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Biodiversity conservation and ecological value of protected areas: a review of current situation and future prospects

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The establishment of protected areas (PAs) is an effective way to biodiversity conservation while maintaining the multiple functions of ecosystem services. However, there is still a lack of comprehensive analysis on the relationship between PAs, biodiversity conservation, and ecological value in the field of research on prospects. Therefore, based on the research progress of literature content, this paper systematically reviews and evaluates domestic and international studies in terms of the biodiversity conservation and the ecological value of PAs. The results showed that relevant studies in recent years have mainly analyzed the spatial layout, area changes and conservation effectiveness of PAs in relation to biodiversity; By constructing the connotation system of ecological value concept of PAs, the research progress of ecological value accounting, ecological value realization and transformation, and ecological value types of PAs is further discussed, and the prospects of biodiversity conservation and ecological value research of PAs is proposed. This study provides a reference for the implementation of the Kunming-Montreal Global Biodiversity Framework and the construction and optimization of PAs system.

KEYWORDS

protected areas, biodiversity conservation, ecological value, key biodiversity areas, human well-being

1 Introduction

Biodiversity is related to human well-being and is an important foundation for human survival and development. The establishment of PAs is an effective way to biodiversity conservation while maintaining the multiple functions of ecosystem services. Addressing climate change and biodiversity conservation are two global hotspots and difficult environmental issues. Advancing synergies between climate change response and biodiversity conservation is critical to addressing the current environmental crisis. PAs are specific spatial areas whose main function is to protect ecosystems, and they play an important role in biodiversity conservation, maintaining the stability of ecosystems and improving the quality of the ecological environment, as well as playing a primary role in maintaining national ecological security (Leverington et al., 2010; McDonald and Boucher, 2011).

As an area designated and managed by countries around the world to effectively protect biodiversity (Borrini-Feyerabend et al., 2013), PAs are one of the most effective ways to protect natural resources and ecological environment. As defined by the International Union for Conservation of Nature (IUCN), a protected area is: "A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley, 2016). According to the classification criteria of the IUCN, PAs can be divided into six categories: strict nature reserve and wilderness area, national park, natural monument or feature, habitat/species management area, protected landscape/seascape, protected area with sustainable use of natural resources. PAs not only provide a large amount of raw materials for human beings, but also have great ecological and economic benefits (Mulongoy and Badu, 2008). The ecological value assessment of PAs has been paid more and more attention, and has become a frontier topic in ecology and environmental economics (Figgis et al., 2015).

Although the concept of PAs is currently defined differently by countries and international organizations around the world, the conservation goals basically cover biodiversity, typical ecosystems and important natural resources. With the development and implementation of the post-2020 global biodiversity framework, research in the field of biodiversity conservation in PAs has also been deepened. The research focuses on key ecosystems and rare and endangered species, their status and changes, and a series of scientific issues such as the number and area of PAs, the number of important ecosystems and species protected, and the effectiveness of biodiversity conservation. The ecological value of PAs is one of the bases for classification and grading of the new PAs system. According to the framework proposed by the IUCN's Wilderness Protected Areas: Management Guidelines for IUCN Category 1b Protected Areas, PAs such as wilderness have instrument value and instinct value, which is essential for protecting biodiversity and maintaining ecosystem services, while helping to maintain cultural and linguistic diversity (Casson et al., 2016). The research of ecological value of PAs is of key significance for promoting the construction and development of new PAs system and deepening the realization of the value of ecological products.

However, there is a lack of systematic analysis and interpretation of hot topics in biodiversity conservation and ecological value research in PAs, which makes it difficult to predict their potential hot spots and research trends. This paper aims to systematically review the main progress of biodiversity conservation research in PAs in the past 20 years, explore the research hotspots and trends in the field of ecological value of PAs, and put forward prospects for the future development direction, so as to promote the in-depth development of related research on PAs, with a view to providing reference for the formulation and implementation of the Kunming-Montreal Global Biodiversity Framework, especially in the construction and optimization of PAs systems.

2 Methods

In order to systematically and comprehensively review the research status of PAs, CNKI (China National Knowledge Infrastructure) and WoS (Web of Science) literature databases were used as data sources, and the search was conducted with the subject terms and titles "protected areas, biodiversity conservation and ecological value". To ensure the comprehensiveness of the data sources, "national park", "nature reserve", "nature park", "scenic area", "natural heritage site", "wetland park" and "forest park" were used to replace the PAs for secondary retrieval; ecological products value, natural capital value, ecosystem service value, ecological capital value, ecosystem assets value, and ecosystem assets value, were used to replace ecological value for re-retrieval. The literature types were defined as articles and review, with a time span of 2003–2022, and the retrieval time was April 2023. All 2,164 documents were de-duplicated in CiteSpace 5.8.R2, and 1,051 valid search results were retained.

After processing and analyzing the literature with the software CiteSpace 5.8.R1, the COOC 9.94 software was used to perform word frequency statistics on the retained valid literature data and determine the high-frequency words, and co-word cluster analysis was used to construct the co-word matrix. Then, high-frequency keywords were clustered in VOSviewer 1.6.16 to realize multi-dimensional quantification and visualization of literature data, identify research hotspots of biodiversity conservation and ecological value in PAs, describe the interaction between research hotspots and the closeness of the internal correlation in the research field, and judge their status and research development.

3 Results

The keywords in the literature were processed with the help of COOC software, and the retained effective keywords were counted. The results showed that the keywords with high frequency were: nature reserves, ecosystem services, biodiversity conservation, etc. (Table 1). In order to improve the credibility of the study, the samples were selected as keywords with a frequency of 10 times or more for subsequent analysis.

3.1 The quantity and spatial distribution of PAs

How many PAs need to be built globally to effectively conserve sufficient biodiversity has always been a key issue of concern for scholars around the world (Baillie and Zhang, 2018). The 2010 target for PAs adopted by the 7th Conference of the Parties to the Convention on Biological Diversity includes the goal of "effectively protecting at least 10% of each ecoregion in the world" (Coad et al., 2009). In recent years, many scholars have proposed the goal that nature reserves and PAs should cover 30% of the world's land,

TABLE 1 Complete co-occurrence matrix of top 10 high-frequency keywords.

	protected areas	ecosystem service	biodiversity conservation	marine protection area	ecological value	climate change	sustainable development	key biodiversity areas	human well-being	social-ecosystem
protected areas	146	52	34	6	37	18	26	41	24	15
ecosystem service	52	135	27	19	13	16	9	12	8	7
biodiversity conservation	34	27	120	5	34	13	11	7	9	4
marine protection area	6	19	5	114	16	6	2	3	7	8
ecological value	37	13	34	16	106	8	9	4	6	3
climate change	18	16	13	6	8	92	3	5	5	4
sustainable development	26	9	11	2	9	3	71	3	1	9
key biodiversity areas	41	12	7	3	4	5	3	68	2	5
human well-being	24	8	9	7	6	5	1	2	57	1
social-ecosystem	15	7	4	8	3	4	9	5	1	54

freshwater and oceans by 2030 (Dinerstein et al., 2019). In order to reverse the continuous decline of biodiversity and ensure the sustainable development of human society, scholars from various countries have also paid more attention to PAs. At the 9th World Wilderness Congress in 2009, Harvey Locke proposed that at least 50% of the area should be set aside as PAs or OECMs (Other Effective Area-based Conservation Measures) at the global scale (Cao et al., 2019). Scientists have also called for 50% of terrestrial and marine areas to be set up as some form of PAs or OECMs, and estimate that these areas could protect 85% of species from extinction (Wilson, 2016).

Biodiversity is not evenly distributed on the earth, and it is necessary to find the most concentration areas of biodiversity for priority conservation, and on this basis balance the economic, social and ecological benefits, so as to achieve the optimal spatial layout of PAs. By identifying important areas of biodiversity such as biodiversity hotspots and key biodiversity areas (KBAs), the key question of "where to conserve" can be further answered. The identification, ranking and vacancy analysis of KBAs can provide an important basis for the expansion of PAs networks (Langhammer et al., 2007), and become an important means to assess the progress of global biodiversity targets. Recent studies have shown that approximately 55.8% of global KBAs have been covered by PAs. When further designating 0.36% of the terrestrial area within the global KBAs into PAs, the conservation coverage of threatened vertebrates can be increased by an average of approximately 14.7% (Kullberg et al., 2019). Determining whether the location and scope of the current PAs is reasonable, and making boundary and location adjustments are essential for effective conservation. For areas affected by long-term human impacts, it is necessary to take advantage of the relationship between communities and nature in different regions to promote sustainable resource utilization and new models of PAs, and to expand the area of PAs based on the existing ones.

3.2 Biodiversity changes and influencing factors in PAs

As one of the core areas of biodiversity conservation, whether PAs can effectively protect the ecosystem and wildlife in the region, i.e., the study of the effectiveness of PAs and its influencing factors, is also a key scientific issue in the field of PAs (Figure 1).

Despite the increasing impacts of climate change and human disturbances on biodiversity, changes in land cover/use and landscape patterns within PAs are generally less than outside PAs (Nagendra, 2008; Rodriguez-Rodriguez et al., 2019), reflecting the stability of PAs in response to external disturbances. Studies around changes in forest and wetland ecosystems are relatively more numerous than those in grassland, desert and marine ecosystems in PAs (Xin et al., 2014; Song et al., 2018). From the perspective of species, scholars in various countries have conducted systematic monitoring of rare and endangered species or flagship species under key protection in PAs. A large number of biodiversity monitoring networks and field stations have been established, and the changes of biodiversity are measured by quantitative monitoring data of ecosystems and species in the field (Geldmann et al., 2021).

The conservation effectiveness of PAs is also one of the research hotspots, and scholars have conducted numerous studies at the global scale, national scale, and individual PAs. The biodiversity change or conservation effectiveness of PAs is affected by a combination of factors such as climate change, human disturbance and related policies. Climate change leads to the continuous migration of some species in search of new suitable

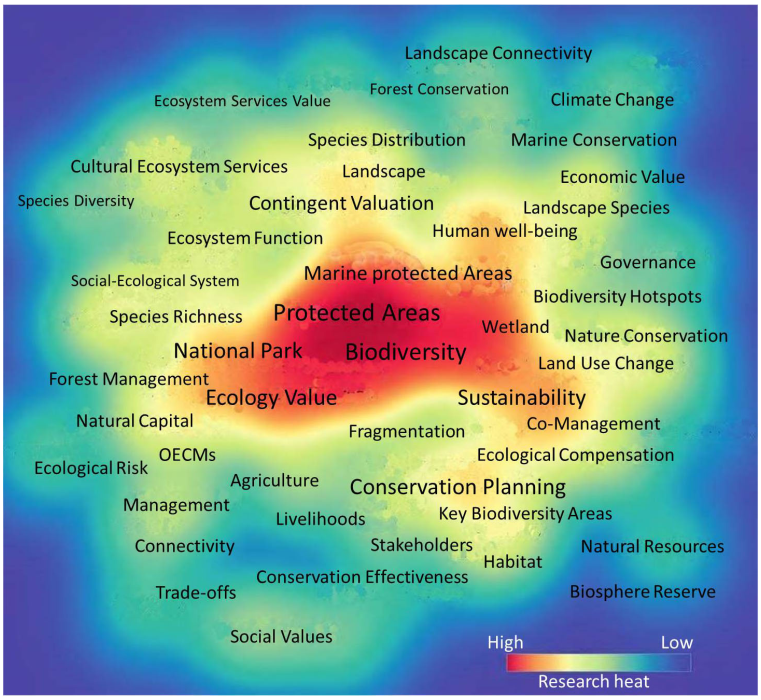

FIGURE 1
Heat map of study distribution.

habitats, and some species even migrate to habitats outside the PAs, resulting in the disappearance of these species within PAs, which will not be conducive to the effective conservation of these species (Klausmeyer and Shaw, 2009; D'Amen et al., 2011). Although the establishment of PAs has mitigated the impact of human disturbance to a certain extent (Guette et al., 2018; Feng et al., 2022), however, a global study still shows that the average degree of human disturbance in some PAs is significantly higher than that outside (Geldmann et al., 2021). The increase of human disturbance has a significant impact on the effectiveness of PAs in protecting ecosystems (Feng et al., 2022) or species (such as giant pandas, Wei et al., 2020). In addition, the human disturbances in the surrounding areas of PAs may be significantly increased due to the existence of PAs. This phenomenon is called the "leakage effect" of PAs, which is not conducive to the overall protection of PAs (Ewers and Rodrigues, 2008). National policy is also an important factor. Recent studies have also focused on the impact of PAs downgrading, downsizing, and degazettement (PADDD) events on the conservation effectiveness (Qin et al, 2019).

3.3 Comprehensive assessment of ecological value of protected areas

The ecological value assessment of PAs is responsible for various tasks such as maintaining ecological sustainability, ensuring equitable distribution of resources, and achieving human well-being (Liu et al., 2010), and the current international ecological value assessment system of PAs mainly covers ecosystem services value (ESV) and ecosystem intrinsic value (EIV).

Ecosystem services are the benefits directly or indirectly obtained by human beings from the ecosystem (Costanza et al., 1997). PAs are the key sources of ecosystem services, and its value assessment is an indispensable step to balance protection and development. At the scale of PAs, the main research contents include comprehensive evaluation and dynamic change of ecosystem service value of PAs (Považan et al., 2015), single ecosystem service value assessment of PAs (Belkayali et al., 2010), and single ecosystem service value assessment of multiple PAs at a specific spatial scale (Mayer and Woltering, 2018) The evaluation methods mainly include two types: monetized valuation and non-monetized valuation. The former includes revealed preference method, stated preference method and cost method, and the latter includes ranking method (Farber et al., 2006). Relatively, the connotation system and evaluation method of the ecosystem intrinsic value are not yet mature and are rarely applied in PAs. However, scholars gradually realize the importance of distinguishing the ecosystem intrinsic value and try to interpret the connotation of the ecosystem intrinsic value, and also believe that the assessment of ecosystem intrinsic value can provide a basis for sustainable management decisions in PAs (Sheng et al., 2019).

The analysis of the interest relationship in the realization of ecological value of PAs is also one of the research hotspots. To achieve the conservation goals of PAs, it is necessary to formulate effective authorization governance and adaptive management plans, and stakeholder participation is an important link. In the study of the influencing factors of ecological value, previous studies have verified the factors that may cause the change of ecological value in monetary valuation or non-monetary valuation, and explored the elastic response mechanism of ecosystem service value to the influencing factors. These factors mainly include: (i) land use type changes, such as arable land expansion and grassland degradation (Shi et al., 2020); (ii) species invasion and biomass changes in PAs (Turpie et al., 2003; Grilli et al., 2017); and (iii) human activity disturbance, indigenous characteristics and public perception (Martín-López et al., 2007; Kenter et al., 2016; Riper et al., 2017).

The ecological value of PAs can promote human well-being. PAs can provide humans with intangible ecological values such as aesthetics, recreation and cultural heritage (Vejre et al., 2010). Human well-being has multiple components, including the basic material conditions needed to maintain a high quality of life, the right to freedom and choice, health, good social relations, and security. Related studies include two main aspects: (i) the impact and assessment of the establishment of PAs on human well-being changes, where negative impacts can be balanced by positive impacts under specific external conditions (Gjertsen, 2005; Pullin et al., 2013; Naidoo et al., 2019), but the discussion on how to achieve this situation needs to be expanded; (ii) The relationship between ecosystem services and human well-being and how to ensure equal access to ecosystem services, such as the role of payment for ecosystem services in poverty reduction, and the impact relationship between increased ecosystem resilience and human well-being promotion (Daw et al., 2011; Daw et al., 2016).

4 Conclusions and future directions

4.1 Conclusion

In order to maintain biodiversity and ensure the stability of ecosystem function, this paper summarizes and reviews the relevant researches in recent years from the aspects of spatial layout of PAs, the relationship with biodiversity distribution, and the change of biodiversity in PAs. The existing research mainly focuses on the state of PAs and biodiversity at a certain stage, and is devoted to exploring a series of key scientific issues such as the number and spatial distribution of PAs. At the same time, the biodiversity in PAs will undergo temporal and spatial dynamic change with climate change, human activities and their own succession, etc. Based on the analysis of biodiversity changes in PAs, a large number of conservation effectiveness assessment studies have been conducted to identify the main influencing factors of different PAs. Ecological value assessment and accounting of PAs is the current core mainstream research hotspot, focusing on the value assessment of ecosystem services provided by PAs to humans, and gradually forming a methodological system, but there is still much room for development in the intrinsic value assessment. The research on the interest relationship of ecological value realization of PAs focuses on the implementation of policies such as eco-industry development and ecological compensation in PAs, as well as the demands and responses of stakeholders in the process of ecological value management. The existing research system on the influencing factors of ecological value of PAs, ecological value and human well-being promotion research needs to be further improved, and further development can be achieved by enhancing the association with mainstream research hotspots in the future.

4.2 Future directions

Studies have shown that focusing solely on the goal of the area, quantity and proportion of PAs, while ignoring the changes in biodiversity, makes it difficult for many PAs to achieve effective protection (di Minin and Toivonen, 2015). Future research should pay more attention to the comprehensive role of PAs in biodiversity conservation, maintaining ecosystem services and carbon sequestration capacity, effectively plan the spatial layout of PAs, and predict potential important areas in combination with future trend changes. Combined with the analysis of the dynamic changes of long-term monitoring data of various indicators, the systematic evaluation of the effectiveness of PAs can be realized. The research results of spatial optimization layout, protection effectiveness evaluation and major conservation objects changes of PAs are integrated to identify and clarify the areas of new PAs and planned corridors, and effectively improve the quality and connectivity of PAs. By combining the PAs with the sustainable development of the areas where they are located, it is further explored how to promote the sustainable development model of human–earth harmony in and around the PAs on the premise of improving or maintaining the protection effectiveness of the PAs.

The establishment of ecological value assessment system applicable to the scale of PAs can carry out comprehensive ecological value assessment practice in different types of PAs, and enrich the research perspective of ecological value realization of PAs. For different types of PAs, comparative and applicability studies on ecological value realization models of PAs to help develop ecological product markets; Construct a stakeholder system for the realization mechanism of ecological value of PAs, explore a benign interaction mechanism between human well-being promotion and ecological value transformation, provide theoretical support for the construction of ecological compensation system and governance optimization of PAs, and promote the sustainable transformation of ecological value of PAs. Strengthen the application research on the influencing factors of ecological value, explore the influencing factors of economy, policy and ecology, carry out validation and comparative studies, provide the basis for the formulation of resource management and utilization policies of PAs, and improve the protection efficiency.

The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

Author contributions

HW: Funding acquisition, Investigation, Methodology, Writing – review & editing. XH: Conceptualization, Data curation, Formal Analysis, Software, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Baillie, J., and Zhang, Y. P. (2018). Space for nature. *Science* 361, 1051. doi: 10.1126/science.aau1397

Belkayali, N., Atan, M., Talay, I., and Akpinar, N. (2010). Determination of economic value of greme historical national park via contingent valuation method. *Sci. Res. Essays.* 5 (9), 934–940.

Borrini-Feyerabend, G., Dudley, N., Jaeger, T., Lassen, B., Broome, N. P., Phillips, A., et al. (2013). *Governance of protected areas: from understanding to action* (Switzerland: IUCN).

Cao, Y., Yang, R., and Martin, V. G. (2019). Nature needs half: A new vision for global protected areas. *Landscape Architecture* 26 (4), 39–44.

Casson, S. A., Martin, V. G., and Watson, A. (2016). *Wilderness protected areas: management guidelines for IUCN category 1b protected areas* (Gland, Switzerland: IUCN), 1–11.

Coad, L., Burgess, N. D., Loucks, C., Fish, L., Scharlemann, J. P. W., Duarte, L., et al. (2009). *The ecological representativeness of the global protected areas estate in 2009: Progress towards the CBD 2010 target* (Cambridge, United Kingdom: UNEP World Conservation Monitoring Centre).

Costanza, R., Arge, R. d., Groot, R. d., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature.* 387, 253–260. doi: 10.1038/387253a0

D'Amen, M., Bombi, P., Pearman, P. B., Schmatz, D. R., Zimmermann, N. E., and Bologna, M. A. (2011). Will climate change reduce the efficacy of protected areas for amphibian conservation in Italy? *Biol. Conserv.* 144, 989–997. doi: 10.1016/j.biocon.2010.11.004

Daw, T., Brown, K., Rosendo, S., and Pomeroy, R. (2011). Applying the ecosystem services concept to poverty alleviation: The need to disaggregate human well-being. *Environ. Conserv.* 38 (4), 370–379. doi: 10.1017/S0376892911000506

Daw, T. M., Hicks, C. C., Brown, K., Chaigneau, T., Januchowski-Hartley, F. A., Cheung, W. W. L., et al. (2016). Elasticity in ecosystem services: exploring the variable relationship between ecosystems and human well-being. *Ecol. Society.* 21 (2), 11. doi: 10.5751/ES-08173-210211

di Minin, E., and Toivonen, T. (2015). Global protected area expansion: Creating more than paper parks. *BioScience.* 65, 637–638. doi: 10.1093/biosci/biv064

Dinerstein, E., Vynne, C., Sala, E., Joshi, A. R., Fernando, S., Lovejoy, T. E., et al. (2019). A global deal for nature: Guiding principles, milestones, and targets. *Sci. Adv.* 5, eaaw2869. doi: 10.1126/sciadv.aaw2869

Dudley, N. (2016). *Guidelines for applying protected area management categories* (Switzerland: IUCN).

Ewers, R. M., and Rodrigues, A. S. L. (2008). Estimates of reserve effectiveness are confounded by leakage. *Trends Ecol. Evol.* 23, 113–116. doi: 10.1016/j.tree.2007.11.008

Farber, S., Costanza, R., Childers, D. L., Erickson, J., Gross, K., Grove, M., et al. (2006). Linking ecology and economics for ecosystem management. *BioScience.* 56 (2), 121–133. doi: 10.1641/0006-3568(2006)056[0121:LEAEFE]2.0.CO;2

Feng, C. T., Cao, M., Liu, F. Z., Zhou, Y., Du, J. H., Zhang, L. B., et al. (2022). Improving protected area effectiveness through consideration of different human-pressure baselines. *Conserv. Biol.* 36, e13887. doi: 10.1111/cobi.13887

Figgis, P., Mackey, B., Fitzsimons, J., and Australian Committee for, I. U. C. N. (2015). *Valuing nature: protected areas and ecosystem services* (Sydney: Australian Committee for IUCN), 54–, 68.

Geldmann, J., Deguignet, M., Balmford, A., Burgess, N. D., Dudley, N., Hockings, M., et al. (2021). Essential indicators for measuring sitebased conservation effectiveness in the post-2020 global biodiversity framework. *Conserv. Lett.* 14, e12792. doi: 10.1111/conl.12792

Gjertsen, H. (2005). Can Habitat Protection lead to improvements in human well-being. *Evidence Mar. protected areas Philippines. World Dev.* 33 (2), 199–217. doi: 10.1016/j.worlddev.2004.07.009

Grilli, G., Ciolli, M., Garegnani, G., Geri, F., Sacchelli, S., Poljanec, A., et al. (2017). A method to assess the economic impacts of forest biomass use on ecosystem services in a national park. *Biomass Bioenergy.* 98, 252–263. doi: 10.1016/j.biombioe.2017.01.033

Guette, A., Godet, L., Juigner, M., and Robin, M. (2018). Worldwide increase in Artificial Light At Night around protected areas and within biodiversity hotspots. *Biol. Conserv.* 223, 97–103. doi: 10.1016/j.biocon.2018.04.018

Kenter, J. O., Jobstvogt, N., Watson, V., Irvine, K. N., Christie, M., and Bryce, R. (2016). The impact of information, value-deliberation and group-based decision-making on values for ecosystem services: integrating deliberative monetary valuation and storytelling. *Ecosystem Services.* 21, 270–290. doi: 10.1016/j.ecoser.2016.06.006

Klausmeyer, K. R., and Shaw, M. R. (2009). Climate change, habitat loss, protected areas and the climate adaptation potential of species in Mediterranean ecosystems worldwide. *PloS One* 4, e6392. doi: 10.1371/journal.pone.0006392

Kullberg, P., di Minin, E., and Moilanen, A. (2019). Using key biodiversity areas to guide effective expansion of the global protected area network. *Global Ecol. Conserv.* 20, e00768. doi: 10.1016/j.gecco.2019.e00768

Langhammer, P. F., Bakarr, M., Bennun, L., Brooks, T., Clay, R., Darwall, W., et al. (2007). *Identification and gap analysis of key biodiversity areas: targets for comprehensive protected area systems* (Gland, Switzerland: IUCN).

Leverington, F., Costa, K. L., Pavese, H., Lisle, A., and Hockings, M. (2010). A global analysis of protected area management effectiveness. *Environ. Manage.* 46 (5), 685–698. doi: 10.1007/s00267-010-9564-5

Liu, S., Costanza, R., Farber, S., and Troy, A. (2010). Valuing ecosystem services: theory, practice, and the need for a transdisciplinary Synthesis. *Ann. New York Acad. Sci.* 1185, 54–78. doi: 10.1111/j.1749-6632.2009.05167.x

Martín-López, B., Montes, C., and Benayas, J. (2007). Influence of user characteristics on valuation of ecosystem services in doñana natural protected area (South-west Spain). *Environ. Conserv.* 34 (3), 215–224. doi: 10.1017/s0376892907004067

Mayer, M., and Woltering, M. (2018). Assessing and valuing the recreational ecosystem services of Germany's national parks using travel cost models. *Ecosystem Services.* 31, 371–386. doi: 10.1016/j.ecoser.2017.12.009

McDonald, R. I., and Boucher, T. M. (2011). Global development and the future of the protected area strategy. *Biol. Conserv.* 144 (1), 383–392. doi: 10.1016/j.biocon.2010.09.016

Mulongoy, K. J., and Badu, G. S. (2008). The value of nature: ecological, economic, cultural and social benefits of protected areas. *Quaternary Sci. Rev.* 73 (4), 31–47. doi: 10.1016/j.quascirev.2013.05.005

Nagendra, H. (2008). Do parks work? Impact of protected areas on land cover clearing. *Ambio* 37, 330–337. doi: 10.1579/06-R-184.1

Naidoo, R., Gerkey, D., Hole, D., Pfaff, A., Ellis, A. M., Golden, C. D., et al. (2019). Evaluating the impacts of protected areas on human well-being across the developing world. *Sci. Advances.* 5 (4), eaav3006. doi: 10.1126/sciadv.aav3006

Považan, R., Getzner, M., and Švajda, J. (2015). On the valuation of ecosystem services in Muránska Planina National Park (Slovakia). *J. Protected Mountain Areas Res. Management.* 7, 61–69. doi: 10.1553/eco.mont-7-2s61

Pullin, A. S., Bangpan, M., Dalrymple, S., Dickson, K., Haddaway, N. R., Healey, J. R., et al. (2013). Human well-being impacts of terrestrial protected areas. *Environ. Evidence.* 2 (1), 2166–2174. doi: 10.1186/2047-2382-2-19

Qin, S. Y., Golden Kroner, R. E., Cook, C., Tesfaw, A. T., Braybrook, R., Rodriguez, C. M., et al. (2019). Protected area downgrading, downsizing, and degazettement as a threat to iconic protected areas. *Conserv. Biol.* 33, 1275–1285. doi: 10.1111/cobi.13365

Rodriguez-Rodriguez, D., Martínez-Vega, J., and Echavarría, P. (2019). A twenty year GIS-based assessment of environmental sustainability of land use changes in and around protected areas of a fast developing country: Spain. *Int. J. Appl. Earth Observation Geoinformation* 74, 169–179. doi: 10.1016/j.jag.2018.08.006

Sheng, H.-X., Xu, H., Zhang, L., and Chen, W. (2019). Ecosystem intrinsic value and its application in decision-making for sustainable development. *J. Nat. Conserv.* 49, 27–36. doi: 10.1016/j.jnc.2019.01.008

Shi, L., Halik, Ü., Mamat, Z., and Wei, Z. (2020). Spatio-temporal variation of ecosystem services value in the northern Tianshan mountain economic zone from 1980 to 2030. *PeerJ.* 8 (3), e9582. doi: 10.7717/peerj.9582

Song, R. L., Yao, J. X., Wu, K. Y., Zhang, X. C., Lü, Z., Zhu, Z. G., et al. (2018). Evaluation of the effectiveness of marine protected areas: Methodologies and progress. *Biodiversity Sci.* 26, 286–294. doi: 10.17520/biods.2018005

Turpie, J. K., Heydenrych, B. J., and Lamberth, S. J. (2003). Economic value of terrestrial and marine biodiversity in the cape floristic region: implications for defining effective and socially optimal conservation strategies. *Biol. Conserv.* 112 (1-2), 233–251. doi: 10.1016/S0006-3207(02)00398-1

Van Riper, C. J., Kyle, G. T., Sherrouse, B. C., Bagstad, K. J., and Sutton, S. G.. (2017). Toward an integrated understanding of perceived biodiversity values and environmental conditions in a national park. *Ecol. Indicators.* 72 (1), 278–287. doi: 10.1016/j.ecolind.2016.07.029

Vejre, H., Jensen, F. S., and Bo, J. T. (2010). Demonstrating the importance of intangible ecosystem services from peri-urban landscapes. *Ecol. Complexity.* 7 (3), 338–348. doi: 10.1016/j.ecocom.2009.09.005

Wei, W., Swaisgood, R. R., Pilfold, N. W., Owen, M. A., Dai, Q., Wei, F., et al. (2020). Assessing the effectiveness of China's panda protection system. *Curr. Biol.* 30, 1280–1286. doi: 10.1016/j.cub.2020.01.062

Wilson, E. O. (2016). *Half-earth: our planet's fight for life* (New York: W.W. Norton).

Xin, L. J., Wang, W., Jin, Y. C., Diao, Z. Y., and Li, J. S. (2014). Indices of ecological effects of grassland nature reserves in China. *Pratacultural Sci.* 31, 75–82. doi: 10.3788/HPLPB20102202.0415