepted 12 December 2019
Available online 13 December 2019

development or have not employed the use of the most recent and widely accepted indicator methodologies, leading to shortfalls in the production and use of indicators for target tracking. For example, the volume of biological inventory and conservation biology research in Southeast Asia lags behind many other regions of the world, with most of the research on Southeast Asia being conducted by scientists based outside of the region (Giam and Wilcove, 2012; Webb et al., 2010). If research is conducted by foreign laboratories, the underlying data often also sit offshore where they are not easily accessible and perhaps not trusted by Southeast Asian governments (Bubb et al., 2011). Also, local capacity to capture, store and manage monitoring data may not grow if most research is conducted without collaborations with national and/or local research groups.

Recently, increased collaboration efforts among governments have focused on the enhancement of national capacity to generate and report on biodiversity information and monitor conservation impacts. The Association of Southeast Asian Nations (ASEAN) is a major regional political body comprising 10 member states (Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam) formed in 1967 to accelerate the economic growth, social progress and cultural development of the region. ASEAN established the ASEAN Centre for Biodiversity (ACB) in 2005 to strengthen the capacity of ASEAN member states to formulate and coordinate biodiversity-related policy, strategy and action. Since then, ACB has leveraged and facilitated efforts by ASEAN member states to address biodiversity-related challenges in the region, including enhancing regional capacity for monitoring progress toward the goals of multilateral environmental agreements. For example, in 2012, ACB co-organized a workshop with the Biodiversity Indicators Partnership, the United Nations (UN) Environment Programme, the UN Environment World Conservation Monitoring Centre, NatureServe, the Biodiversity Conservation Agency of Vietnam, and 31 delegates from 9 Southeast Asian countries to strengthen capacity in the production of indicators as part of the development of each nation's National Biodiversity Strategy and Action Plan (the principal instrument for implementing the CBD at national levels) (Han et al., 2014). ACB is coordinating its efforts with global initiatives including the Global Biodiversity Information Facility, the Group on Earth Observations Biodiversity Observation Network and its regional network, the Asia-Pacific Biodiversity Observation Network. It has also joined the International Oceanographic Data and Information Exchange (IODE) programme of the International Oceanographic Commission as an IODE Associate Data Unit to ensure that its marine biodiversity data holdings are following global data standards. In addition, ACB established the ASEAN Clearing-House Mechanism to provide ready access to biodiversity information relevant to member states' reporting requirements to multilateral environmental agreements (ACB, 2017). Aside from ACB's efforts, the CBD Secretariat facilitated 2 workshops with government representatives in the early 2010s to explain the then-new Aichi Targets and corresponding monitoring needs.

To date, no study has evaluated or documented trends in the use of indicators specific to Southeast Asia. Here we ask to what extent have efforts to strengthen capacity for indicator production resulted in improved information about the status and trends of biodiversity? Parties to the CBD are required to report approximately every 5 years on both the actions taken to contribute toward implementation of the Convention and the effectiveness of these actions. These reports represent the highest level of government reporting with regard to implementation of the CBD at the national scale and present an opportunity to study patterns in indicator use. The most recent reports, the 4th and 5th national reports, were submitted in 2010 and 2015, respectively. The Aichi Targets, adopted just after the submission of the 4th national reports, were the first quantifiable targets set through the CBD process, catalyzing global efforts to develop global biodiversity indicators (Tittensor et al., 2014).

To address our research question, we examined changes in the use of biodiversity indicator information by the governments of ASEAN Member States (Fig. 1; one Southeast Asian country, Timor Leste, is not an ASEAN Member State and is excluded from our analysis) in their 4th and 5th national reports to the CBD. Specifically, we quantified changes in the use of nonquantitative, quantitative baseline, and quantitative trend indicators in the reports, and examined how the number and types of indicators varied across environmental themes. We predicted that if efforts at improving capacity in the use of biodiversity indicators are having success, then (1) the number of indicators used should increase, (2) the proportion of indicators derived from quantitative (baseline and trend) data should increase, and (3) the number of conservation themes addressed by quantitative indicators should increase. We conclude by identifying current data gaps and evaluating prospects for filling them.

2. Material and methods

We extracted information about indicator use from the 4th and 5th national reports presented to the CBD by ASEAN member states (Fig. 1; reports available at CBD 4th National Report Portal, 2010 and CBD 5th National Report Portal, 2015). We defined indicators as any descriptive or quantitative metric that was meant to convey information about a biodiversity issue. Some countries reported the trend in gross domestic product and human population as pressures, but we do not count these as specific indicators for this study because they provide contextual information and do not necessarily identify specific threats to or describe the status of biodiversity. In each report, we counted the number of indicators presented, and classified their level of development (Table 1). In some cases, quantitative baseline or trend data were presented for a region of the country or specific sites instead of the entire country; we categorized these cases as subnational indicators.

We organized the indicators by the 10 themes that align with the drivers of biodiversity loss summarized in the ASEAN Biodiversity Outlook 2 review (ACB, 2017). Each theme represents an important aspect of Southeast Asian biodiversity and relates to one or more Aichi Targets (Table 2). In the few situations in which an indicator related to multiple themes, we counted the indicator as relevant to both themes. For example, the indicator 'mangrove forest area change' relates to both the forest and freshwater and marine ecosystem themes. Similarly, the indicator for the numbers of native medicinal plant species was relevant to both the species diversity and forest themes. In these cases, we counted the indicator only once for overall analyses of numbers of indicators. Analyses of numbers of indicators by theme were conducted within themes only such that data independence was not compromised by scoring an indicator as relevant to 2 themes. We compared regional medians of the number of indicators used in 2010 and 2015 by level of development and themes. We used non-parametric Wilcoxon signed-rank tests for comparisons. Because of a relatively small sample size ($N = 10$ countries), we indicate marginal ($0.05 < P \leq 0.1$) as well as significant ($P \leq 0.05$) differences.

3. Results

Comparing the 4th and 5th national reports, there was a trend toward more comprehensive (i.e., nationwide coverage) and more trend indicators. The number of indicators that covered only a portion of a country decreased to almost none while the use of quantitative trend indicators doubled (Fig. 2). Meanwhile, the number of nonquantitative descriptive and quantitative baseline variables showed no detectable change (Fig. 2). On average, 12 trend indicators (range 1–22) were presented in the 5th national reports. This was an improvement over the 4th national reports in which number of trend indicators varied from 1 to 15, with a regional average of just 6 (Figs. 2 and 3). Overall, 5 countries increased their use of quantitative baseline indicators while 4 decreased and 1 used the same number. Eight countries increased use of quantitative trend indicators whereas 1 country decreased, and 1 country used the same number of trend indicators.

The number of themes measured by at least one baseline indicator (resulting from a single measurement) or at least one trend indicator (compiled from multiple measurements in different years) increased

Fig. 1. The 10 Association of Southeast Asian Nations (ASEAN) that were the focus of this study.

Table 1
Definitions and examples of the three classes of indicator level of development used in this study.

Level of Development	Definition	Examples
Nonquantitative	Descriptive statements or lists with no numerical component	List of domestic animal breeds; list of invasive species
Quantitative baseline	Numerical "snapshot" value resulting from a single measurement	Species diversity; tree nursery production
Quantitative trend	Numerical measurements repeated in multiple years	Change in percent coverage of protected areas; international tourist arrivals 1993–2011

marginally, by one theme on average, from the 2010 to 2015 reports (Fig. 4). Among specific themes, the quantity of indicators reported varied from near zero to more than 5 (Fig. 5). The number of indicators appeared to increase in all but 2 of the 10 themes, with a statistically significant increase for species diversity and "Others," and borderline statistical significance for freshwater and marine ecosystems (Fig. 5). Some indicators presented in 4th national reports were dropped from the 5th national reports. In fact, the mean number of indicators for agricultural and invasive species themes suffered a net decline (Fig. 5).

Only a single indicator, species diversity, was reported by every country studied. For this measure, most countries used global IUCN Red List data to report the number of threatened species in different taxonomic groups. Other indicators that are commonly reported by most countries include the extent of protected areas coverage as baseline information and trend in forest cover.

Results of our compilation of indicator data for individual countries are provided in a related Data in Brief article.

4. Discussion

Our review of the 4th and 5th national reports submitted by the ASEAN Member States reveals that indicator use improved across several categories; however, overall application of indicators remains limited despite available datasets and indicator methodologies that could be applied in the region (e.g., those available via the ASEAN Clearing House Mechanism). The number of indicators depicting temporal trends and the number of environmental themes covered by indicators increased between the two reports. The use of baseline indicators dropped, but this change was due to these converting to trend indicators as data from additional time steps became available. For example, tiger population numbers reported by Malaysia changed from a quantitative baseline to a quantitative trend between the 4th and 5th reports. Not all indicators used in the 4th national reports also appeared in the subsequent report. For example, if the 4th national report presented data from a published study that was not continued, this information typically was not repeated in the 5th national report. In other cases, indicators presented in a 4th national report that were not relevant to one of the Aichi Targets, which were introduced after the completion of the 4th national reports, were not presented in the corresponding 5th national report.

This result is consistent with the notion that regional and global efforts at building capacity for the development and use of biodiversity indicators are achieving some success, although this study cannot assign direct causation. The adoption of the Aichi Targets by the CBD between the 4th and 5th reporting periods may also have contributed to the uptick in trend indicators used in national reports. Further, the results point to

Table 2
Environmental themes examined for the use of indicators in Southeast Asian national reports to the Convention on Biological Diversity (CBD), importance to Southeast Asia, related CBD Aichi Biodiversity Targets and example indicators presented in national reports. The related Data in Brief article contains a complete list of all indicators presented.

Themes	Importance for Southeast Asia	Relevant Aichi Target(s)[a]	Illustrative Indicators
Forest	Southeast Asian forests are among the most biologically diverse in the world, but are over-exploited (ACB, 2017; Sodhi et al., 2010b).	5, 7	Forest cover and area, Land use/land cover, Non-timber forest products, Timber volume
Agriculture	Southeast Asian agriculture is highly productive, feeding 632 million people (United Nations, 2015) but experiencing pressures from genetic erosion, agricultural land conversion, declining pollinators, and invasive species (ACB, 2017).	4, 7, 13, 18	Agriculture land area, Genetic strains of crops and livestock, Production of food commodities
Freshwater and marine ecosystems	Inland waters are the most threatened habitats in the region, which harbors 1/3 of the world's coastal and marine habitats (ACB, 2017).	5, 6, 7, 8, 10, 11, 12, 14	Fisheries productivity, Marine protected areas, Richness and abundance of freshwater aquatic species
Species diversity	Most of Southeast Asia falls within a biodiversity hotspot (Sundaland, Wallacea, Philippines and Indo-Burma; Myers et al., 2000; Sodhi et al., 2010b).	12, 19	Number of newly discovered species, Number of species by taxonomic groups, Number of threatened species
Wildlife exploitation	Southeast Asia is a global centre for poaching, trafficking and consumption of illegally traded wildlife parts and products (ACB, 2017).	4, 12	Number of animals in wildlife trafficking, Number of plant species found in seizures of illegally extracted timber, Weight of illegal ivory traded
Invasive species	At least 112 invasive species have been identified that affect forests, agriculture and aquatic ecosystems (ACB, 2017).	9	Number of indigenous species lost due to invasive species, Number of invasive species identified
Climate change	Southeast Asia is highly vulnerable to climate change, with all terrestrial and marine ASEAN Heritage Parks projected to be affected (ACB, 2017).	10, 14, 15	Economic value of damage caused by extreme weather events, Number of extreme weather events, Number of flash floods
Information sharing and knowledge building	Sharing of best practices and systematic integration of biodiversity concerns in conservation planning, management and policy development needed to improve natural resource management	16, 18, 19	Number of biodiversity research projects, Number of conservation training events
	efficiency (ACB, 2017).		
Natural area protection	Protected areas are key to preserving habitat for biodiversity in a highly populated region, as well as for food and water security, human health and well-being, disaster risk reduction, and buffering the effects of climate change (ACB, 2017).	5, 6, 10, 11, 14	Establishment of protection law or act, Number of protected important biodiversity areas, Number of terrestrial and marine protected areas
Others	Less frequently used indicators have been developed to address unique national needs.	2, 3, 4, 5, 6, 8, 14, 20	Revenue from ecotourism, Singapore city biodiversity index, Weight of garbage and wastewater

[a] Aichi Biodiversity Targets — 1: Public awareness; 2: Mainstreaming biodiversity values; 3: Subsidies and incentives; 4: Sustainable production and consumption; 5: Habitat loss, degradation and fragmentation; 6: Fisheries; 7: Sustainable agriculture, aquaculture, forestry; 8: Pollution; 9: Invasive species; 10: vulnerable ecosystems; 11: Protected areas; 12: Threatened species; 13: Genetic diversity; 14: Ecosystem services; 15: Resilience and restoration; 16: Access and benefit sharing; 17: National biodiversity strategies and action plans; 18: Traditional knowledge; 19: Science-based knowledge; 20: Resource mobilization.

several ongoing gaps and opportunities to improve the use of indicators to monitor progress toward goals of multilateral environmental agreements. Because the limited use of indicators in National Reports is not unique to Southeast Asian countries (Bubb et al., 2011), the lessons derived from this analysis are likely of relevance for other countries and regions facing the challenge of effectively accessing and applying indicators to track and respond to conservation targets.

Despite the opportunities for regional coordination provided by the ASEAN framework and ACB specifically for biodiversity conservation, we found little use of regional indicators. Two countries reported on the number of ASEAN Heritage Sites in their 4th national reports, but then did not do so in their subsequent reports. Future cross-border collaboration to fill gaps in indicator availability may be an option for surmounting barriers to indicator development and promoting coordinated policy response.

Both the 4th and 5th national reports included at least one indicator each for 5 of the 10 environmental themes examined (forest, species diversity, aquatic ecosystems, natural area protection and agriculture), representing 11 of the 20 Aichi Targets. Thus, countries have a means of measuring progress toward these Targets. We note that ACB (2017) found that satisfactory progress was being made in the region toward only 2 of the Aichi Targets (Target 11, protected areas, and Target 17, national strategies and action plans) and that poor progress was being made in 7 of the Targets (Targets 4–6, 10, 12–14) (Fig. 6; ACB, 2017). The use of indicators facilitates this sort of assessment, providing the means to determine whether and when actions will begin to have a positive effect on biodiversity. Moreover, 8 of the 9 Targets for which ASEAN member states have not adequately developed indicators (Targets 1–3, 8, 9, 15,16, 20) are associated with limited implementation (Fig. 6; ACB, 2017). Regional or global indicators were available for some of these targets, but national disaggregations were unavailable for some and countries may have been unaware of or unwilling to use those that were available (Han et al., 2017). Clearly, more indicator development efforts are needed for these Targets to monitor, assess, and guide the outcomes of forthcoming actions undertaken by governments to address these

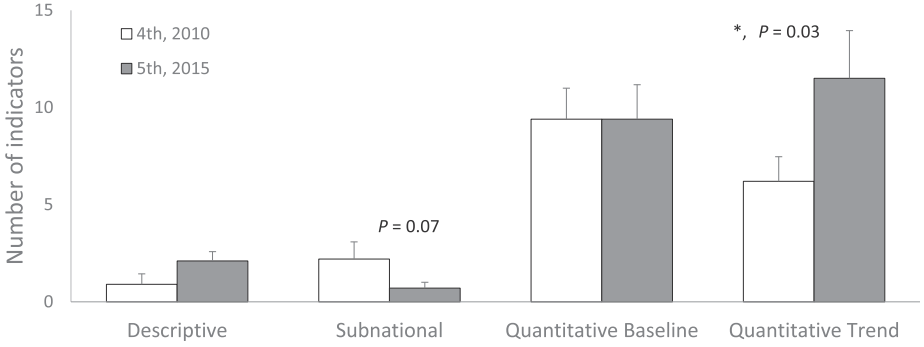

Fig. 2. Mean number of indicators in different levels of development and spatial coverage (all indicators were national except those quantified in the "Subnational" category) presented in the 4th and 5th national reports to the Convention on Biological Diversity by 10 Southeast Asian countries. Subnational indicators comprise both quantitative baseline and quantitative trend indicators. Error bars indicate +1 SE of the means. *P*-values from Wilcoxon signed-rank tests. * indicates significance at the $P \leq 0.05$ level.

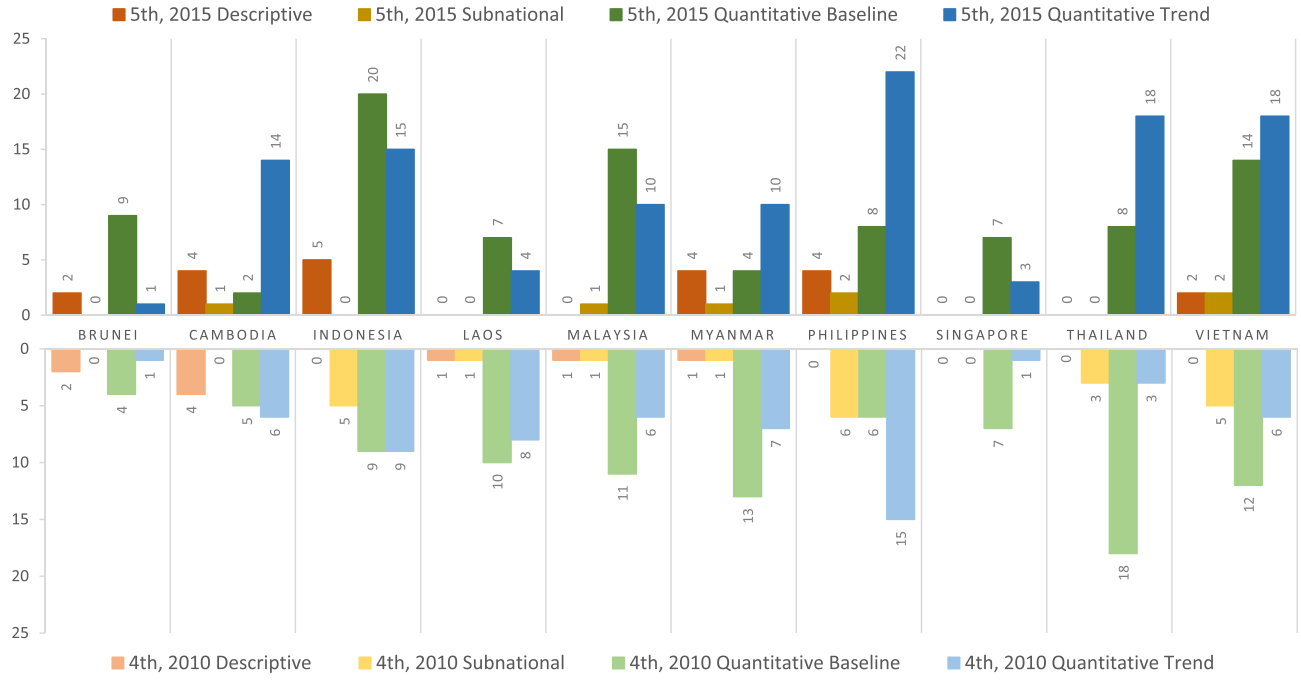

Fig. 3. Numbers of indicators in 4 levels of development (descriptive, subnational, quantitative baseline and quantitative trend) used in ASEAN member states' 5th (upper) and 4th (lower) national reports to the Convention on Biological Diversity (CBD). Subnational indicators comprise both quantitative baseline and quantitative trend indicators.

shortcomings. In fact, recent analysis of global progress towards the Aichi targets showed a positive correlation between target measurability and target progress (Green et al., 2019), strengthening the argument for targets to be effectively measured if progress is to be made.

Despite the recent progress in indicator use documented here, several well-known pressures on Southeast Asian biodiversity do not have good quality indicators to support monitoring. As stated above, habitat destruction, wildlife trade, over-exploitation, climate change, invasive species, and pollution are all serious threats to biodiversity in Southeast Asia, yet very few countries in the region have indicators to track any of these pressures other than measures of forest cover. Although all countries examined report on the IUCN Red List status of major taxonomic groups of species inhabiting their countries, none present national Red List Indices of trends in threat status. The Red List Index is a powerful tool for depicting trends in the conservation status of species (Butchart et al., 2004, 2007), and can be calculated either through analysis of national Red List data (Han et al., 2017) or through disaggregation of global Red List data (Rodrigues et al., 2014). Increasingly, Red List Index data are becoming readily accessible to facilitate use in national reports (Han et al., 2017; Han et al., 2014; IBAT, 2018).

As would be expected in such a diverse region, countries varied in the number and identity of indicators reported. National priorities are reflected in some indicators, such as the City Biodiversity Index to monitor urban biodiversity in the small island city-state of Singapore, an indicator of the genetic diversity of agricultural crops in the Philippines, and indicators for pollution and wastewater in Thailand and Vietnam. Overall, more indicators were used to document the state of biodiversity (such as Red List status) and government responses (such as extent of protected areas) than for the specific pressures on biodiversity, thereby limiting the opportunity to guide effective policy that addresses the fundamental issues driving biodiversity loss. Also, indicators were rarely presented in spatially explicit formats such as maps that could identify specific areas where actions are needed. However, in some cases metrics were reported by region or sites within countries. These gaps, together with the wide range in the number of indicators reported (1–22 for trend indicators, and 2–20 for baseline indicators), suggest that capacity to monitor and report on biodiversity indicators varies substantially in the region.

The reports rarely mentioned methods used to generate indicators, making it difficult to discern the technical origin of the indicators. Clear evidence of the use of global datasets to generate indicators in the 5th national reports was shown by the use of IUCN Red List (5 reports), Key Biodiversity Areas (KBAs; 3 reports) and RAMSAR sites (2 reports) in

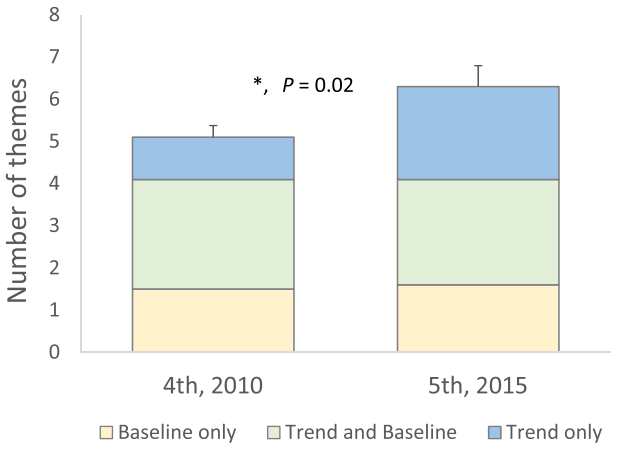

Fig. 4. Mean number of environmental themes measured with quantitative data in the 4th and 5th National Reports to the Convention on Biological Diversity by 10 Southeast Asian countries. Overall quantitative indicators include baseline (single measurement) and trend (measurements in multiple years) indicators. Error bars indicate +1 SE of the means. *P*-values from Wilcoxon signed-rank tests. * indicates significance at the $P \leq 0.05$ level.

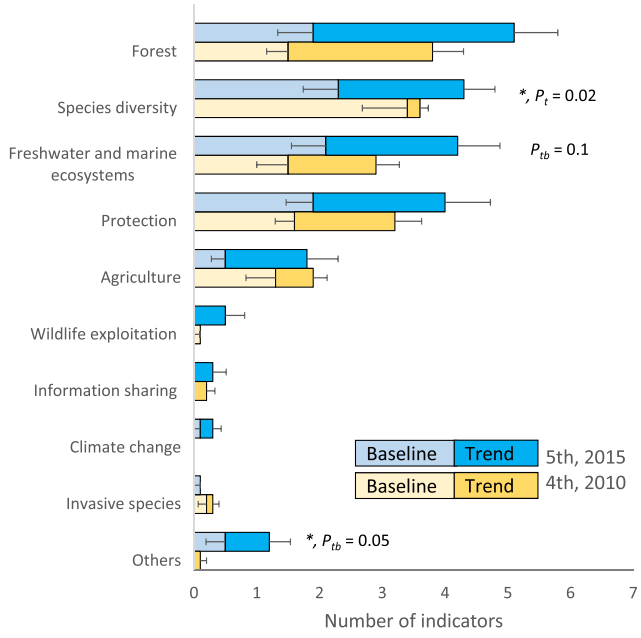

Fig. 5. Mean number of quantitative indicators by themes, ordered by the total number of indicators, presented in the 5th national reports to the Convention on Biological Diversity by 10 Southeast Asian countries (with "Others" presented last). Error bars indicate +1 SE of the means. *P*-values from Wilcoxon signed-rank tests: P_t is for trend indicators only; P_b is for baseline indicators only; P_{tb} is for all quantitative indicators, i.e., baseline indicators and trend indicators combined. * indicates significance at the $P \leq 0.05$ level.

indicators presented. Three reports clearly used remote sensing data analyzed by in-country GIS offices to estimate forest cover. Greater capacity in remote sensing may allow countries to better track trends in land use and area of sensitive habitats such as mangroves.

Although governments employ a variety of practices to track progress towards their own targeted conservation and sustainability goals (de Freitas et al., 2019; de Oliveira et al., 2017; Salvati and Carlucci, 2014), such efforts may not be available for every country across all themes. One option for consideration by countries with limited resources to dedicate toward biodiversity monitoring and indicator development is the use of disaggregated global indicators to fill data gaps until local sources of data become available (Han et al., 2017). Global data sets have several advantages such as their ready availability and published methods, but they have potential disadvantages too, including lack of local buy-in, re-measurement time frame and methods out of the control of countries that use them, potential incompatibility with future nationally-generated data, and misinterpretation of metrics. Other than IUCN Red List assessments and counts of KBAs and RAMSAR sites, to date Southeast Asian countries have not used global data in their reports. Examples of global indicators to consider for filling these gaps are the Ecological Footprint (Borucke et al., 2013; Galli et al., 2014; addresses habitat destruction), Extent of Intact Forests (Potapov et al., 2017; Potapov et al., 2008; addresses habitat destruction), Red List Index (Butchart et al., 2007; Butchart et al., 2004; addresses wildlife trade and over exploitation), Protected Area Coverage of Key Biodiversity Areas (Butchart et al., 2012; addresses habitat destruction, over exploitation), and Carbon Sequestration Potential (Han et al., 2017; addresses climate change). For coastal countries, 2 global marine indicators could be disaggregated for national reporting on habitat destruction, over exploitation and pollution in these ecosystems: Ocean Health Index (Halpern et al., 2012, 2015) and Cumulative Human Impacts on Marine Ecosystems (Halpern et al., 2015). To date, no global indicators with data for ASEAN countries are available to monitor the effects that invasive species and climate change have on biodiversity. For some indicators, local data will be needed to calibrate or validate models generated at global scales (Collen et al., 2013).

5. Conclusions

Our findings that indicator use by Southeast Asian governments is slowly improving but with considerable room for improvement in both the level of development and thematic breadth of indicators provide several lessons for improving the effective use of indicators to guide conservation investment. First, government offices responsible for monitoring and reporting on progress to the CBD should emphasize the use of quantitative indicators that measure trends over time because these indicators provide the most clarity on how biodiversity is faring. Greater coordination between the agency responsible for reporting and those responsible for managing and measuring activities addressed by the Aichi Targets may help to achieve this goal.

Second, although past investment in improving capacity to use indicators (e.g., Brown et al., 2014; Bubb et al., 2014) appears to have had some success, continuing efforts to improve monitoring and indicator development in the region are clearly needed to fill gaps in national reporting. In fact, the ACB is currently working to adopt the use of global indicators for regional use to monitor resource use conflicts, pollution, and invasive species, and is exploring the possibility of adopting the global Key Biodiversity Area concept (IUCN, 2016). ACB is collaborating with NatureServe to visualize indicators and incorporate visualizations in the ASEAN Clearing-House Mechanism and potentially the Clearing-House Mechanisms of individual member states to help inform decision making and policy development. Improved use of indicators in the 6th national reports (for which submission is ongoing in 2019) will aid reporting on global progress toward meeting the Aichi Targets via the Global Biodiversity Outlook 5 report that is compiled using information from the 6th national reports among other sources.

Third, cross-border and international exchanges could be beneficial to share best practices and local solutions to regional indicator challenges, and to explore prospects for collaborative indicator development to economize costs. Encouragingly, several ASEAN member states mentioned information sharing in their reports. New tools, such as an indicator visualization dashboard created by the Biodiversity Indicators Partnership (2018; https://www.bipindicators.net), are also providing easier access to national disaggregations of global indicator data. New technologies and techniques for rapid, and automated analysis of large spatiotemporal datasets offer the potential for more automated, standardized and near, real-time generation of indicators and updates to

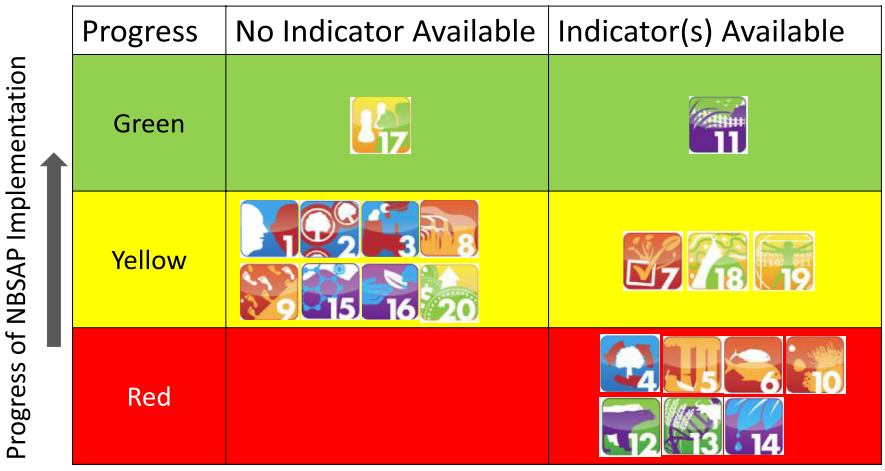

Fig. 6. Availability of indicators to measure progress toward Aichi Targets in relation to progress in the implementation of 2011–2020 National Biodiversity Strategy and Action Plans (NBSAP) in Southeast Asia. Progress according to ACB (2017): Green, most, if not all of the 10 ASEAN member states have taken the necessary actions towards the achievement of this target and have registered positive outcomes in their 5th National Reports to the Convention on Biological Diversity; yellow, at least half of the member states report that they have mobilized necessary actions towards the achievement of this target; and red, less than half of the member states have mobilized initiatives leading towards the achievement of this Aichi Target and have not demonstrated related positive impacts. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

track trends (Allen et al., 2019; Jetz et al., 2019).

Fourth, a weak underlying scientific infrastructure in much of Southeast Asia (Giam and Wilcove, 2012; Webb et al., 2010) may restrict indicator availability and the underlying data required to produce them (Navarro et al., 2017). With limited academic research programs to contribute to indicator conceptual development and measurement, governments become largely responsible not only for reporting on indicators but designing and measuring them. Targeted investment in national research institutions could help improve the availability and rigor of suitable biodiversity indicators, albeit over an intermediate to long time scale. In addition, researchers in biodiversity fields of study can help their governments by directing some of their research attention at developing and sharing data on indicators relevant to the Aichi Targets. Further efforts to enhance biodiversity observation efforts would lead to an increase in availability of local data to underpin such indicator generation.

With the year 2020 approaching, Southeast Asian countries will need to rapidly invest more attention to biodiversity indicators if they are to deploy robust suites of indicators to effectively measure progress toward the CBD Aichi Targets by the time that these Targets are meant to be achieved. These efforts will also provide a solid foundation for the region to guide effective and efficient conservation efforts to move towards the goals or targets that will emerge to replace the Aichi Targets after 2020.

Declaration of competing interest

None.

Acknowledgements

We thank Rashi Bhatt and Nicole Sears for their comments on previous drafts of this manuscript. This work was supported by the John D. And Catherine T. MacArthur Foundation (grant 15-109139-000-CSD).

References

Allen, J.M., Folk, R.A., Soltis, P.S., Soltis, D.E., Guralnick, R.P., 2019. Biodiversity synthesis across the green branches of the tree of life. Native Plants 5, 11–13. https://doi.org/10.1038/s41477-018-0322-7.

ASEAN Centre for Biodiversity (ACB), 2017. ASEAN Biodiversity Outlook 2. ASEAN Centre for Biodiversity, Philippines.

Bickford, D., Howard, S.D., Ng, D.J.J., Sheridan, J.A., 2010. Impacts of climate change on the amphibians and reptiles of Southeast Asia. Biodivers. Conserv. 19, 1043–1062. https://doi.org/10.1007/s10531-010-9782-4.

Borucke, M., Moore, D., Cranston, G., Gracey, K., Iha, K., Larson, J., Lazarus, E., Morales, J.C., Wackernagel, M., Galli, A., 2013. Accounting for demand and supply of the biosphere's regenerative capacity: the National Footprint Accounts' underlying methodology and framework. Ecol. Indicat. 24, 518–533. https://doi.org/10.1016/j.ecolind.2012.08.005.

Brooks, T.M., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Rylands, A.B., Konstant, W.R., Flick, P., Pilgrim, J., Oldfield, S., Magin, G., Hilton-Taylor, C., 2002. Habitat loss and extinction in the hotspots of biodiversity. Conserv. Biol. 16, 909–923. https://doi.org/10.1046/j.1523-1739.2002.00530.x.

Brown, C., Reyers, B., Ingwall-King, L., Mapendembe, A., Nel, J., O'Farrell, P., Dixon, M., Bowles-Newark, N.J., 2014. Measuring Ecosystem Services: Guidance on Developing Ecosystem Service Indicators. UNEP-WCMC, Cambridge, UK. https://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/303/original/1850_ESI_Guidance_A4_WEB.pdf?1424707843.

Bubb, P., Brooks, S., Chenery, A., 2014. Incorporating Indicators into NBSAPs - Guidance for Practitioners. UNEP-WCMC, Cambridge, UK. http://nbsapforum.net/sites/default/files/Incorporating%20Indicators%20into%20NBSAPs_FINAL.pdf.

Bubb, P., Chenery, A.M., Herkenrath, P., Kapos, V., Mapendembe, A., Stanwell-Smith, D., Walpole, M., 2011. National Indicators, Monitoring and Reporting for the Strategy for Biodiversity 2011-2020. UNEP-WCMC, Cambridge, UK.

Butchart, S.H.M., Akcakaya, H.R., Chanson, J., Baillie, J.E.M., Collen, B., Quader, S., Turner, W.R., Amin, R., Stuart, S.N., Hilton-Taylor, C., 2007. Improvements to the red list index. PLoS One 2. https://doi.org/10.1371/journal.pone.0000140.

Butchart, S.H.M., Scharlemann, J.P.W., Evans, M.I., Quader, S., Arico, S., Arinaitwe, J., Balman, M., Bennun, L.A., Bertzky, B., Besancon, C., Boucher, T.M., Brooks, T.M., Burfield, I.J., Burgess, N.D., Chan, S., Clay, R.P., Crosby, M.J., Davidson, N.C., De Silva, N., Devenish, C., Dutson, G.C.L., Fernandez, D., Fishpool, L.D.C., Fitzgerald, C., Foster, M., Heath, M.F., Hockings, M., Hoffmann, M., Knox, D., Larsen, F.W., Lamoreux, J.F., Loucks, C., May, I., Millett, J., Molloy, D., Morling, P., Parr, M., Ricketts, T.H., Seddon, N., Skolnik, B., Stuart, S.N., Upgren, A., Woodley, S., 2012. Protecting important sites for biodiversity contributes to meeting global conservation targets. PLoS One 7. https://doi.org/10.1371/journal.pone.0032529.

Butchart, S.H.M., Stattersfield, A.J., Bennun, L.A., Shutes, S.M., Akcakaya, H.R., Baillie, J.E.M., Stuart, S.N., Hilton-Taylor, C., Mace, G.M., 2004. Measuring global trends in the status of biodiversity: red list indices for birds. PLoS Biol. 2, 2294–2304. https://doi.org/10.1371/journal.pbio.0020383.

Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vie, J.C., Watson, R., 2010. Global biodiversity: indicators of recent declines. Science 328, 1164–1168. https://doi.org/10.1126/science.1187512.

Cardillo, M., Mace, G.M., Gittleman, J.L., Purvis, A., 2006. Latent extinction risk and the future battlegrounds of mammal conservation. Proc. Natl. Acad. Sci. U. S. A 103, 4157–4161. https://doi.org/10.1073/pnas.0510541103.

CBD, 2011. Strategic Plan for Biodiversity 2011–2020 and the Aichi Targets. Convention on Biological Diversity. Montreal, Canada. http://www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-EN.pdf.

CBD 4th National Report Portal, 2010. http://www.cbd.int/reports/nr4/.

CBD 5th National Report Portal, 2015. http://www.cbd.int/reports/nr5/.

Collen, B., Pettorelli, N., Baillie, J.E.M., Durant, S., 2013. Biodiversity Monitoring and Conservation: Bridging the Gap between Global Commitment and Local Action. Wiley-Blackwell, Cambridge, U.K.

de Freitas, D.S., de Oliveira, T.E., de Oliveira, J.M., 2019. Sustainability in the Brazilian pampa biome: a composite index to integrate beef production, social equity, and ecosystem conservation. Ecol. Indicat. 98, 317–326. https://doi.org/10.1016/j.ecolind.2018.10.012.

de Oliveira, T.E., de Freitas, D.S., Gianezini, M., Ruviaro, C.F., Zago, D., Mercio, T.Z., Dias, E.A., L'Ampert, V.D., Barcellos, J.O.J., 2017. Agricultural land use change in the

Brazilian pampa biome: the reduction of natural grasslands. Land Use Policy 63, 394–400. https://doi.org/10.1016/j.landusepol.2017.02.010.
Galli, A., Wackernagel, M., Iha, K., Lazarus, E., 2014. Ecological Footprint: implications for biodiversity. Biol. Conserv. 173, 121–132. https://doi.org/10.1016/j.biocon.2013.10.019.
Giam, X., Wilcove, D.S., 2012. The geography of conservation ecology research in Southeast Asia: current biases and future opportunities. Raffles Bull. Zool. 29–36.
Green, E.J., Buchanan, G.M., Butchart, S.H.M., Chandler, G.M., Burgess, N.D., Hill, S.L.L., Gregory, R.D., 2019. Relating characteristics of global biodiversity targets to reported progress. Conserv. Biol. https://doi.org/10.1111/cobi.13322.
Halpern, B.S., Longo, C., Hardy, D., McLeod, K.L., Samhouri, J.F., Katona, S.K., Kleisner, K., Lester, S.E., O'Leary, J., Ranelletti, M., Rosenberg, A.A., Scarborough, C., Selig, E.R., Best, B.D., Brumbaugh, D.R., Chapin, F.S., Crowder, L.B., Daly, K.L., Doney, S.C., Elfes, C., Fogarty, M.J., Gaines, S.D., Jacobsen, K.I., Karrer, L.B., Leslie, H.M., Neeley, E., Pauly, D., Polasky, S., Ris, B., St Martin, K., Stone, G.S., Sumaila, U.R., Zeller, D., 2012. An index to assess the health and benefits of the global ocean. Nature 488, 615. https://doi.org/10.1038/nature11397.
Halpern, B.S., Longo, C., Lowndes, J.S.S., Best, B.D., Frazier, M., Katona, S.K., Kleisner, K.M., Rosenberg, A.A., Scarborough, C., Selig, E.R., 2015. Patterns and emerging trends in global Ocean Health. PLoS One 10. https://doi.org/10.1371/journal.pone.0117863.
Han, X.M., Josse, C., Young, B.E., Smyth, R.L., Hamilton, H.H., Bowles-Newark, N., 2017. Monitoring national conservation progress with indicators derived from global and national datasets. Biol. Conserv. 213, 325–334. https://doi.org/10.1016/j.biocon.2016.08.023.
Han, X.M., Smyth, R.L., Young, B.E., Brooks, T.M., de Lozada, A.S., Bubb, P., Butchart, S.H.M., Larsen, F.W., Hamilton, H., Hansen, M.C., Turner, W.R., 2014. A biodiversity indicators dashboard: addressing challenges to monitoring progress towards the Aichi biodiversity targets using disaggregated global data. PLoS One 9. https://doi.org/10.1371/journal.pone.0112046.
Integrated Biodiversity Assessment Tool (IBAT), 2018. IBAT for Research and Conservation Planning. Online resource.
International Union for Conservation of Nature (IUCN), 2016. A Global Standard for the Identification of Key Biodiversity Areas, first ed. IUCN, Gland, Switzerland, Version 1.0.
Jetz, W., McGeoch, M.A., Guralnick, R., Ferrier, S., Beck, J., Costello, M., Fernandez, M., Geller, G.N., Keil, P., Merow, C., Meyer, C., Muller-Karger, F.E., Pereira, H.M., Regan, E.C., Schmeller, D.S., Turak, E., 2019. Essential biodiversity variables for mapping and monitoring species populations. Nat. Ecol. Evol. 3, 539–551. https://doi.org/10.1038/s41559-019-0826-1.
Koh, L.P., Sodhi, N.S., 2010. Conserving Southeast Asia's imperiled biodiversity: scientific, management, and policy challenges. Biodivers. Conserv. 19, 913–917. https://doi.org/10.1007/s10531-010-9818-9.
Lee, T.M., Jetz, W., 2008. Future battlegrounds for conservation under global change. Proc. R. Soc. Biol. Sci. 275, 1261–1270. https://doi.org/10.1098/rspb.2007.1732.
Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858. https://doi.org/10.1038/35002501.
Navarro, L.M., Fernández, N., Guerra, C., Guralnick, R., Kissling, W.D., Londoño, M.C., Muller-Karger, F., Turak, E., Balvanera, P., Costello, M.J., Delavaud, A., Serafy, G.E., Ferrier, S., Geijzendorffer, I., Geller, G.N., Jetz, W., Kim, E.S., Kim, H., Martin, C.S., McGeoch, M.A., Mwampamba, T.H., Nel, J.L., Nicholson, E., Pettorelli, N., Schaepman, M.E., Skidmore, A., Sousa Pinto, I., Vergara, S., Vihervaara, P., Xu, H., Yahara, T., Gill, M., Pereira, H.M., 2017. Monitoring biodiversity change through effective global coordination. Curr. Opin. Environ. Sustain. 29, 158–169.
Nijman, V., 2010. An overview of international wildlife trade from Southeast Asia. Biodivers. Conserv. 19, 1101–1114. https://doi.org/10.1007/s10531-009-9758-4.
Peh, K.S.H., 2010. Invasive species in Southeast Asia: the knowledge so far. Biodivers. Conserv. 19, 1083–1099. https://doi.org/10.1007/s10531-009-9755-7.
Potapov, P., Hansen, M.C., Laestadius, L., Turubanova, S., Yaroshenko, A., Thies, C., Smith, W., Zhuravleva, I., Komarova, A., Minnemeyer, S., Esipova, E., 2017. The last frontiers of wilderness: tracking loss of intact forest landscapes from 2000 to 2013. Sci. Adv. 3 https://doi.org/10.1126/sciadv.1600821.
Potapov, P., Yaroshenko, A., Turubanova, S., Dubinin, M., Laestadius, L., Thies, C., Aksenov, D., Egorov, A., Yesipova, Y., Glushkov, I., Karpachevskiy, M., Kostikova, A., Manisha, A., Tsybikova, E., Zhuravleva, I., 2008. Mapping the world's intact forest landscapes by remote sensing. Ecol. Soc. 13.
Rodrigues, A.S.L., Brooks, T.M., Butchart, S.H.M., Chanson, J., Cox, N., Hoffmann, M., Stuart, S.N., 2014. Spatially explicit trends in the global conservation status of vertebrates. PLoS One 9. https://doi.org/10.1371/journal.pone.0113934.
Salvati, L., Carlucci, M., 2014. A composite index of sustainable development at the local scale: Italy as a case study. Ecol. Indicat. 43, 162–171. https://doi.org/10.1016/j.ecolind.2014.02.021.
Schipper, J., Chanson, J.S., Chiozza, F., Cox, N.A., Hoffmann, M., Katariya, V., Lamoreux, J., Rodrigues, A.S.L., Stuart, S.N., Temple, H.J., Baillie, J., Boitani, L., Lacher, T.E., Mittermeier, R.A., Smith, A.T., Absolon, D., Aguiar, J.M., Amori, G., Bakkour, N., Baldi, R., Berridge, R.J., Bielby, J., Black, P.A., Blanc, J.J., Brooks, T.M., Burton, J.A., Butynski, T.M., Catullo, G., Chapman, R., Cokeliss, Z., Collen, B., Conroy, J., Cooke, J.G., da Fonseca, G.A.B., Derocher, A.E., Dublin, H.T., Duckworth, J.W., Emmons, L., Emslie, R.H., Festa-Bianchet, M., Foster, M., Foster, S., Garshelis, D.L., Gates, C., Gimenez-Dixon, M., Gonzalez, S., Gonzalez-Maya, J.F., Good, T.C., Hammerson, G., Hammond, P.S., Happold, D., Happold, M., Hare, J., Harris, R.B., Hawkins, C.E., Haywood, M., Heaney, L.R., Hedges, S., Helgen, K.M., Hilton-Taylor, C., Hussain, S.A., Ishii, N., Jefferson, T.A., Jenkins, R.K.B., Johnston, C.H., Keith, M., Kingdon, J., Knox, D.H., Kovacs, K.M., Langhammer, P., Leus, K., Lewison, R., Lichtenstein, G., Lowry, L.F., Macavoy, Z., Mace, G.M., Mallon, D.P., Masi, M., McKnight, M.W., Medellin, R.A., Medici, P., Mills, G., Moehlman, P.D., Molur, S., Mora, A., Nowell, K., Oates, J.F., Olech, W., Oliver, W.R.L., Oprea, M., Patterson, B.D., Perrin, W.F., Polidoro, B.A., Pollock, C., Powel, A., Protas, Y., Racey, P., Ragle, J., Ramani, P., Rathbun, G., Reeves, R.R., Reilly, S.B., Reynolds, J.E., Rondinini, C., Rosell-Ambal, R.G., Rulli, M., Rylands, A.B., Savini, S., Schank, C.J., Sechrest, W., Self-Sullivan, C., Shoemaker, A., Sillero-Zubiri, C., De Silva, N., Smith, D.E., Srinivasulu, C., Stephenson, P.J., van Strien, N., Talukdar, B.K., Taylor, B.L., Timmins, R., Tirira, D.G., Tognelli, M.F., Tsytsulina, K., Veiga, L.M., Vie, J.C., Williamson, E.A., Wyatt, S.A., Xie, Y., Young, B.E., 2008. The status of the world's land and marine mammals: diversity, threat, and knowledge. Science 322, 225–230. https://doi.org/10.1126/science.1165115.
Sodhi, N.S., Koh, L.P., Brook, B.W., Ng, P.K.L., 2004. Southeast Asian biodiversity: an impending disaster. Trends Ecol. Evol. 19, 654–660. https://doi.org/10.1016/j.tree.2004.09.006.
Sodhi, N.S., Koh, L.P., Clements, R., Wanger, T.C., Hill, J.K., Hamer, K.C., Clough, Y., Tscharntke, T., Posa, M.R.C., Lee, T.M., 2010a. Conserving Southeast Asian forest biodiversity in human-modified landscapes. Biol. Conserv. 143, 2375–2384. https://doi.org/10.1016/j.biocon.2009.12.029.
Sodhi, N.S., Posa, M.R.C., Lee, T.M., Bickford, D., Koh, L.P., Brook, B.W., 2010b. The state and conservation of Southeast Asian biodiversity. Biodivers. Conserv. 19, 317–328. https://doi.org/10.1007/s10531-009-9607-5.
Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E., Rodrigues, A.S.L., Fischman, D.L., Waller, R.W., 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306, 1783–1786. https://doi.org/10.1126/science.1103538.
Tittensor, D.P., Walpole, M., Hill, S.L.L., Boyce, D.G., Britten, G.L., Burgess, N.D., Butchart, S.H.M., Leadley, P.W., Regan, E.C., Alkemade, R., Baumung, R., Bellard, C., Bouwman, L., Bowles-Newark, N.J., Chenery, A.M., Cheung, W.W.L., Christensen, V., Cooper, H.D., Crowther, A.R., Dixon, M.J.R., Galli, A., Gaveau, V., Gregory, R.D., Gutierrez, N.L., Hirsch, T.L., Hoft, R., Januchowski-Hartley, S.R., Karmann, M., Krug, C.B., Leverington, F.J., Loh, J., Lojenga, R.K., Malsch, K., Marques, A., Morgan, D.H.W., Mumby, P.J., Newbold, T., Noonan-Mooney, K., Pagad, S.N., Parks, B.C., Pereira, H.M., Robertson, T., Rondinini, C., Santini, L., Scharlemann, J.P.W., Schindler, S., Sumaila, U.R., Teh, L.S.L., van Kolck, J., Visconti, P., Ye, Y.M., 2014. A mid-term analysis of progress toward international biodiversity targets. Science 346, 241–244. https://doi.org/10.1126/science.1257484.
United Nations, 2015. Probabilistic Population Projections Based on the World Population Prospects: the 2015 Revision. Population Division, DESA.
Walpole, M., Almond, R.E.A., Besancon, C., Butchart, S.H.M., Campbell-Lendrum, D., Carr, G.M., Collen, B., Collette, L., Davidson, N.C., Dulloo, E., Fazel, A.M., Galloway, J.N., Gill, M., Goverse, T., Hockings, M., Leaman, D.J., Morgan, D.H.W., Revenga, C., Rickwood, C.J., Schutyser, F., Simons, S., Stattersfield, A.J., Tyrrell, T.D., Vie, J.C., Zimsky, M., 2009. Tracking progress toward the 2010 biodiversity target and beyond. Science 325, 1503–1504. https://doi.org/10.1126/science.1175466.
Webb, C.O., Slik, J.W.F., Triono, T., 2010. Biodiversity inventory and informatics in Southeast Asia. Biodivers. Conserv. 19, 955–972. https://doi.org/10.1007/s10531-010-9817-x.
Wilcove, D.S., Koh, L.P., 2010. Addressing the threats to biodiversity from oil-palm agriculture. Biodivers. Conserv. 19, 999–1007. https://doi.org/10.1007/s10531-009-9760-x.