

Butterflies as bioindicators of environmental quality: A review of their contribution to ecosystem assessment and conservation

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Abstract

Assessing environmental quality is a major challenge for ecosystem conservation and the development of effective environmental management strategies. In this context, bioindicators provide valuable tools for detecting and interpreting ecological changes resulting from both anthropogenic pressures and natural processes, offering an integrated assessment of ecosystem condition. This review aimed to analyse the contribution of butterflies as bioindicators of environmental quality, highlighting their applications in ecosystem assessment, environmental monitoring, and biodiversity conservation. The review was based on peer-reviewed scientific articles, books, and institutional reports addressing bioindicators, butterfly ecology, environmental monitoring, and ecosystem assessment. The evidence indicates that butterflies exhibit high sensitivity to habitat fragmentation, land-use change, pollution, and climate change, making them reliable indicators of ecological integrity and ecosystem condition. Their biological characteristics and ecological responses support a wide range of applications, including biodiversity monitoring, habitat assessment, ecological restoration, and conservation planning. The review also proposes the Butterfly-Based Environmental Quality Assessment Framework (BEQAF), a conceptual framework that integrates environmental pressures, butterfly community responses, ecological indicators, and their applications in ecosystem assessment and biodiversity conservation. Overall, the evidence reviewed indicates that butterflies represent effective bioindicators for supporting evidence-based environmental management and promoting biodiversity conservation.

Keywords: *Biodiversity conservation; Biomonitoring; Ecological integrity; Environmental monitoring; Lepidoptera.*

Introduction

Human activities have profoundly altered terrestrial ecosystems, affecting biodiversity, ecological processes, and environmental stability. Habitat conversion, agricultural expansion, urbanisation, pollution, and climate change have reduced the capacity of ecosystems to maintain essential ecosystem services and sustain biological diversity. Consequently, reliable approaches for assessing ecosystem condition have become increasingly important to support environmental monitoring, biodiversity conservation, and the sustainable management of natural resources (Millennium Ecosy-

stem Assessment, 2005; IPBES, 2019). Traditionally, ecosystem condition has been assessed using physical and chemical parameters of soil, water, and air. However, these measurements often provide only a snapshot of environmental conditions and may not adequately reflect the cumulative effects of environmental disturbances. Bioindicators complement conventional monitoring by integrating biological responses to multiple environmental pressures over time, thereby providing a more comprehensive assessment of ecological integrity and ecosystem functioning. Unlike isolated physical or chemical measurements,

bioindicators reveal how environmental changes influence ecosystem structure and ecological processes, making them valuable tools for environmental assessment (Markert et al., 2003; Niemi and McDonald, 2004). Among the organisms used as bioindicators, insects are particularly valuable because of their remarkable diversity, broad geographical distribution, relatively short life cycles, and rapid responses to environmental change. Within this group, butterflies (Lepidoptera) are especially suitable owing to their close association with microclimatic conditions, vegetation structure, and host plant availability. Changes in species richness, abundance, community composition, and geographical distribution have consistently been associated with habitat fragmentation, land-use change, pollution, and climate change, making butterflies reliable indicators of ecological integrity and ecosystem condition (Bonebrake et al., 2010; Samways, 2020). Beyond their ecological sensitivity, butterflies are among the most extensively used organisms in biodiversity monitoring and conservation programmes. Their ecological characteristics, combined with well-established sampling protocols and extensive taxonomic knowledge, have supported their incorporation into long-term monitoring initiatives worldwide. Programmes such as the European Butterfly Monitoring Scheme (eBMS) and indicators developed by the European Environment Agency (EEA) demonstrate the value of butterflies for tracking population trends, assessing habitat condition, and evaluating the effective-

ness of biodiversity conservation policies (van Swaay et al., 2020; European Environment Agency, 2023). Despite this recognised importance, the available literature remains fragmented regarding the integration of the multiple ecological applications of butterflies in environmental assessment. Most studies focus on specific aspects of butterfly ecology, biodiversity monitoring, or conservation, whereas fewer investigations provide an integrated perspective linking environmental pressures, butterfly community responses, ecological indicators, and their practical applications in environmental management. To address this gap, Figure 1 presents the Butterfly-Based Environmental Quality Assessment Framework (BEQAF), a conceptual framework proposed in this review to integrate the principal environmental pressures affecting butterfly communities, their ecological responses, the resulting biological indicators, and their applications in ecosystem assessment, environmental monitoring, and biodiversity conservation. The framework synthesises the evidence discussed throughout this review and provides an integrated perspective on the relationships between ecological processes, environmental assessment, and evidence-based decision-making. In light of this knowledge gap, this review aimed to analyse the contribution of butterflies as bioindicators of environmental quality by examining their applications in ecosystem assessment, environmental monitoring, and biodiversity conservation through a narrative review of the scientific literature.

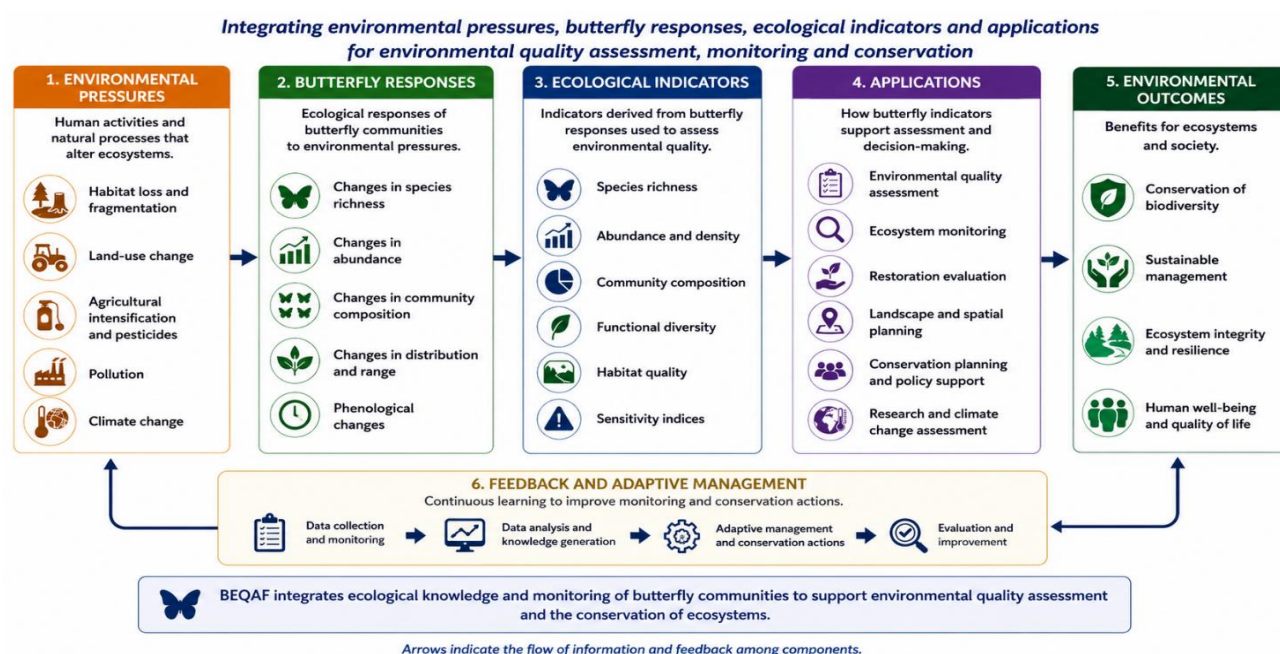


Figure 1. Butterfly-Based Environmental Quality Assessment Framework (BEQAF). Source: Prepared by the authors.

Materials and Methods

This review was conducted as a qualitative narrative literature review to analyse the contribution of butterflies as bioindicators of environmental quality and their applications in ecosystem assessment, environmental monitoring, and biodiversity conservation. The literature search was carried out using the scientific databases Web of Science, Scopus, Google Scholar, and SciELO. To ensure a comprehensive overview of the topic, the search was complemented by books, technical reports, and institutional publications, particularly documents produced by the Millennium Ecosystem Assessment (MEA), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the European Environment Agency (EEA), and the European Butterfly Monitoring Scheme (eBMS, 2024). The search strategy combined the descriptors *bioindicators*, *environmental quality*, *environmental monitoring*, *butterflies*, *Lepidoptera*, *biodiversity conservation*, and *ecosystem assessment*, as well as their Portuguese equivalents. Priority was given to peer-reviewed scientific articles, classical references,

and recent publications with recognised relevance to bioindication, butterfly ecology, environmental monitoring, ecosystem assessment, and biodiversity conservation. The selected studies were critically analysed and organised into four thematic areas: (i) butterflies as indicators of environmental quality; (ii) responses of butterfly communities to environmental pressures; (iii) applications in environmental monitoring and ecosystem assessment; and (iv) contributions to biodiversity conservation and environmental management. The synthesis of the reviewed evidence supported the development of the Butterfly-Based Environmental Quality Assessment Framework (BEQAF) (Fig. 1), which integrates environmental pressures, butterfly community responses, ecological indicators, and their applications in ecosystem assessment and biodiversity conservation. The figures and tables included in the Results and Discussion section were designed to summarise the principal findings identified in the reviewed literature. The methodological procedures adopted in this review are summarised in Table 1.

Table 1. Methodological procedures adopted in the narrative literature review.

Stage	Methodological procedure	Purpose
1. Literature search	Identification of scientific publications in Web of Science, Scopus, Google Scholar, and SciELO, complemented by books, technical reports, and institutional publications.	To identify the scientific evidence supporting the review.
2. Study selection	Selection of peer-reviewed articles, classical references, and recent publications relevant to bioindicators, butterfly ecology, environmental monitoring, ecosystem assessment, and biodiversity conservation.	To ensure the scientific relevance and quality of the reviewed literature.
3. Thematic organisation	Classification of the selected studies into four thematic areas: (i) butterflies as indicators of environmental quality; (ii) responses to environmental pressures; (iii) applications in environmental monitoring and ecosystem assessment; and (iv) contributions to biodiversity conservation and environmental management.	To organise the evidence into coherent analytical categories.
4. Critical analysis and synthesis	Comparative interpretation of the selected studies to identify convergent findings, scientific advances, and research gaps.	To synthesise the current state of knowledge on butterflies as bioindicators.
5. Framework development	Integration of the reviewed evidence to develop the Butterfly-Based Environmental Quality Assessment Framework (BEQAF) presented in Figure 1.	To propose an integrated conceptual framework linking environmental pressures, butterfly responses, ecological indicators, and ecosystem assessment.

Source: Prepared by the authors based on the methodological procedures adopted in this review.

Results and Discussion

Butterflies as Indicators of Environmental Quality

Bioindicators have become essential tools for assessing environmental quality because they integrate the cumulative effects of environmental disturbances over time, providing a more comprehensive representation of ecosystem condition than isolated physical or chemical measurements (Markert et al., 2003; Niemi and McDonald, 2004). Among the diverse groups of bioindicators, insects are particularly valuable owing to their exceptional diversity, broad geographical distribution, relatively short life cycles, and rapid responses to environmental disturbances. Within this group, butterflies (Lepidoptera) are especially suitable as bioindicators because their occurrence, abundance, and population dynamics are closely associated with vegetation structure, microclimatic conditions, and host plant availability. Consequently, changes in species richness, abundance, community composition, and geographical distribution have consistently been associated with habitat fragmentation, land-use change, pollution, and climate change, making butterflies reliable indicators of ecological integrity and ecosystem condition (Bonebrake et al., 2010; Samways, 2020). In addition to their ecological sensitivity, butterflies offer several practical advantages that facilitate their application in environmental monitoring programmes. Their wide distribution, relatively simple sampling methods, well-established monitoring protocols, and extensive taxonomic

and ecological knowledge allow consistent comparisons across different ecosystems and over time, supporting the assessment of habitat quality, environmental degradation, conservation status, and ecological restoration (Pollard and Yates, 1993; Thomas, 2005). Evidence from studies conducted across different biogeographical regions consistently demonstrates that well-preserved habitats support richer butterfly assemblages and a greater proportion of habitat-specialist species, whereas disturbed environments tend to be dominated by generalist species that are more tolerant of environmental change. Consequently, butterfly communities provide robust information on habitat quality and ecological integrity, enabling environmental changes to be detected across multiple spatial and temporal scales (Bonebrake et al., 2010; Niemi and McDonald, 2004). More recently, international monitoring initiatives have incorporated indicators based on species richness, abundance, community composition, functional diversity, and population trends to assess ecosystem condition and support biodiversity conservation. Together, these biological attributes demonstrate that butterflies represent far more than simple indicators of environmental change; they integrate multiple ecological responses that provide a reliable basis for ecosystem assessment, environmental monitoring, and conservation planning. The principal biological and ecological characteristics that support the use of butterflies as bioindicators are synthesised in Figure 2.

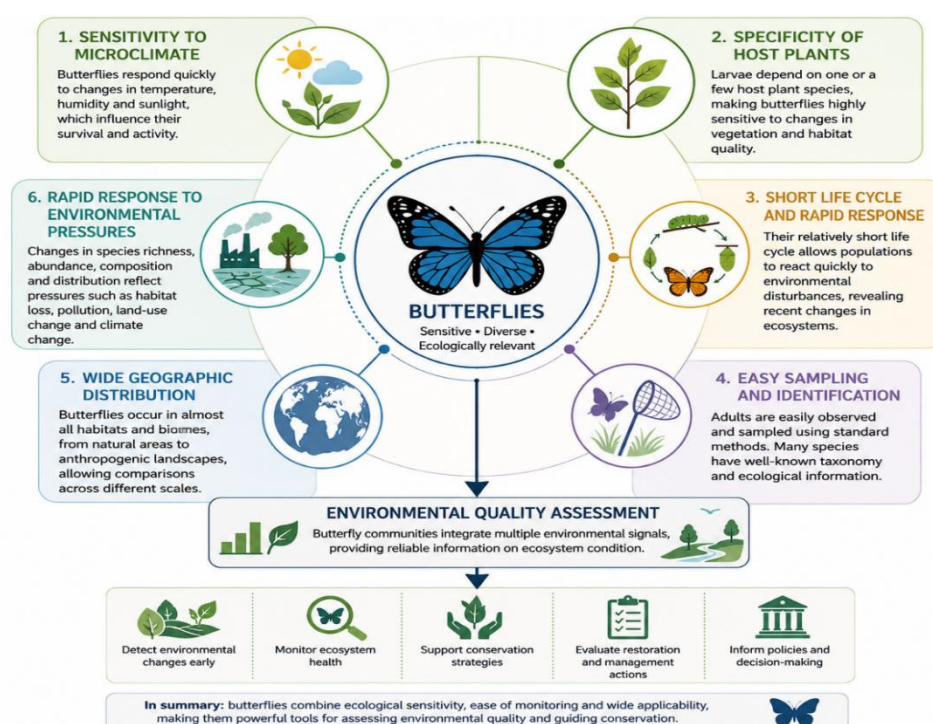


Figure 2

Biological and ecological characteristics supporting the use of butterflies as bioindicators of environmental quality.

Source: Prepared by the authors.

Responses of Butterfly Communities to environmental pressures

Butterfly communities respond rapidly and consistently to environmental disturbances, making them highly sensitive indicators of changes in ecosystem condition. Their ecological responses are closely associated with vegetation structure, microclimatic conditions, host plant availability, and landscape connectivity. Consequently, different environmental pressures produce measurable changes in species richness, abundance, community composition, geographical distribution, and functional diversity, providing valuable information on habitat quality and ecological integrity (Bonebrake et al., 2010; Samways, 2020). Habitat fragmentation is recognised as one of the principal drivers of butterfly decline. The reduction and isolation of natural habitats restrict dispersal, decrease resource availability, and reduce gene flow among populations. These processes disproportionately affect habitat-specialist species, simplify community structure, and ultimately reduce ecological resilience and ecosystem integrity (Haddad et al., 2015). Land-use change resulting from agricultural expansion and urbanisation further alters vegetation structure and landscape heterogeneity, reducing the availability of host plants and floral resources required throughout the butterfly life cycle. Consequently, sensitive species decline while disturbance-tolerant generalists become increasingly dominant, leading to substantial changes in community composition and ecological functioning (New, 1997; Thomas, 2005). Agricultural intensification also contributes to butterfly

decline through the widespread use of pesticides, fertilisers, and monoculture systems, which reduce plant diversity and increase both direct and indirect mortality. Likewise, climate change influences butterfly phenology, geographical distribution, voltinism, and population dynamics, whereas environmental pollution causes physiological stress and reproductive impairment, compromising long-term population persistence (Potts et al., 2010; Parmesan, 2006; Sánchez-Bayo and Wyckhuys, 2019; Forister et al., 2019). Although each environmental pressure produces distinct ecological responses, their combined effects consistently modify butterfly communities in predictable ways. The integration of these biological responses provides robust indicators of ecosystem condition and ecological integrity, reinforcing the value of butterflies as reliable bioindicators for environmental assessment, ecosystem monitoring, and biodiversity conservation. The principal environmental pressures affecting butterfly communities, their ecological responses, and the implications for ecosystem assessment are summarised in Table 2. As shown in Table 2, butterfly communities integrate the effects of habitat fragmentation, land-use change, agricultural intensification, climate change, and environmental pollution into measurable biological responses. These responses provide reliable indicators of ecosystem condition, habitat quality, and ecological integrity, reinforcing the value of butterflies for environmental assessment, biodiversity conservation, and evidence-based environmental management.

Table 2. Major environmental pressures, butterfly responses, and their implications for ecosystem assessment.

Environmental pressure	Ecological response of butterfly communities	Implications for ecosystem assessment
Habitat fragmentation	Decline in species richness, loss of habitat specialists, reduced dispersal, and decreased landscape connectivity	Indicates habitat degradation, reduced ecological integrity, and loss of ecosystem resilience
Land-use change	Simplification of community composition, replacement of specialist species by generalists, and reduction of host plant availability	Indicates ecosystem disturbance, declining habitat quality, and reduced landscape heterogeneity
Agricultural intensification	Population decline associated with pesticide exposure, monocultures, and loss of floral and larval resources	Indicates biodiversity loss, ecological imbalance, and increasing anthropogenic pressure
Climate change	Shifts in phenology, geographical distribution, voltinism, and population dynamics	Indicates ecosystem responses to climate change and species vulnerability
Environmental pollution	Physiological stress, reduced survival, impaired reproduction, and altered community structure	Indicates environmental contamination and ecological stress

Source: Prepared by the authors based on the reviewed literature.

Applications of Butterflies in environmental monitoring and ecosystem assessment

Butterfly monitoring has become an effective approach for assessing ecosystem condition and tracking changes in ecological integrity over time. Unlike physical and chemical indicators, which describe environmental conditions at a particular point in time, butterfly communities integrate the cumulative effects of multiple environmental pressures, providing a more comprehensive understanding of ecosystem functioning and long-term ecological change (Niemi and McDonald, 2004; Samways, 2020). The high ecological sensitivity of butterflies to changes in vegetation structure, microclimatic conditions, and landscape connectivity has led to their widespread application in biomonitoring programmes aimed at detecting environmental degradation, evaluating conservation outcomes, and assessing ecological restoration. Variations in species richness, abundance, community composition, and functional diversity provide robust ecological indicators for evaluating ecosystem condition across different spatial and temporal scales (Bonebrake et al., 2010; Cardoso et al., 2020). Beyond biodiversity monitoring, butterfly-based indicators have increasingly been applied to assess habitat restoration, landscape connectivity, the effectiveness of protected areas, and the ecological impacts of climate change. Recent advances in remote sensing, geographic information systems (GIS), species distribution modelling, citizen science, and artificial intelligence have further expanded the capacity of butterfly monitoring to support ecosystem assessment, conservation planning, and evidence-based environmental management (Forister et al., 2019; Cardoso et

al., 2020; van Klink et al., 2020). These scientific advances have also supported the establishment of long-term monitoring programmes. One of the best-known examples is the European Butterfly Monitoring Scheme (eBMS), which applies standardised monitoring protocols to assess population trends and generate ecological indicators for biodiversity conservation. Likewise, the European Environment Agency (EEA) incorporates butterfly-based indicators into assessments of habitat condition and ecosystem change across Europe, demonstrating their relevance for evaluating conservation policies and supporting environmental decision-making (van Swaay et al., 2020; European Environment Agency, 2023). The principal applications of butterflies in environmental monitoring, the biological indicators most frequently employed, and their contributions to ecosystem assessment are summarised in Table 3. As summarised in Table 3, butterflies contribute to multiple dimensions of ecosystem assessment, ranging from biodiversity monitoring and habitat conservation to ecological restoration and climate change assessment. Their capacity to integrate biological responses across different spatial and temporal scales provides robust ecological indicators that support conservation planning, environmental management, and evidence-based decision-making.

Contributions to ecosystem conservation and environmental management

The evidence synthesised in this review demonstrates that the value of butterflies as bioindicators extends well beyond biodiversity monitoring. By responding sensitively to changes in vegetation structure, landscape

Table 3. *Main applications of butterflies in environmental monitoring and ecosystem assessment.*

Application	Butterfly-based indicator	Contribution to ecosystem assessment
Biodiversity monitoring	Species richness and abundance	Detects ecological change and environmental degradation
Habitat conservation	Community composition	Assesses habitat quality and ecological integrity
Ecological restoration	Recovery of habitat-specialist species	Evaluates restoration success
Protected area management	Population trends	Assesses the effectiveness of conservation measures
Climate change assessment	Species distribution and phenology	Detects ecological responses to climate change
Environmental management	Functional diversity	Supports environmental planning and evidence-based decision-making

Source: Prepared by the authors based on the reviewed literature.

connectivity, and microclimatic conditions, butterfly communities provide ecological information that supports ecosystem conservation, environmental planning, and evidence-based environmental management (Samways, 2020; European Environment Agency, 2023). Butterfly-based indicators contribute to a wide range of conservation and management actions, including the identification of priority areas for conservation, the design of ecological corridors, the monitoring of protected areas, and the evaluation of ecological restoration programmes. In addition, indicators derived from species richness, community composition, habitat-specialist species, and population trends provide valuable information for assessing habitat quality and supporting landscape planning and biodiversity conservation policies (Bonebrake et al., 2010; Haddad et al., 2015; Thomas, 2005). Another important contribution of butterflies lies in their capacity to connect scientific research with society. Citizen science and participatory monitoring programmes have substantially increased the availability of biodiversity data while promoting environmental awareness and public engagement in conservation initiatives. These collaborative approaches also expand the spatial and temporal coverage of biodiversity monitoring, generating long-term datasets that strengthen eco-

system assessment and support adaptive environmental management (Pollard and Yates, 1993; van Swaay et al., 2020). The principal contributions of butterflies to ecosystem conservation and environmental management are summarised in Table 4. As summarised in Table 4, butterflies provide valuable ecological information that supports biodiversity conservation, environmental planning, and ecosystem management. Their capacity to integrate biological responses to multiple environmental pressures enables comprehensive assessments of ecological integrity while strengthening evidence-based decision-making for the sustainable management of natural resources (Markert et al., 2003; Niemi and McDonald, 2004). Despite significant advances in butterfly-based biomonitoring, important challenges remain, including the standardisation of monitoring protocols, the expansion of long-term datasets, and the strengthening of monitoring networks in tropical regions. Addressing these challenges, together with the integration of emerging technologies and collaborative monitoring initiatives, will further enhance the application of butterflies as bioindicators in ecosystem assessment, biodiversity conservation, and sustainable environmental management (Forister et al., 2019; van Swaay et al., 2020).

Table 4. Contributions of butterfly bioindicators to ecosystem conservation and environmental management.

Conservation objective	Butterfly-based information	Management contribution
Biodiversity conservation	Species richness and community composition	Identification of priority areas for biodiversity conservation
Ecological restoration	Recovery of habitat-specialist species	Assessment of restoration success
Landscape planning	Habitat connectivity	Design of ecological corridors and ecological networks
Protected area management	Population trends	Evaluation of conservation effectiveness and adaptive management
Environmental policy	Ecological indicators	Support for environmental planning and evidence-based decision-making
Citizen science and environmental education	Public participation in biodiversity monitoring	Promotion of environmental awareness and biodiversity conservation

Source: Prepared by the authors based on the reviewed literature

Conclusions

This review demonstrates that butterflies are among the most reliable bioindicators of environmental quality because of their close association with habitat structure, microclimatic conditions, and landscape connectivity. Variations in species richness, abundance, community composition, functional diversity, and geo-

graphical distribution consistently reflect environmental disturbances, providing robust indicators of ecosystem condition and ecological integrity across a wide range of ecosystems. The evidence synthesised in this review highlights that the application of butterflies extends far beyond biodiversity monitoring. Butterfly-based indicators contribute to ecosystem assessment,

habitat conservation, ecological restoration, landscape planning, climate change assessment, and evidence-based environmental management. Their capacity to integrate biological responses to multiple environmental pressures makes them valuable tools for supporting conservation strategies and sustainable natural resource management. The principal contribution of this review is the development of the Butterfly-Based Environmental Quality Assessment Framework (BEQAF), an integrative conceptual framework that brings together environmental pressures, butterfly community responses, ecological indicators, and their applications in ecosystem assessment and biodiversity conservation. Rather than representing a predictive model, the BEQAF provides an evidence-based conceptual synthesis that organises current knowledge and offers a structured framework to support future research, biomonitoring programmes, and environmental decision-making. Despite the substantial advances achieved in butterfly-based bio-monitoring, important challenges remain, particularly regarding the standardisation of monitoring protocols, the expansion of long-term datasets, and the development of monitoring networks in tropical regions. Future research should focus on validating and refining the BEQAF under different ecological conditions while incorporating emerging technologies, citizen science initiatives, and integrated monitoring approaches. These advances will further strengthen the application of butterflies as bioindicators and enhance their contribution to ecosystem assessment, biodiversity conservation, and sustainable environmental management.

References

- BONEBRAKE T.C., PONISIO L.C., BOGGS C.L., EHR-
LICH P.R. (2010) More than just indicators: a review of
tropical butterfly ecology and conservation. *Biological Con-
servation*, 143(8): 1831–1841.
<https://doi.org/10.1016/j.biocon.2010.04.044>
- CARDOSO P., BARTON P.S., BIRKHOFFER K.,
CHICHORRO F., DEACON C., FARTMANN T.,
FUKUNAGA A., HABEL J.C., HALLMANN C.A., HILL
M.J., HOCHKIRCH A., KWAK M.L., MAMMOLA S.,
NORIEGA J.A., ORFINGER A.B., PEDERSEN M.W.,
PRZEWOŹNY M., RABELING C., REIS R.E.,
SAMWAYS M.J. (2020) Scientists' warning to humanity on
insect extinctions. *Biological Conservation*, 242: 108426.
<https://doi.org/10.1016/j.biocon.2020.108426>
- EUROPEAN BUTTERFLY MONITORING SCHEME
(eBMS) (2024) European Butterfly Monitoring Scheme.
Available Mat: <https://butterfly-monitoring.net>
- EUROPEAN ENVIRONMENT AGENCY (2023)
European grassland butterfly indicator. Copenhagen: EEA.
Available at: <https://www.eea.europa.eu>
- FORISTER M.L., PELTON E.M., BLACK S.H. (2019)
Declines in insect abundance and diversity: We know enough
to act now. *Conservation Science and Practice*, 1(8): e80.
<https://doi.org/10.1111/csp2.80>
- HADDAD N.M., BRUDVIG L.A., CLOBERT J., DAVIES
K.F., GONZALEZ A., HOLT R.D., LOVEJOY T.E.,
SEXTON J.O., AUSTIN M.P., COLLINS C.D., COOK
W.M., DAMSCHEN E.I., EWERS R.M., FOSTER B.L.,
JENKINS C.N., KING A.J., LAURANCE W.F., LEVEY
D.J., MARGULES C.R. (2015) Habitat fragmentation and its
lasting impact on Earth's ecosystems. *Science Advances*,
1(2): e1500052. <https://doi.org/10.1126/sciadv.1500052>
- IPBES (2019) Summary for policymakers of the global
assessment report on biodiversity and ecosystem services of
the Intergovernmental Science-Policy Platform on
Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S.
Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P.
Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A.
Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian,
G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A.
Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy
Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis,
and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany.
56 pages. <https://doi.org/10.5281/zenodo.3553579>
- MARKERT B.A., BREURE A.M., ZECHMEISTER H.G.
(Eds) (2003) *Bioindicators and Biomonitoring: Principles,
Concepts and Applications*. Elsevier, Amsterdam.
- MILLENNIUM ECOSYSTEM ASSESSMENT (2005)
Ecosystems and Human Well-being: Synthesis. Island Press,
Washington, DC.
<https://wedocs.unep.org/handle/20.500.11822/8701>
- NEW T.R. (1997) *Butterfly Conservation*. 2nd ed. Oxford
University Press, Melbourne.
- NIEMI G.J., McDONALD M.E. (2004) Application of
ecological indicators. *Annual Review of Ecology, Evolution,
and Systematics*, 35: 89–111.
<https://doi.org/10.1146/annurev.ecolsys.35.112202.130132>
- PARMESAN C. (2006) Ecological and evolutionary
responses to recent climate change. *Annual Review of
Ecology, Evolution, and Systematics*, 37: 637–669.
<https://doi.org/10.1146/annurev.ecolsys.37.091305.110100>
- POLLARD E., YATES T.J. (1993) *Monitoring Butterflies
for Ecology and Conservation*. Chapman & Hall, London.
- POTTS S.G., BIESMEIJER J.C., KREMEN C.,
NEUMANN P., SCHWEIGER O., KUNIN W.E. (2010)
Global pollinator declines: Trends, impacts and drivers.
Trends in Ecology and Evolution, 25(6): 345–353.
<https://doi.org/10.1016/j.tree.2010.01.007>

DOI: 10.60923/issn.2281-4485/25881

SÁNCHEZ-BAYO F., WYCKHUYS K.A.G. (2019) Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation*, 232: 8–27.

<https://doi.org/10.1016/j.biocon.2019.01.020>

SAMWAYS M.J. (2020) *Insect Conservation: A Global Synthesis*. 2nd ed. CABI, Wallingford.

THOMAS J.A. (2005) Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360(1454): 339–357.

<https://doi.org/10.1098/rstb.2004.1585>

VAN KLINK R., BOWLER D.E., GONGALSKY K.B., SWENGEL A.B., GENTILE A., CHASE J.M. (2020) Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances. *Science*, 368(6489): 417–420.

<https://doi.org/10.1126/science.aax9931>

VAN SWAAY C.A.M., DENNIS E.B., SCHMUCKI R., SEVILLEJA C.G., AGHABABYAN K., ÅSTRÖM S., BALALAIKINS M., BONELLI S., BOTHAM M., BOURN N., BRERETON T., et al. (2020) *Assessing Butterflies in Europe – Butterfly Indicators 1990–2018*. Technical report. Butterfly Conservation Europe and ABLE/eBMS, Wageningen. Available at: <https://butterfly-monitoring.net>.