2026

DOCTORAL COURSE

Methodological Workshop in Evolutionary Biology

- practical part

The Librarian, Giuseppe Arcimboldo 1562

Systematic reviews:

- **Mental health effects of GLP-1 receptor agonists**
- **Biodiversity interventions and management practices on university campuses**

Compiled by Patrycja Wąchała

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Course Participants

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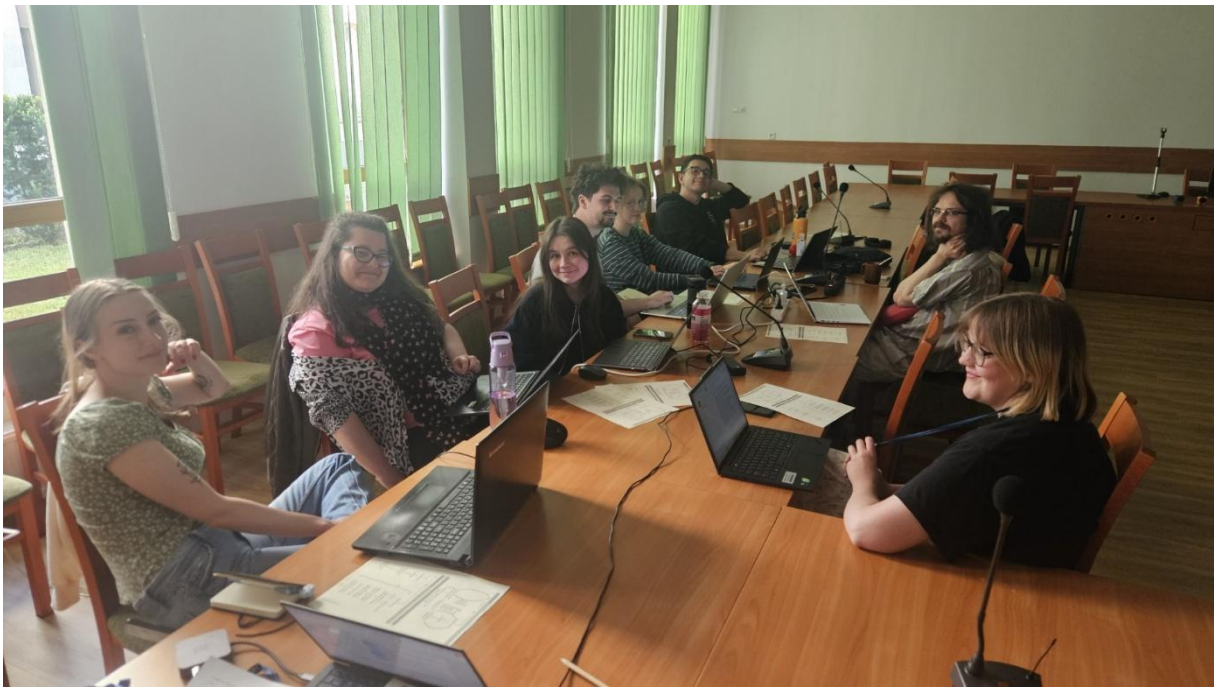

Course participants, 2026

Topics

Suggested topics

1. What nations conduct research in tropical forests?
2. How are author roles and contributions distinguished from acknowledgements in biological research?
3. Catalogue brain structure/ gene expression changes in autism spectrum disorder
4. Catalogue of environmental factors involved in development autism spectrum disorder
5. Do (rodent) animal behavior studies account for time of day?
6. Which study systems/taxa are overrepresented in genomic studies about e.g. mechanisms of speciation? (to check: how do their genomes differ? it may affect how some patterns emerge)
7. Catalogue of urban biodiversity interventions.
8. In what contexts are the effects of GMOs on biodiversity studied?
9. Catalogue of recommendations on how to reduce carbon emissions of universities.
10. Difference between microbiome composition of athletes from different sports, and their relationship with mental disorders such as anxiety and depression
11. Long-term and Short Term Trade-offs of Agroecological Interventions
12. Catalogue of questions that citizen science answers / aim to answer
13. Types of biodiversity data collected in studies about urban greenery
14. What public policies have been applied focused on controlling the sale of antibiotics without prescription with the aim of containing the development of antibiotic resistance?
15. Catalogue of methods used in phytoremediation
16. The relationship between intensive agricultural methods and soil biodiversity.

Final topics

1. A systematic review of the mental health effects of GLP-1 receptor agonists
2. A systematic review of the biodiversity interventions and management practices on university campuses

Systematic review of the mental health effects of GLP-1 receptor agonists

First version of the systematic review

A systematic review of the mental health effects of GLP-1 receptor agonists

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Summary

Glucagon-like peptide-1 receptor agonists (GLP-1 RAs) have become increasingly widely used for the treatment of type 2 diabetes and obesity. As their use has expanded, concerns have emerged about possible neuropsychiatric effects. This systematic review aimed to synthesize the current evidence on the mental health effects of GLP-1 RAs, with a focus on depression, anxiety, mood disorders, suicidality, sleep disturbances, and eating-related behaviors. A systematic search of PubMed and Scopus was conducted on 5 May 2026. Studies investigating semaglutide, tirzepatide, liraglutide, and dulaglutide in relation to mental health outcomes were included. Human and animal studies reporting beneficial, adverse, or null findings were considered eligible. A total of 93 studies were included in the review, of which 81 clearly reported an effect on mental health. Depression was the most frequently reported outcome, followed by suicidality. Sleep disturbances and eating-related disorders were less commonly described. Semaglutide and liraglutide were the most frequently reported GLP-1 RAs, while dulaglutide appeared least often. The available literature suggests that GLP-1 RAs may have complex and potentially bidirectional effects on mental health. Current evidence does not indicate a uniform effect of GLP-1 receptor agonists on mental health. While some studies

suggest potential psychological benefits, concerns regarding depression and suicidality remain incompletely understood. Further prospective research with standardized psychiatric outcomes is needed to clarify the mental health safety profile of these increasingly prescribed medications.

Keywords: anxiety; depression; GLP-1 receptor agonists; mental health; obesity; suicidality.

1. Introduction

Driven by the viral success of medications like Ozempic and Wegovy, the use of glucagon-like peptide-1 receptor agonists (GLP-1 RAs) has surged globally, moving beyond diabetes management into mainstream weight loss treatment (Han et al., 2024). However, this rapid shift into mainstream obesity treatment has outpaced our understanding of their secondary effects (Ard et al., 2021). As these medications cross the blood-brain barrier and interface with regions governing reward and emotion, urgent questions have surfaced regarding their influence on neuropsychiatric stability, ranging from mood fluctuations and anxiety to more severe concerns regarding suicidality (Arillotta et al., 2023; Manoharan et al., 2024). To address these emerging clinical uncertainties, this systematic review provides a synthesis of current evidence of the effects of GLP-1 RAs on mental health across different populations.

Our analysis encompasses a broad range of neuropsychiatric outcomes, such as depression, anxiety, mood disorders, suicidality, sleep disturbances, and eating-related behaviors. By integrating data from clinical trials, observational cohorts, and experimental animal models, this review captures the full trajectory of both short-term and long-term effects. To ensure a balanced and comprehensive assessment, the scope is limited to studies reporting beneficial, adverse, and null outcomes published in English-language, peer-reviewed journals. This review is intended for clinicians, researchers, and healthcare professionals involved in the management of obesity and type 2 diabetes mellitus, as well as those interested in the neuropsychiatric effects of emerging pharmacological treatments.

In this systematic review, we include all scientific papers that investigate the effects of GLP-1 RAs: Semaglutide (synonym: Ozempic, Wegovy, Rybelsus), Tirzepatide (synonym: Mounjaro, Zepbound), Liraglutide (synonym: Saxenda, Victoza) and Dulaglutide (synonym: Trulicity) (Suran, 2023). All of these drugs mimic hormones released by the gut after eating.

Their role is to control blood sugar and decrease appetite, which is why they are used for weight loss treatments.

To assess how GLP-1 RA affects mental health, we will focus on effects associated with depression, anxiety, mood disorders, and suicidality. Such mental health disorders and other conditions that are linked with them, like insomnia or eating disorders, are being investigated in the context of GLP-1 RA more frequently in recent years due to the growing popularity of weight loss drugs. We want to investigate which mental health disorders are being detected after taking drugs based on GLP-1 RAs. We focus on either beneficial or adverse effects on mental state.

2. Material and Methods

We decided to focus our search on three parts: GLP-1 receptor agonists (different drugs and their synonyms), mental health disorders, and emphasis on side effects. To collect relevant scientific papers, two databases were searched on May 5th 2026 – Scopus and PubMed.

Search string for Scopus:

(semaglutide OR Ozempic OR Wegovy OR Rybelsus OR "glucagon-like peptide 1 receptor agonist*" OR "GLP-1 receptor agonist*" OR "GLP-1 RA*" OR Mounjaro OR Tirzepatide OR Zepbound OR Saxenda OR Liraglutide OR Trulicity OR dulaglutide OR Victoza)

AND

("mental health" OR psychiatric* OR neuropsychiatric* OR psychologic* OR depression OR depressive OR "major depressive disorder" OR anxiety OR "anxiety disorder*" OR suicid* OR "suicidal ideation" OR mood OR "mood disorder*" OR "eating disorder*" OR binge OR "sleep disorder*" OR insomnia)

AND

"adverse effect*" OR "side effect*" OR "adverse event*" OR "adverse outcome*" OR efect* OR benefi* OR positiv* OR advert*

Search string for PubMed:

(semaglutide[tiab] OR Ozempic[tiab] OR Wegovy[tiab] OR Rybelsus[tiab] OR "glucagon-like peptide-1 receptor agonist*"[tiab] OR "GLP-1 receptor agonist*"[tiab] OR "GLP-1 RA*"[tiab]

OR Mounjaro[tiab] OR tirzepatide[tiab] OR Zepbound[tiab] OR Saxenda[tiab] OR liraglutide[tiab] OR Trulicity[tiab] OR dulaglutide[tiab] OR Victoza[tiab])

AND

("mental health"[tiab] OR psychiatric*[tiab] OR neuropsychiatric*[tiab] OR psychologic*[tiab] OR depression[tiab] OR depressive[tiab] OR "major depressive disorder"[tiab] OR anxiety[tiab] OR "anxiety disorder*"[tiab] OR suicid*[tiab] OR "suicidal ideation"[tiab] OR mood[tiab] OR "mood disorder*"[tiab] OR "eating disorder*"[tiab] OR binge[tiab] OR "sleep disorder*"[tiab] OR insomnia[tiab])

AND

("adverse effect*"[tiab] OR "side effect*"[tiab] OR "adverse event*"[tiab] OR "adverse outcome*"[tiab] OR benefi*[tiab] OR positiv*[tiab] OR advent*[tiab])

Based on this search string, we had 1,133 records in Scopus and 346 in PubMed. These records were uploaded to Rayyan for deduplication and screening. We excluded irrelevant papers in two teams (2x2) based on the relevance of the abstracts according to the decision tree (Fig. 1.). Selected papers were exported to Zotero and divided into four parts for every team member to further check if they can be included. Each team member answered questions that were prepared in advance in the protocol for data collection with the use of Microsoft Forms.

3. Results

The included records primarily comprised studies involving humans (n = 78), with a smaller subset conducted on animals (n = 15), all of which involved rodents. Most articles focused on the use of GLP-1 receptor agonists (GLP-1 RAs) for the treatment of obesity or weight loss (n = 55) and type 2 diabetes (n = 38). Only a few studies explored the application of GLP-1 RAs in mental health disorders, with most reported mental health effects described as side effects of other treatments.

The analysis of reported mental health side effects across the selected articles (n = 81) revealed that depression was the most frequently cited condition in the literature (n = 61), followed by suicidality (n = 39) (Fig. 2.). Conversely, eating-related disorders (n = 17) and sleep disturbances (n = 22) were the least frequently documented side effects. Across all GLP1 RAs, semaglutide and liraglutide accounted for the largest volume of reported cases (Fig. 1.).

Dulaglutide was the rarest, although present in all categories of side effects (Fig. 1.). Overall, each of the proposed side effects and GLP-1 RAs was represented in the screened articles.

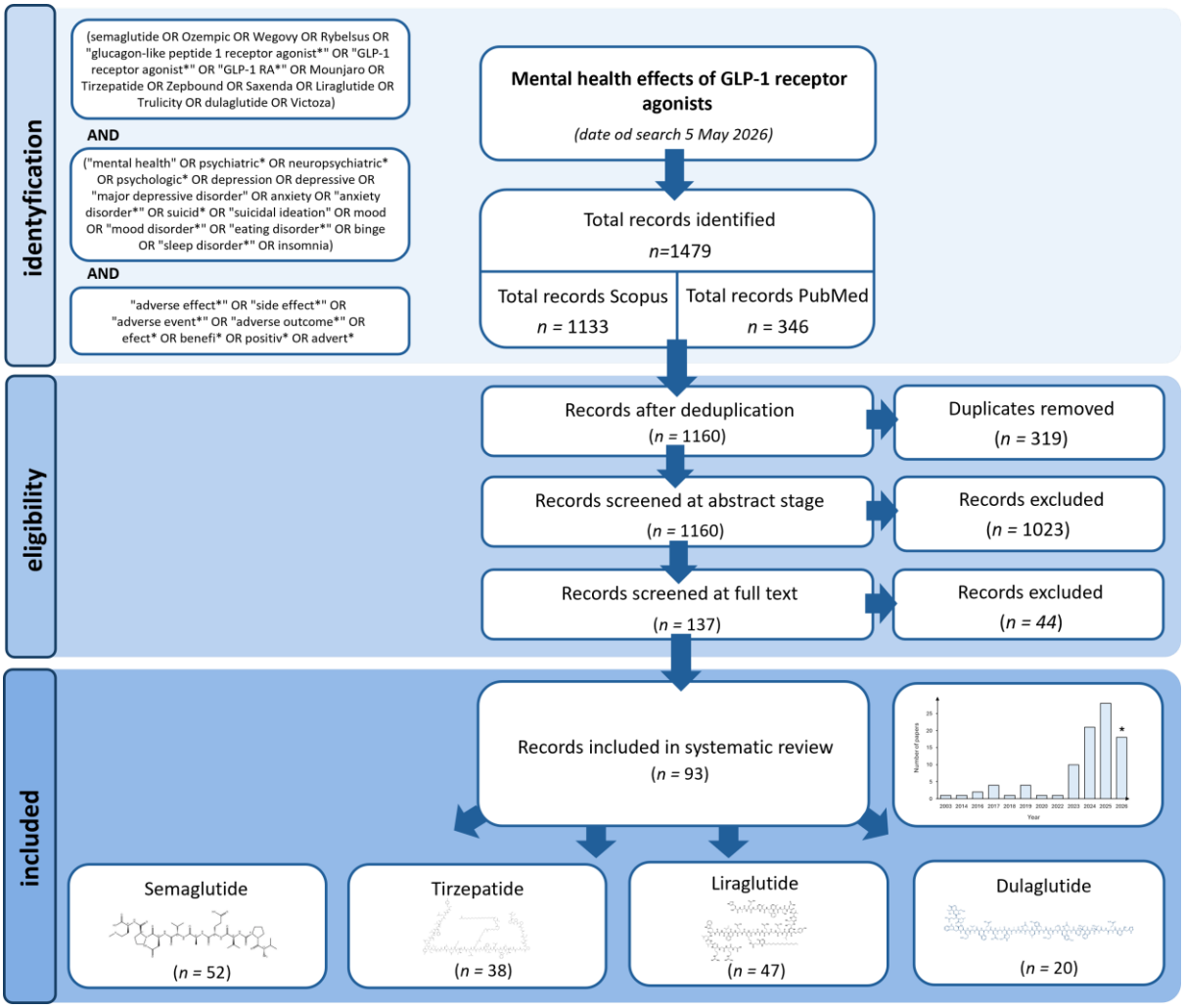

Figure 1. Overview of the literature search, screening, eligibility assessment, and study inclusion process for the systematic review examining the effects of GLP-1 receptor agonists on mental health outcomes. Values (n = x) indicate the number of records or studies at each stage of the review. Included studies were further classified according to the GLP-1 receptor agonist investigated (semaglutide, tirzepatide, liraglutide, and dulaglutide). An asterisk (*) indicates that records from 2026 represent a partial year, as the literature search was conducted on 5 May 2026.

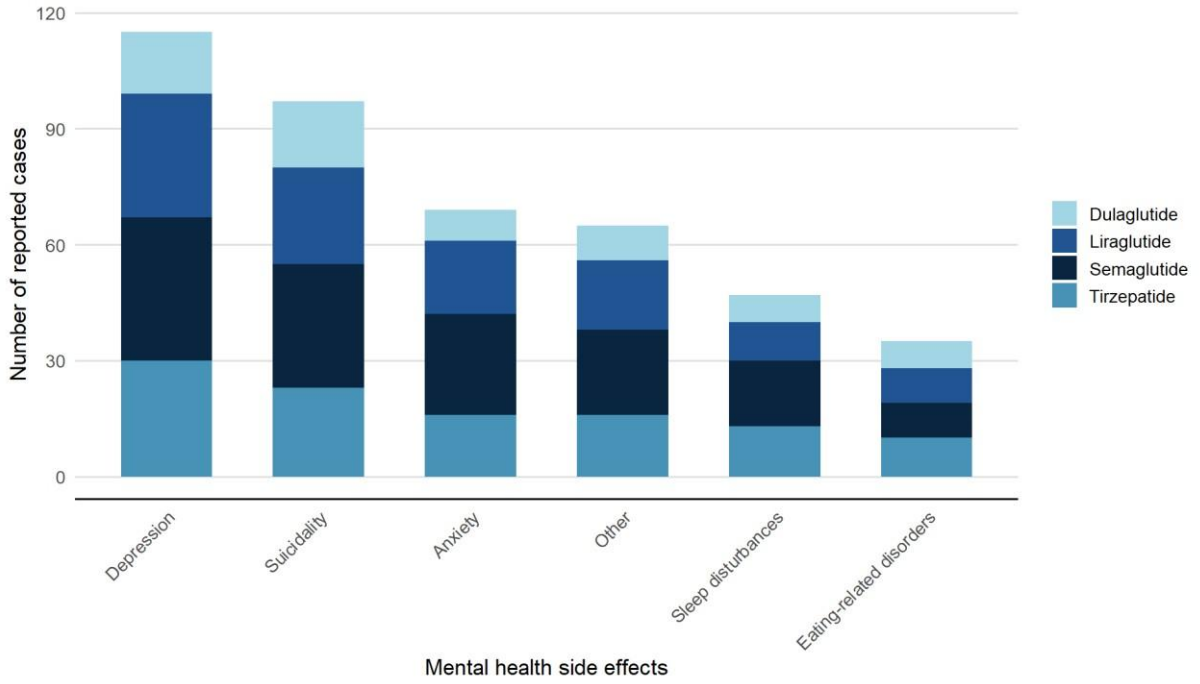

Figure 2. Distribution of reported mental health side effects by different GLP-1 receptor agonists. The plot illustrates the total number of reported cases of mental health side effects extracted from included articles (N = 81), categorized by specific GLP-1 receptor agonists (*semaglutide, liraglutide, tirzepatide,* and *dulaglutide*). Individual bars represent the total indications for each condition, with color-coded segments representing the proportion contributed by each substance.

4. Discussion

This systematic review identified a growing body of literature on the mental health effects of GLP-1 receptor agonists. Depression was the most frequently reported outcome, followed by suicidality, while sleep disturbances and eating-related disorders were discussed less often. Semaglutide and liraglutide appeared most frequently in the included studies, which likely reflects their wider clinical use and popularity in treatment. Overall, the available literature suggests that interest in this topic is increasing as these drugs become more common in everyday practice.

GLP-1 receptor agonists may affect mental health through both beneficial and adverse pathways. On the beneficial side, GLP-1 receptors are present in brain regions involved in appetite, reward, and emotion, and treatment may improve wellbeing through weight loss, better metabolic control, reduced inflammation, and less food-related distress (Au et al., 2025). On the other hand, alterations in dopaminergic reward signaling could potentially reduce pleasure responses or contribute to emotional blunting in susceptible individuals. Rapid weight loss, gastrointestinal adverse effects, and changes in appetite may also negatively affect quality

of life for some patients (Badulescu et al., 2024). This bidirectional mechanism may help explain why studies report both positive and adverse psychiatric outcomes.

The larger number of reports involving semaglutide and liraglutide probably reflects their broader use rather than a higher psychiatric risk. Dulaglutide was less frequently represented, although it was still present across outcome categories. Therefore, the number of published reports should be interpreted cautiously, as it does not necessarily reflect true incidence.

This review has several limitations, including heterogeneity in study design, outcome definitions, and quality. Many studies relied on reported symptoms rather than standardized psychiatric measures, and the review reflects reporting frequency rather than true risk. The search was also limited to PubMed, Scopus, and English-language publications.

Future research should use larger prospective cohorts, longer follow-up, and standardized mental health outcomes. Comparative studies of individual GLP-1 receptor agonists and high-risk psychiatric populations are also needed. Overall, further research is required to clarify the mental health safety profile of these medications

Acknowledgements

We would like to express our sincere gratitude to Professor Joanna Rutkowska for designing and leading the course, as well as for her valuable guidance, constructive feedback, and support throughout the preparation of this systematic review.

References:

1. Ard J, Fitch A, Fruh S, Herman L. 2021 Weight loss and maintenance related to the mechanism of action of glucagon-like peptide 1 receptor agonists. *Adv. Ther.* **38**, 2821–2839.

2. Arillotta D, Floresta G, Guirguis A, Corkery JM, Catalani V, Martinotti G, Schifano F. 2023 GLP-1 receptor agonists and related mental health issues: insights from a range of social media platforms using a mixed-methods approach. *Brain Sci.* **13**, 1503.
3. Au HCT, Zheng YJ, Le GH, Wong S, Phan L, Teopiz KM, Kwan ATH, Rhee TG, Rosenblat JD, Ho R, McIntyre RS. 2025 A systematic review in effects of glucagonlike peptide-1 (GLP-1) mono-agonists on functional connectivity: target engagement and

rationale for the development in mental disorders. *J. Affect. Disord.* **370**, 321–327. (doi:10.1016/j.jad.2024.11.019)

4. Badulescu S, Tabassum A, Le GH, Wong S, Phan L, Gill H, Llach C-D, McIntyre RS, Rosenblat J, Mansur R. 2024 Glucagon-like peptide 1 agonist and effects on reward behaviour: a systematic review. *Physiol. Behav.* **283**, 114622. (doi:10.1016/j.physbeh.2024.114622)
5. Han SH, Safeek R, Ockerman K, Trieu N, Mars P, Klenke A, Sorice-Virk S. 2024 Public interest in the off-label use of glucagon-like peptide 1 agonists (Ozempic) for cosmetic weight loss: a Google Trends analysis. *Aesthet. Surg. J.* **44**, 60–67.
6. Hlavinka E. 2024 Can diabetes drugs like Ozempic tackle the mental health crisis? *ACS Cent. Sci.* **10**, 1427–1431. (doi:10.1021/acscentsci.4c01250)
7. Suran M. 2023 As Ozempic's popularity soars, here's what to know about semaglutide and weight loss. *JAMA* **329**, 1627–1629. (doi:10.1001/jama.2023.2438)

Reviews of the first version of the systematic review

Review 1.

Citations are sparse throughout the paper. Authors use dubious citations that do not seem to support the presented claims. The key statement (line 35 – 37) on a slow pace of side effect research in the wake of the introduction of the new therapy, is supported by an article that is 5 years old, which might have been enough to change the described trend. Moreover, I have not found credible justification for using paper by Badulescu et al., 2024 to substantiate the claim on the impact of physiological side effects (line 142). The sentence (lines 135–137) is not supported by the literature. However, readers might suspect that it refers to the literature screened in the study, although this is not explicitly stated. Such issues call for a complete revision of the use of the literature in this paper. Incomplete and faulty bibliography might raise doubts on both the authors' competency and the novelty of the findings.

The basis for proper application of methodology should be research question. Unfortunately proposed research question (62-63) does not correspond to the incorporated methodology. Authors claim that they want to explore "which" (62) mental disorders are detected, whereas they assume them in the introductory statement (58-59). Therefore, as the authors focus on the frequency of the reported disorders in the results (109), the question should be concerned with "what is the frequency".

While the authors in the Discussion (152-153), properly address the issue of lack of a uniform method of detection of the mental disorders, the results should be at least differentiated in some way between the types of measures used. Therefore, the question should not include the word "detect", which is reserved only for more reliable, empirical methods. Use of a more general term like the word "reported" applied throughout the further chapters and the summary (21-22) would be more acceptable here.

Operationalizing the term "mental disorder" (line 62) in the context of this study is also questionable, contradicting with the "mental health effects" (1) term used in the title. This leads to further confusion, because mental disorders are often chronic and the study lacks any control for association between people who are susceptible to mental disorders with the use of GLP-1 receptor agonists. Finally, authors claim that they wanted to investigate possible positive mental health effects of the therapy, however this intent was not realized later on.

Conclusions are properly limited in accordance with the presented data. However, they should more clearly describe the lack of assessment of the methodology and reliability of the reviewed papers in addition to what was stated (152-153). What's more the problem of possible correlations or interactions should be discussed.

In summary, while some terms should be used more consistently throughout the article and the research question should be stated more clearly, the lack of any assessment of the methodology of the reviewed studies represents a serious weakness of the paper. The simplicity of the study, clear langaguage and the constrain of the authors in forming conclusions is commendable. However, if this manuscript were submitted for publication, I would recommend rejection. However, given the context, I would recommend a major revision.

Review 2.

While I was genuinely interested (outside of my expertise) in the topic and I do appreciate the effort you put into exploring the mental health effects of GLP-1 receptor agonists, I have to say I am definitely disappointed. The reason is simple: this work is not original. It reads more like a copy-paste from a previously published article than a fresh systematic review. I completely understand that this study was conducted within a limited time frame – likely as part of a course assignment. But even with time constraints, I believe that exploring a bit more beyond what has already been done would have been good. At the very least, I would have expected the authors to acknowledge that this work was built upon the previous systematic review by Silvia Tempia Valenta et al. 2024 (***Tempia Valenta, S., Nicastri, A., Perazza, F., Marcolini, F., Beghelli, V., Atti, A. R., & Petroni, M. L. (2024). The impact of GLP-1 receptor agonists (GLP-1 RAs) on mental health: a systematic review. Current Treatment Options in Psychiatry, 11(4), 310-357.).*** Give them proper credit. Then, show what new studies have appeared after 2024 and how your work updates or complements theirs. That would have been honest and academically sound. Instead, I see identical search structures, the same numbers of included studies (~120), the same drug categories, and even the same ranking of outcomes – depression most frequent, suicidality second. The figures are also strikingly similar. For a literature review, not referencing the original source from which most of the data and structure are taken is, frankly, unacceptable. It gives the impression that the work has been poorly done. Let me also point out specific issues from the PDF with my comments. The review claims to cover beneficial, adverse, and null effects, but in reality the analysis focuses almost entirely on adverse events. Beneficial outcomes are only mentioned superficially in the discussion, and null findings are barely discussed at all. The methods section says one thing, but the results deliver another. That needs to be fixed.

There is a clear disconnect between what was promised and what was delivered. The scope is also inconsistent: the introduction mentions sleep disturbances and eating-related behaviours, but the analysis does not treat them with the same depth as depression or suicidality. I have attached several other comments in the PDF. But to be completely honest with you, I sincerely believe that this work in its current form – is a complete replica of an existing publication. It cannot be accepted at this moment. My recommendation is to go back to the drawing board: reframe the study as a replication or an update, properly cite the original 2024 review, and add a clear section on what (if anything) is new since 2024. Without those changes, I cannot recommend acceptance.

Review 3.

The reviewed work is an unbelievably valuable piece of gathered information about a topic of high relevance in the medical field. However, the title initially prepares the reader to face a review that encompasses a comprehensive evaluation of the effects of the mentioned antagonists on all types of mental health issues but ends up focusing on certain selected mental health conditions. It is also important to mention that the reason the authors decided to focus on those specific conditions is not justified as well. For this reason, I suggest searching for a term that can encompass the selected conditions and to use this term instead of "mental health effects" on the title.

The abstract describes in full accuracy the content of the manuscript, providing enough detail to catch the attention of the reader, but at the same time promoting the review of the full text. As for the introduction, the context provides the necessary information for any reader to understand the importance of the use of these types of treatments for certain conditions (e.g., obesity), and their impact on mental health. However, the authors failed to indicate the value of the review in the context of the research around GLP-1 Ras on mental health, meaning that it is not clear if the review is the first of its kind or if it seeks to provide an update from the last extant review.

As for the results and discussion sections, there is a critical mistake that impedes the correct assessment of the validity of the data collected, the results generated, and how these were discussed. This critical mistake involves authors failing to point out in the methodology what data was collected from the full text review using Microsoft forms. This mistake does not allow the reviewer to check if the results provided by the authors provide a complete picture of the data collected, and if there are important pieces of information that are being ignored or that could be included as graphics or other elements. For the same reason, it is exceedingly difficult to assess if the discussion has the necessary depth to cover all the important results generated from the gathered data.

For the reasons previously mentioned, the manuscript will be returned for correction but not rejected. I personally think that this review could provide a very complete picture of the effect of GLP-1 RAs with the appropriate adjustments.

Review 4.

The presented systematic review has been conducted in satisfactory manner in terms of the methodology, in particular given the time constraints that were imposed. The topic is currently highly popular and of great relevance from scientific and medical viewpoints. However, it is recommended that this paper be submitted to a medical journal, rather than Biology Letters. This is not only because it is not suitable for this journal but also it will be more visible in a medical journal and will potentially have a greater impact on society. The paper is generally well written; however, some language corrections are recommended prior to publication. In regard to the structure and content of the article, the following recommendations are provided for consideration to enhance its quality and comprehensibility.

It is recommended that the introduction be revised in order to achieve a more balanced presentation of the background and state of the art of the topic. Currently, the focus is exclusively on the study itself, while the background and state of the art are addressed in only one paragraph. The paper would benefit from an extension of the background part, for example by the addition of data on the number of people using GLP-1 RAs, with a purpose of demonstrating the significance of the subject. Furthermore, it is suggested to include the rationale for the inclusion of specific neuropsychiatric outcomes as opposed to others, as well as the rationale for the inclusion of studies on animals. The introduction could also emphasise the manner in which it would help researchers and clinicians in future work with these drugs.

The process of screening the papers is adequately described, although the section entitled “Methods” makes a reference to “the decision tree (Fig. 1.)”, despite the fact that Figure 1 does not display any inclusion or exclusion criteria other than search strings and duplications. It is strongly recommended that inclusion and/or exclusion criteria be incorporated into the text.

It is important to note that the description of the methods should clearly state whether in the final screening only papers reporting actual neuropsychiatric conditions in patients were included, or whether papers in which researchers assessed patients in this regard were included, regardless of whether these occurred in patients. At present, this information is only stated in the description of Figure 2 (“the total number of reported cases of mental health side effects”). Despite the use of the term “side effects”, the paper does not provide a clear information whether the articles included in the systematic review exclusively reported the presence of these neuropsychiatric conditions after the treatment, or whether they were also evaluated prior to treatment and the papers reported the alteration in these conditions. It may be beneficial to

include this information in the discussion or introduction, as it could be a valuable point for consideration. For instance, it is important to acknowledge that individuals suffering from obesity frequently experience these conditions prior to undergoing treatment.

The final recommendation is to extend the introduction and the discussion. The present paper makes reference to a total of seven other articles, of which a mere two are cited in the discussion section. The word count falls significantly below the established limit of 2,500 words, thereby offering an opportunity for further elaboration.

By the implementation of the aforementioned recommendations, this paper has the potential to provide a substantial contribution to the field of GLP-1 RAs treatment, a matter of particular importance in today's world, which is characterised by a prevalence of lifestyle diseases, such as obesity and diabetes.

Review 5.

In the presented study the authors aim to systematically map out current state of knowledge on the impact of the glucagon-like peptide-1 receptor agonists use on mental health. The manuscript is written in an understandable style. I think it is both scientifically and socially important to provide such overview regarding this field of research since the use of the GLP-1 receptor antagonists becomes increasingly common. This systematic review covers a substantial number of papers and draws interesting conclusions based on them. The authors clearly indicate the limitations of the study and provide a set of adjustments that could be implemented in future research. However, I can see some issues mostly regarding the discussion section.

- Lines 62-64: here the authors state their research objective, however it is a little confusing because the authors say that they want to investigate which disorders are detected after the drug use and in the following sentence they declare that they focus on beneficial, adverse or null effects on mental state. I think I know what the authors meant by that, but it needs to be rephrased in my opinion.

- Figure 1. includes a graph presenting number of studies per year which unfortunately is too small and, in my opinion, it would be better to present it as an additional graph in Figure 2.

- In lines 138-146 the authors provide the reason why papers report both positive and negative effects of GLP-1 receptor antagonists, but in the results section the share of papers describing positive and negative effects is not included. I think it would be beneficial to provide such information.

- In the description of Figure 2. I think it is worth adding that the reported cases describe either beneficial or adverse effects. In this form it is somehow misleading since the authors suggested that they came across studies recording both positive and negative effects.

- Lines 147-148: I think it requires a suitable citation. Otherwise, as a reader without sufficient knowledge regarding this field of research, I have to rely only on the authors' expertise.

- The discussion section could be a little further expanded, e.g. in my opinion the authors could briefly discuss why among all of the recorded disorders depression is the most frequently recorded side effect of the GLP-1 receptor antagonists use.

Despite all of the aforementioned issues I think that the authors of presented manuscript prepared a very interesting piece of work. Especially given the very limited time they had to conduct the systematic review and the fact that this is their first attempt to conduct this type of study.

Final version of the systematic review

A systematic review of the mental health effects of GLP-1 receptor agonists

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Summary

Glucagon-like peptide-1 receptor agonists (GLP-1 RAs) have become increasingly widely used for the treatment of type 2 diabetes and obesity. As their use has expanded, concerns have emerged about possible neuropsychiatric effects. This systematic review aimed to synthesize the current evidence on the mental health effects of GLP-1 RAs, with a focus on depression, anxiety, mood disorders, suicidality, sleep disturbances, and eating-related behaviours. A systematic search of PubMed and Scopus was conducted on 5 May 2026. Studies investigating semaglutide, tirzepatide, liraglutide, and dulaglutide in relation to mental health outcomes were included. Human and animal studies reporting beneficial, adverse, or null findings were considered eligible. A total of 93 studies were included in the review. Of these, 81 were classified according to the reported direction of mental health effects (positive, negative, or no significant effect). Depression was the most frequently reported outcome, followed by suicidality. Sleep disturbances and eating-related disorders were less commonly described. Semaglutide and liraglutide were the most frequently reported GLP-1 RAs, while dulaglutide appeared least often. The available literature suggests that GLP-1 RAs may have complex and potentially bidirectional effects on mental health. Current evidence does not

indicate a uniform effect of GLP-1 receptor agonists on mental health. While some studies suggest potential psychological benefits, concerns regarding depression and suicidality remain incompletely understood. Further prospective research with standardized psychiatric outcomes is needed to clarify the mental health safety profile of these increasingly prescribed medications.

Keywords: anxiety; depression; GLP-1 receptor agonists; mental health; obesity; suicidality.

1. Introduction

Driven by the viral success of medications like Ozempic and Wegovy, the use of glucagon-like peptide-1 receptor agonists (GLP-1 RAs) has surged globally, moving beyond diabetes management into mainstream weight loss treatment (Han et al., 2024). However, this rapid shift into mainstream obesity treatment has outpaced our understanding of their secondary effects (Ard et al., 2021; Kim and Yoo, 2025). GLP-1 RAs act on the central nervous system by modulating brain regions controlling appetite and influencing neurotransmitter and peptide release to suppress appetite and enhance satiety signaling. As a result, caloric intake is reduced, leading to weight loss (Moiz et al., 2025). As these medications cross the blood-brain barrier and interface with regions governing reward and emotion, urgent questions have surfaced regarding their influence on neuropsychiatric stability, ranging from mood fluctuations and anxiety to more severe concerns regarding suicidality (Arillotta et al., 2023; Manoharan et al., 2024). Physicians and patients with obesity or overweight reported high satisfaction and compliance/adherence to their weight management treatment in which the base was the use of low dose of semaglutide (Zhang et al., 2026). Systematic review of randomised placebo-controlled trials of once-weekly subcutaneous semaglutide 2.4 mg in adults with overweight or obesity showed improvement in patient-reported outcomes. Nevertheless, average functional benefits are moderate and should be perceived consciously and carefully (Eisa and Khoury, 2026). To address these emerging clinical uncertainties, this systematic review provides a synthesis of up-to-date evidence of the effects of GLP-1 RAs on mental health across different populations. This review is intended for clinicians, researchers, and healthcare professionals involved in the management of obesity and type 2 diabetes mellitus, as well as those interested in the neuropsychiatric effects of emerging pharmacological treatments.

Recently published systematic reviews focus on one particular mental health outcome, like suicidality (Chan et al., 2026) or depression in people with type 2 diabetes mellitus (Ferrer Zavala et al., 2026). We are aware that this topic was broadly covered in the systematic review of Tempia Valenta et al. (2024). Nevertheless, we believe that such rapid development in this

field requires constant updating of knowledge status for the sake of patients. At the moment of conducting this research, a simple search of “GLP-1 receptor agonist” term in PubMed showed more than 7,800 results in the years 2024-2026, so after the publication of the above-mentioned article.

To ensure a balanced and comprehensive assessment, the scope of our review is limited to studies published in English-language, peer-reviewed journals. Our analysis encompasses a broad range of neuropsychiatric outcomes, such as depression, anxiety, mood disorders, suicidality, sleep disturbances, and eating-related behaviors. We include all scientific papers that investigate the effects of GLP-1 RAs: Semaglutide (synonym: Ozempic, Wegovy, Rybelsus), Tirzepatide (synonym: Mounjaro, Zepbound), Liraglutide (synonym: Saxenda, Victoza) and Dulaglutide (synonym: Trulicity) (Suran, 2023). All of these drugs mimic hormones released by the gut after eating. By integrating data from clinical trials, observational cohorts, and experimental animal models, this review captures the full trajectory of both short-term and long-term effects. Differently than in the work of Tempia Valenta et al. (2024), we included studies in which effects of mental health were assessed in patients with preexisting mental disorders. Our work aimed to update and extend the systematic review by Tempia Valenta et al. (2024) by incorporating studies published after their search period and providing an updated synthesis of evidence. Moreover, we wanted to indicate the number of articles reporting beneficial, adverse or null outcomes for prospective meta-analysis.

2. Materials and Methods

We decided to focus our search on three parts: GLP-1 receptor agonists (different drugs and their synonyms), mental health effects, and emphasis on side effects. To collect relevant scientific papers, two databases were searched on May 5th 2026 – Scopus and PubMed.

Search string for Scopus:

(semaglutide OR Ozempic OR Wegovy OR Rybelsus OR "glucagon-like peptide 1 receptor agonist*" OR "GLP-1 receptor agonist*" OR "GLP-1 RA*" OR Mounjaro OR Tirzepatide OR Zepbound OR Saxenda OR Liraglutide OR Trulicity OR dulaglutide OR Victoza)

AND

("mental health" OR psychiatric* OR neuropsychiatric* OR psychologic* OR depression OR depressive OR "major depressive disorder" OR anxiety OR "anxiety disorder*" OR suicid* OR

"suicidal ideation" OR mood OR "mood disorder*" OR "eating disorder*" OR binge OR "sleep disorder*" OR insomnia)

AND
"adverse effect*" OR "side effect*" OR "adverse event*" OR "adverse outcome*" OR effect* OR benefi* OR positiv* OR advert*

Search string for PubMed:

(semaglutide[tiab] OR Ozempic[tiab] OR Wegovy[tiab] OR Rybelsus[tiab] OR "glucagon-like peptide-1 receptor agonist*"[tiab] OR "GLP-1 receptor agonist*"[tiab] OR "GLP-1 RA*"[tiab] OR Mounjaro[tiab] OR tirzepatide[tiab] OR Zepbound[tiab] OR Saxenda[tiab] OR liraglutide[tiab] OR Trulicity[tiab] OR dulaglutide[tiab] OR Victoza[tiab])

AND

("mental health"[tiab] OR psychiatric*[tiab] OR neuropsychiatric*[tiab] OR psychologic*[tiab] OR depression[tiab] OR depressive[tiab] OR "major depressive disorder"[tiab] OR anxiety[tiab] OR "anxiety disorder*"[tiab] OR suicid*[tiab] OR "suicidal ideation"[tiab] OR mood[tiab] OR "mood disorder*"[tiab] OR "eating disorder*"[tiab] OR binge[tiab] OR "sleep disorder*"[tiab] OR insomnia[tiab])

AND

("adverse effect*"[tiab] OR "side effect*"[tiab] OR "adverse event*"[tiab] OR "adverse outcome*"[tiab] OR benefi*[tiab] OR positiv*[tiab] OR advent*[tiab])

Based on this search string, we had 1,133 records in Scopus and 346 in PubMed (1479 in total). These records were uploaded to Rayyan for deduplication and screening. We excluded irrelevant papers in two teams (2x2) based on the relevance of the abstracts according to the decision tree (Fig. 1.). Selected papers were exported to Zotero and divided into four parts for every team member to further check if they can be included. Each team member answered questions that were prepared in advance in the protocol for data collection with the use of Microsoft Forms. After excluding irrelevant records, we identified 93 articles that mentioned mental health effects associated with GLP-1 RAs. However, to clearly illustrate substance-specific effects, the plot excludes 12 records that did not specify a particular substance or mental health outcome (i.e., those categorized as 'Unclear' across all variables).

3. Results

The included records primarily comprised studies involving humans (n = 78), with a smaller subset conducted on animals (n = 15), all of which involved rodents. Most articles focused on the use of GLP-1 receptor agonists (GLP-1 RAs) for the treatment of obesity or weight loss (n = 55) and type 2 diabetes (n = 38). Only a few studies explored the application of GLP-1 RAs in mental health effects, with most reported mental health effects described as side effects of other treatments.

The analysis of reported mental health side effects across the selected articles (n = 81) revealed that depression was the most frequently cited condition in the literature (n = 61), followed by suicidality (n = 39) (Fig. 2.). Conversely, eating-related disorders (n = 17) and sleep disturbances (n = 22) were the least frequently documented side effects. Across all GLP-1 RAs, semaglutide and liraglutide accounted for the largest volume of reported cases (Fig. 1.). Dulaglutide was the rarest, although present in all categories of side effects (Fig. 1.). Overall, each of the proposed side effects and GLP-1 RAs was represented in the screened articles.

The direction of the reported mental health effects varied considerably across studies. Beneficial, adverse, and no significant effects were identified for all major mental health outcomes, although their distribution differed depending on the outcome assessed. Depression was associated with a comparable number of beneficial and adverse findings, whereas studies evaluating suicidality more frequently reported adverse or no significant effects. Eating-related outcomes were more commonly associated with beneficial effects than with adverse effects. A summary of the reported direction of mental health effects across the included studies is presented in Table 2.

In contrast to Tempia Valenta et al. (2024), this review included 13 studies involving participants with pre-existing mental health conditions, of which eight reported positive effects, three reported no effects, and two reported negative effects on mental health.

Table 2. Distribution of reported mental health outcomes across the included studies. Studies were categorized according to the mental health outcomes they assessed. Studies evaluating multiple mental health outcomes contributed to each relevant category. The direction of the reported effect (positive, negative, or no significant effect) was determined according to the predefined data extraction form. Studies classified as *unclear* were excluded from the summary. Consequently, the total number of studies across outcome categories may exceed the number of included studies, and the sum of effect categories may be lower than the total number of studies assessing a given outcome.

Mental health outcome	Studies assessing the outcome (n)	Positive effect	Negative effect	No significant effect
Depression	61	23	23	11
Anxiety	39	15	13	6
Suicidality	36	5	18	12
Sleep disturbances	22	6	11	4
Eating-related disorders	17	9	7	3
Other mental health outcomes	37	15	12	8

The reported mental health outcomes were assessed using heterogeneous methods across the included studies, including validated psychiatric questionnaires, clinical diagnoses, electronic health records, adverse event reporting systems, and behavioral assessments in animal models.

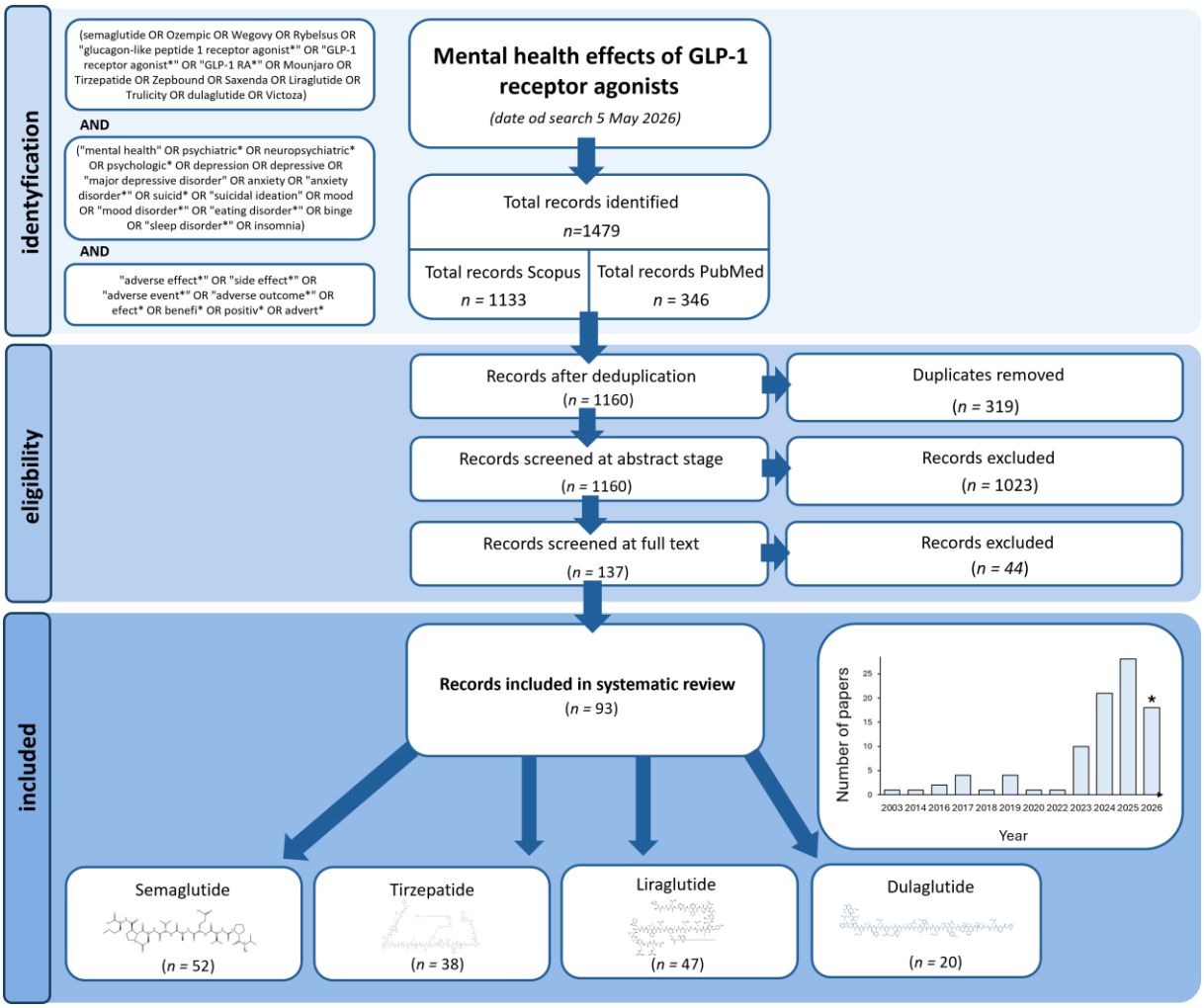

Figure 1. Overview of the literature search, screening, eligibility assessment, and study inclusion process for the systematic review examining the effects of GLP-1 receptor agonists on mental health outcomes. Values (n = x) indicate the number of records or studies at each stage of the review. Included studies were further classified according to the GLP-1 receptor agonist investigated (semaglutide, tirzepatide, liraglutide, and dulaglutide). An asterisk (*) indicates that records from 2026 represent a partial year, as the literature search was conducted on 5th May 2026.

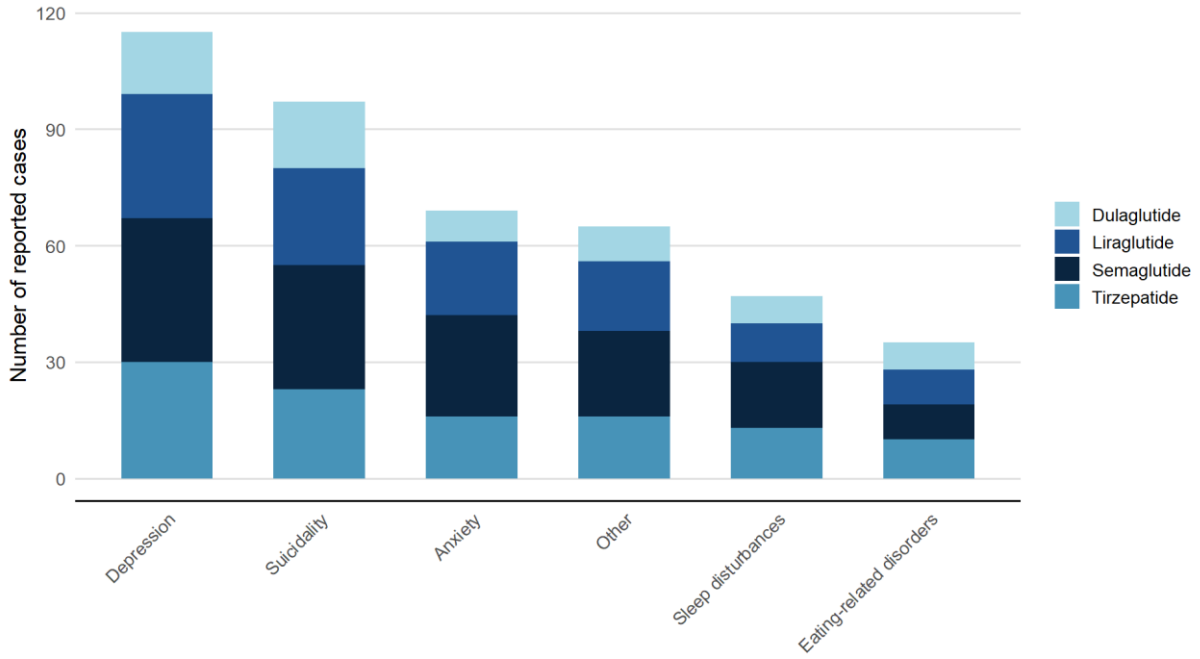

Figure 2. Distribution of reported mental health outcomes across different GLP-1 receptor agonists. The plot illustrates the total number of reported cases of mental health side effects extracted from included articles (N = 81), categorized by specific GLP-1 receptor agonists (*semaglutide, liraglutide, tirzepatide,* and *dulaglutide*). Individual bars represent the total indications for each condition, with color-coded segments representing the proportion contributed by each substance.

4. Discussion

This systematic review identified a growing body of literature on the mental health effects of GLP-1 receptor agonists. This review represents a substantial update to Tempia Valenta et al. (2024), incorporating 68 additional studies published between 2024 and 2026 and thereby providing a more current and comprehensive synthesis of the evidence.

Depression was the most frequently reported outcome, followed by suicidality, while sleep disturbances and eating-related disorders were discussed less frequently. This disparity may be partially attributed to regulatory requirements that emphasize monitoring mood changes, such as anxiety, suicidality risk, or depression, during the testing and introduction of new drugs (Sa et al., 2026). Semaglutide and liraglutide appeared most frequently in the included studies, which likely reflects their wider clinical use and popularity in treatment. Overall, the available literature suggests that interest in this topic is increasing as these drugs become more common in everyday practice.

GLP-1 receptor agonists may affect mental health through both beneficial and adverse pathways. On the beneficial side, GLP-1 receptors are present in brain regions involved in

appetite, reward, and emotion, and treatment may improve well-being through weight loss, better metabolic control, reduced inflammation, and less food-related distress (Au et al., 2025). On the other hand, alterations in dopaminergic reward signaling could potentially reduce pleasure responses or contribute to emotional blunting in susceptible individuals. Rapid weight loss, gastrointestinal adverse effects, and changes in appetite may also negatively affect quality of life for some patients (Badulescu et al., 2024). This bidirectional mechanism may help explain why studies report both positive and adverse psychiatric outcomes.

The larger number of reports involving semaglutide and liraglutide probably reflects their broader use rather than a higher psychiatric risk. Dulaglutide was less frequently represented, although it was still present across outcome categories. Therefore, the number of published reports should be interpreted cautiously, as it does not necessarily reflect true incidence.

Importantly, by including participants with pre-existing mental health conditions, this review provides a more comprehensive assessment of the intervention's effects in clinically relevant populations and highlights potential variability in outcomes across different mental health profiles.

This review has several limitations, including heterogeneity in study design, outcome definitions, and methods used to assess mental health outcomes, ranging from validated psychiatric scales and clinical diagnoses to spontaneous adverse event reporting systems and animal behavioral models. Many studies relied on reported symptoms rather than standardized psychiatric measures, and the review reflects reporting frequency rather than true risk. The search was also limited to PubMed, Scopus, and English-language publications. We are aware of search string errors that were found during the review process, such as repeating the same words in one search string (e.g. anxiety OR "anxiety disorder*"). However, we decided to keep it in the final version of the systematic review to have original data with corresponding results.

Future research should use larger prospective cohorts, longer follow-up, and standardized mental health outcomes. Comparative studies of individual GLP-1 receptor agonists and high-risk psychiatric populations are also needed. Overall, further research is required to clarify the mental health safety profile of these medications

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References:

Ard J, Fitch A, Fruh S, Herman L. (2021) Weight loss and maintenance related to the mechanism of action of glucagon-like peptide 1 receptor agonists. *Adv. Ther.* **38**, 2821–2839.

Arillotta D, Floresta G, Guirguis A, Corkery JM, Catalani V, Martinotti G, Schifano F. (2023) GLP-1 receptor agonists and related mental health issues: insights from a range of social media platforms using a mixed-methods approach. *Brain Sci.* **13**, 1503.

Au HCT, Zheng YJ, Le GH, Wong S, Phan L, Teopiz KM, Kwan ATH, Rhee TG, Rosenblat JD, Ho R, McIntyre RS. (2025) A systematic review in effects of glucagon-like peptide-1 (GLP-1) mono-agonists on functional connectivity: target engagement and rationale for the development in mental disorders. *J. Affect. Disord.* **370**, 321–327. (doi:10.1016/j.jad.2024.11.019)

Badulescu S, Tabassum A, Le GH, Wong S, Phan L, Gill H, Llach C-D, McIntyre RS, Rosenblat J, Mansur R. (2024) Glucagon-like peptide 1 agonist and effects on reward behaviour: a systematic review. *Physiol. Behav.* **283**, 114622. (doi:10.1016/j.physbeh.2024.114622)

Chan, T. H., Cosler, L. E., Gionfriddo, M. R., Leppien, E. E., Sommers, E. J., & Lussier, M. E. (2026). Association Between Glucagon-Like Peptide-1 Receptor Agonists and Suicidality: A Systematic Review. *Diabetes, obesity & metabolism*, 10.1111/dom.70878. Advance online publication. https://doi.org/10.1111/dom.70878

Eisa, N., & Khoury, M. (2026). The Effect of Semaglutide on Quality of Life in Adults With Overweight or Obesity: A Brief Systematic Review and Meta-Analysis. *Diabetes, obesity & metabolism*, 10.1111/dom.70992. Advance online publication. https://doi.org/10.1111/dom.70992

Ferrer Zavala, G. M., Caro Rodriguez, C. F., Carrion Carrion, P., Martinez Artiga, L., Morales Del Cid, Z. Y., Chia, J. E., & Valladares, C. (2026). Risk of Depression With Glucagon-Like Peptide-1 (GLP-1) Receptor Agonists Compared to Other Antidiabetic Medications in Adults With Type 2 Diabetes: A Systematic Review and Meta-Analysis. *Cureus*, 18(4), e106972. https://doi.org/10.7759/cureus.106972

Han SH, Safeek R, Ockerman K, Trieu N, Mars P, Klenke A, Sorice-Virk S. (2024) Public interest in the off-label use of glucagon-like peptide 1 agonists (Ozempic) for cosmetic weight loss: a Google Trends analysis. *Aesthet. Surg. J.* **44**, 60–67.

Hlavinka E. (2024) Can diabetes drugs like Ozempic tackle the mental health crisis? *ACS Cent. Sci.* **10**, 1427–1431. (doi:10.1021/acscentsci.4c01250)

Kim, J. A., & Yoo, H. J. (2025). Exploring the Side Effects of GLP-1 Receptor Agonist: To Ensure Its Optimal Positioning. *Diabetes & metabolism journal*, 49(4), 525–541. https://doi.org/10.4093/dmj.2025.0242

Moiz, A., Filion, K. B., Tsoukas, M. A., Yu, O. H., Peters, T. M., & Eisenberg, M. J. (2025). Mechanisms of GLP-1 Receptor Agonist-Induced Weight Loss: A Review of Central and Peripheral Pathways in Appetite and Energy Regulation. *The American journal of medicine*, 138(6), 934–940. https://doi.org/10.1016/j.amjmed.2025.01.021

Sa, B., Maristany, A., Subramaniam, A., Kumbkarni, N., Lange, R., Oldak, S., Buciuc, A. G., & Padilla, V. (2026). Retrospective chart review on psychiatric manifestations of GLP-1 agonist usage. *Journal of psychiatric research*, *195*, 92–96. https://doi.org/10.1016/j.jpsychires.2026.01.042

Suran M. (2023) As Ozempic's popularity soars, here's what to know about semaglutide and weight loss. *JAMA* **329**, 1627–1629. (doi:10.1001/jama.2023.2438)

Tempia Valenta, S., Nicastri, A., Perazza, F. , Marcolini F., Beghelli V., Atti A.R., Petroni M. L. (2024). The Impact of GLP-1 Receptor Agonists (GLP-1 RAs) on Mental Health: A Systematic Review. *Curr Treat Options Psych* 11, 310–357. https://doi.org/10.1007/s40501-024-00331-y

Zhang, Y., Zhao, Z., Higgins, V., & Barlow, S. (2026). Real-world experience of semaglutide 2.4 mg in the US: a retrospective analysis of profiles, satisfaction, and treatment patterns in people with obesity and overweight. *Current medical research and opinion*, 1–12. Advance online publication. https://doi.org/10.1080/03007995.2026.2689307

Systematic review on biodiversity interventions and management practices on university campuses

First version of the systematic review

Biodiversity Interventions and Management Practices on University Campuses: A Systematic Review

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Summary

University campuses can serve as important urban biodiversity refuges and living laboratories for sustainability, yet little is known about the interventions implemented to preserve or enhance the biodiversity within these settings. To fill this gap, we conducted a systematic review of biodiversity-focused interventions on university campuses.

The literature was concentrated in the Global North, particularly the United States. Institutional policies were the most common governance mechanism, while habitat restoration, vegetation management, and green infrastructure were the dominant intervention types. Green roofs emerged as the single most frequently reported intervention. The papers focused primarily on ecological objectives and outcomes, with plants and insects receiving the greatest attention. Social outcomes and several taxonomic groups, including vertebrates and soil organisms, were comparatively underrepresented. Although more than half of the studies reported successful interventions, the evidence base was highly heterogeneous in terms of intervention types, evaluation methods, and outcome measures.

Overall, university campuses demonstrate considerable potential as living laboratories for biodiversity conservation and sustainable urban development. However, the literature remains fragmented, geographically biased, and focused on a limited range of interventions and taxa.

Introduction

University campuses are valuable parts of cities. By providing knowledge, entrepreneurship, education, and employment opportunities, they contribute significantly to urban development (Leal Filho et al., 2023; Peng & Xu, 2024). However, their role in building educated and resilient societies extends beyond these functions. University-owned spaces can also serve as models for sustainable urban development (Martínez-Acosta et al., 2023).

Global biodiversity has declined substantially and is expected to continue decreasing in the future (Pereira et al., 2024). Although urban areas may support increased abundance and species richness for some taxa, such as birds and plants (Faeth et al., 2011), biodiversity in other groups has declined (Piano et al., 2019; Chatelain et al., 2023). University campuses are often characterised by surprisingly high levels of biodiversity (Liu et al., 2021), frequently exceeding those found in other parts of the city (Zhang et al., 2021). As a result, campuses can function as important urban biodiversity refuges. Owing to both their ecological value and educational mission, campuses can also serve as living labs where biodiversity is integrated into teaching, research, restoration practice, and citizen science, directly connecting students and the wider public with nature.

As socially responsible institutions, universities bear a responsibility to conserve biodiversity and enhance the ecological value of their green and blue spaces (Ryan-Fogarty et al., 2022). Consequently, many universities have implemented a range of biodiversity-focused interventions on their campuses. These initiatives are typically designed to promote local biodiversity and take various forms, including reduced mowing frequencies (Lerew, 2024), the creation of small habitats and the cultivation of native plant species (Winkler et al., 2021), the integration of restoration projects into curricula (Christensen et al., 2025), and support for local wildlife (Cousquer et al., 2024).

Despite growing interest in campus biodiversity, most scientific literature focuses on biodiversity patterns and species composition on campuses rather than on interventions aimed at enhancing biodiversity (e.g., Liu et al., 2021; Arjona et al., 2023). To address this gap, we

conducted a systematic review to identify and synthesise biodiversity interventions implemented on university campuses and reported in scientific literature.

Methods

Search strategy

Prior to constructing our search strings, we established the PECO (Population, Exposure, Comparators, Outcomes) framework. On its basis, we selected suitable keywords (Table 1.). Our search string was designed to retrieve papers related to the interventions aimed at supporting biodiversity at university campuses (e.g. habitat restoration, reducing mowing frequency, tree planting).

Table 1. PECO framework for studies included in the systematic review.

Element	**Evidence**	**Keywords**
Population	Biodiversity at campuses.	((("fauna" OR "flora" OR "Wildlife") AND (("rich") OR ("richness") OR ("abundan*") OR ("divers*"))) OR ("diversity" AND (biolog* OR ecolog* OR habitat*)) OR (biodivers* OR "biological divers*" OR "species divers*" OR "species richness" OR "species abundance")) AND (universit* OR campus* OR "higher education institution*" OR "college*" OR "higher education" OR "academic institution*")
Exposure	Different types of interventions in campuses, e.g. enforcement of governance policies (targeting biodiversity), establishment of physical barriers to restrain free mobility of organisms, abstaining from mowing, creating artificial ponds, plantation of native species.	(intervention* OR manage* OR policy OR policies OR conservat* OR planning OR "restorat*" OR "practice*" OR "treatment*")

Comparators	Comparator components were not applied because comparison between interventions or against control conditions was not relevant to the scope of this study.	
Outcomes	Any measures applied to assess the success of the interventions	

We searched two databases, Scopus and Web of Science, using the following search strings:

Scopus:

((("fauna" OR "flora" OR "Wildlife") AND (("rich") OR ("richness") OR ("abundan*") OR ("divers*"))) OR ("diversity" AND (biolog* OR ecolog* OR habitat*)) OR (biodivers* OR "biological divers*" OR "species divers*" OR "species richness" OR "species abundance")) AND (universit* OR campus* OR "higher education institution*" OR "college*" OR "higher education" OR "academic institution*") AND (intervention* OR manage* OR policy OR policies OR conservat* OR planning OR "restorat*" OR "practice*" OR "treatment*")

Web of Science:

((("fauna" OR "flora" OR "Wildlife") AND (("rich") OR ("richness") OR ("abundan*") OR ("divers*"))) OR ("diversity" AND (biolog* OR ecolog* OR habitat*)) OR (biodivers* OR "biological divers*" OR "species divers*" OR "species richness" OR "species abundance")) AND (universit* OR campus* OR "higher education institution*" OR "college*" OR "higher education" OR "academic institution*") AND (intervention* OR manage* OR policy OR policies OR conservat* OR planning OR "restorat*" OR "practice*" OR "treatment*")

Screening process

In total, we obtained 8876 records. All of them were imported to Ryyan (Ouzzani, 2016) for duplicate removal and the abstract screening. The abstract screening process was done by two teams of two researchers each with following inclusion criteria applied:

1. Papers published in English,

2. Peer reviewed empirical research papers,
3. Studies describing any type of intervention aimed at supporting biodiversity,
4. Intervention has to concern local biodiversity at university campuses.

Articles that fulfilled the inclusion criteria were imported to Zotero for the full-text screening which was done independently by four researchers. In order to efficiently conduct the full-text screening we created a form to collect the data regarding: (1) country of the campus; (2) campus setting (urban, suburban or rural); (3) governance of the intervention (institutional policy, bottom-up initiative, research experiment); (4) stated objective of the intervention (ecological, social or infrastructural objectives); (5) type of the intervention; (6) studied groups of organisms; (7) measured outcomes (ecological, social or infrastructural outcomes) and their assessing method type (quantitative or qualitative). Approximately 40% of articles were excluded at this stage, either because they failed to meet the inclusion criteria, or due to the restricted access. In total, 50 articles were included in the systematic review. The exact numbers of articles included and excluded at each stage of the systematic review are presented on the PRISMA diagram (Fig. 1)

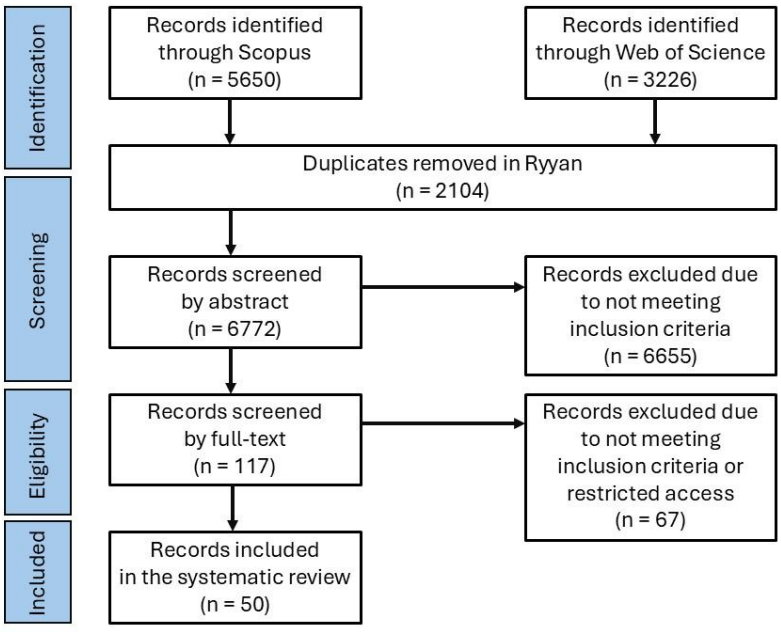

Fig. 1. PRISMA diagram presenting each step of our systematic review.
n – number of articles.

Results

The studies included were geographically concentrated in the Global North, which represented 58% of the sample. By country, the United States accounted for the largest share, with 30% of the studies, followed by Spain, with 10%, and Japan, with 6%. Other countries, including the United Kingdom, India, Taiwan, China, Canada and Mexico, each represented 4% of the sample. At the regional level, Asia accounted for 22% of studies, Latin America for 12%, Africa for 6%, and Australia for 2% (Fig. 2A.).

Most interventions were implemented in urban campuses, which represented 44% of the studies. Suburban campuses accounted for 18%, while the campus setting was not specified in 38% of the cases (Fig 2B.). Regarding governance, interventions were most often framed as institutional policies, representing 43% of the sample. Research experiments accounted for 25%, whereas bottom-up initiatives represented 9%. Governance was not specified in 23% of the studies (Fig 2C.).

The interventions primarily pursued ecological objectives, which represented 45% of all reported objectives. Human or social objectives accounted for 29%, while management or infrastructure objectives represented 26% (Fig. 2D.). The most common intervention types were habitat creation or restoration and vegetation or landscape management, each accounting for 27% of intervention types. These were followed by green infrastructure (25%), monitoring or research activities (11%), and species-support interventions (9%) (Fig. 2E.).

At the level of specific interventions, green roofs were the most frequent, representing 16% of studies. Green policy or management accounted for 10%, while forest restoration and wetland construction or restoration each represented 8%. Stormwater management accounted for 6%. Other interventions, such as wildlife conflict management, native plantings, pollinator gardens, reduced mowing, invasive species management, bird houses and bee nests, were less frequent and each represented between 2% and 4% of the sample (Table 2.).

The taxonomic focus of the literature was uneven. Plants were the most frequently studied group, representing 37% of the reported taxa, followed by insects, with 19%. Birds accounted for 3%, while fish, amphibians, reptiles and soil organisms each represented 2%. In addition, the targeted taxa were not specified in 21% of the studies. This suggests that campus biodiversity interventions have been evaluated mainly through plant and insect related indicators, while other taxonomic groups remain underrepresented (Table 2.).

Most papers included some form of outcome evaluation, with 92% reporting evaluated outcomes and 8% not reporting any evaluation. Ecological outcomes were the most common, representing 56% of outcome categories. In contrast, human or social outcomes relied more often on qualitative approaches, which accounted for 62%, while quantitative methods represented 38%. Management or infrastructure outcomes were also mostly assessed quantitatively, with quantitative methods representing 69% of assessments.

Finally, 53% of the studies classified the intervention as successful, while 14% reported partially successful interventions and 6% classified the intervention as unsuccessful. However, intervention success was not specified in 27% of the studies. Overall, the evidence suggests that campus biodiversity interventions are generally reported as successful or partially successful, although this conclusion should be interpreted cautiously given the heterogeneity of interventions, outcomes and evaluation methods.

Taken together, the literature is concentrated in Global North and urban campus contexts, is frequently driven by institutional policies, and focuses mainly on ecological objectives through habitat restoration, vegetation management, and green infrastructure. The evidence is strongest for plants and insects, while other taxonomic groups remain underrepresented.

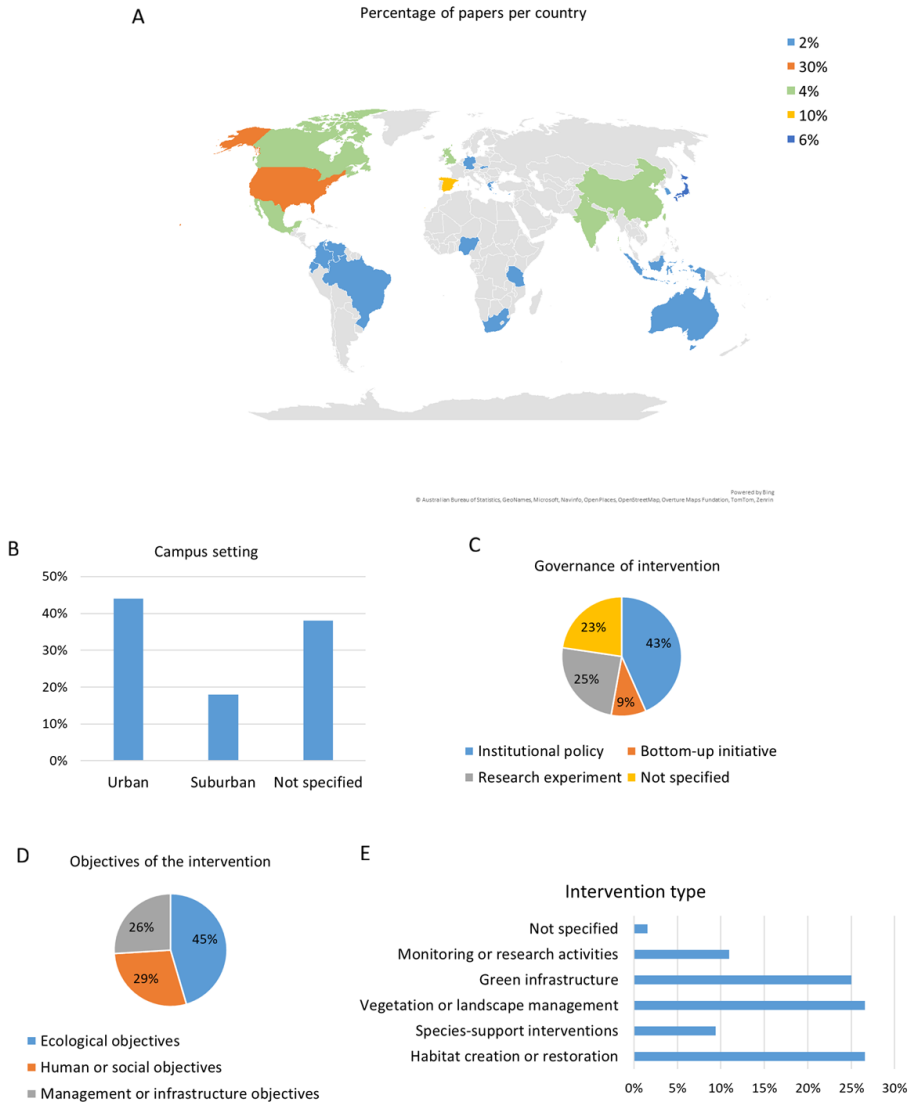

Fig. 2. Systematic review results. (A) the geographic distribution of the articles; (B) setting of the campus where intervention was conducted; (C) the governance of the intervention; (D) the stated objectives of the interventions; (E) the types of implemented interventions.

Table 2. Frequency of biodiversity intervention types and taxonomic groups studied in the reviewed papers.

Category	Item	Number of papers describing the item	Percentage of papers describing the item
Taxa studied	Plants	23	37%
	Insects	12	19%
	Non-insect invertebrates	5	8%
	Mammals	4	6%
	Birds	2	3%
	Fish	1	2%
	Amphibians	1	2%
	Reptiles	1	2%
	Soil organisms	1	2%
	Not specified	13	21%
Intervention type	Green roofs	8	16%
	Green policy / management	5	10%
	Forest restoration	4	8%
	Wetland construction / restoration	3	6%
	Stormwater management	3	6%
	Native plantings	2	4%
	Forest management	2	4%
	Pollinator gardens	2	4%
	Citizen science	2	4%
	Stray cats / dogs control	2	4%
	Invasive / non-native speciel management	2	4%
	Water bodies management	2	4%
	Wildlife conflicts management	1	2%

Greywater irrigation	1	2%
Landfill restoration	1	2%
Meadow restoration	1	2%
Reduced mowing	1	2%
Community gardens	1	2%
Rain garden	1	2%
Ecogarden	1	2%
Introducing species supporting ecosystem	1	2%
Riverbank restoration	1	2%
Small botanical refuges	1	2%
Bird houses	1	2%
Bee nests	1	2%
Ecosystem restoration	1	2%

Discussion

Our aim in this study was to present an overview of the state of the art in the field of biodiversity-supporting interventions on university campuses. The concept of science in action is not new (Lewin, 1946); moreover, it was renewed lately by the accelerated emergence of the living lab methodology (Bajgier et al., 1991). The idea began to gain more traction when the European Union introduced the Living Lab concept in its policy in 2006, when the Finnish EU Presidency launched the European Network of Living Labs (ENoLL, 2024) and the European Commission began funding living labs (Franz et al., 2015; Mulder, 2012).

Proximity, familiarity with the management structure, and the possibility of student engagement are but a few advantages that this setting has to offer to researchers (Tercanli & Jongbloed, 2022). And yet our results suggest that researchers are not eager to transform their local ecosystems. The overall number of retrieved papers after abstract screening was low (~2%). The most often recurring exclusion reason after full-text screening was the lack of a real intervention in the study (52%). The first reason for such results is the effect of including the "University" keyword in the search string, which generated a high number of studies that mentioned their affiliation in the abstract. The second reason is of a speculative and

metascientific nature. Despite favourable opinions among scientists towards engaged research, they often struggle in this field (Rose et al., 2020). A frequently cited reason is institutional inertia and the publish-or-perish ecosystem and its relation to funding (Becker & Lukka, 2023). Scientists are recognized for their contributions to theoretical foundations, and actively engaged individuals are often perceived as less serious than their colleagues (Martinez-Conde, 2016). Moreover, journals seek novel results, which are difficult to achieve while implementing existing frameworks (Kien et al., 2014). Scientific work is therefore governed by the flow of funding and publishing trends (Ramassa et al., 2024). Therefore, it is not surprising that 43% of the analysed studies were concerned with the influence of institutional policy.

The resulting publication landscape poses a substantial challenge for performing a systematic review (Chapman et al., 2023). The effectiveness of many interventions could not be conclusively assessed at the time of publication, as measurable outcomes often require extended monitoring periods or are inherently difficult to evaluate in the short term. Consequently, several studies reported only preliminary or partial evidence of success. Where intervention outcomes were assessed, evaluation was predominantly based on biological and ecological indicators, including biodiversity indices, species richness, abundance measures, and plant survival rates. In contrast, although many authors emphasized potential benefits for human well-being and user experience, these dimensions were assessed considerably less frequently and with less methodological rigour. The final decision on the success of the study was highly subjective. Often there was no criteria of success or failure provided, therefore our data on this matter should be treated with caution, supporting the need for uniform procedure of evaluation for action oriented research (Chapman et al., 2023; Klaus-Rosińska & Iwko, 2023).

The only preference that can be established among the chosen types of intervention is the low representation of species-support interventions, which might not be well perceived in the context of biodiversity-focused interventions. Examples of the interventions reviewed lack unification or significant replication, with 55% of cases appearing incidentally solely once or twice. The only type of intervention that received higher consideration was the green roof (8 examples, described in 16% of papers). A possible reason behind this is the ease of implementation by campus governance when ground-level space is a limiting factor (Zhang & He, 2021). Beyond the establishment of vegetated roof surfaces, several studies investigated approaches to enhance their functional performance. These included modifications to substrate composition aimed at improving thermal regulation while maintaining suitable conditions for plant growth and survival.

The majority of the identified interventions targeted plants. Insect-related interventions, particularly those concenrning pollinators, constituted another noteworthy category of biodiversity-enhancement strategies. Notably, two studies addressed the management of free-ranging cat and dog populations. Although less common than habitat-based interventions, such measures are particularly relevant due to the direct impacts that unmanaged animal populations can have on local biodiversity (Hughes & Macdonald, 2013).

Furthermore, many studies framed biodiversity interventions within a broader sustainability context, emphasizing their multiple co-benefits (Kabisch et al., 2022). In addition to supporting biodiversity conservation, green infrastructure measures were frequently associated with improvements in user well-being, enhanced campus management, and increased operational resilience (Mouratidis & Yiannakou, 2022). Examples included interventions designed to mitigate flooding risks, reduce local temperatures, and improve overall environmental quality within campus settings.

The authors tend to notice that urban biodiversity remains one of the essential problems to address and recognize the importance and the special place of university campus in the urban context, yet the resulting publication landscape is chaotic and barren. However, a crucial limitation that has to be considered while assessing the conclusions of this review is the lack of grey literature inclusion, which might prove to be essential in discovering which biodiversity interventions are really practised on academic campuses.

To prepare this report, we used DeepL for grammar corrections.

Bibliography:

Arjona, J. M., Ibáñez-Álamo, J. D., & Sanllorente, O. (2023). Mediterranean university campuses enhance butterfly (Lepidoptera) and beetle (Coleoptera) diversity. *Frontiers in Ecology and Evolution*, *11*, 1130557.

Bajgier, S. M., Maragah, H. D., Saccucci, M. S., Verzilli, A., & Prybutok, V. R. (1991). Introducing Students to Community Operations Research by Using a City Neighborhood as a Living Laboratory. *Operations Research*, *39*(5), 701–709.

Becker, A., & Lukka, K. (2023). Instrumentalism and the publish-or-perish regime. *Critical Perspectives on Accounting*, *94*, 102436. https://doi.org/10.1016/j.cpa.2022.102436

Chapman, A., Rankin, N. M., Jongebloed, H., Yoong, S. L., White, V., Livingston, P. M., Hutchinson, A. M., & Ugalde, A. (2023). Overcoming challenges in conducting systematic reviews in implementation science: A methods commentary. *Systematic Reviews*, *12*(1), 116. https://doi.org/10.1186/s13643-023-02285-3

Chatelain, M., Rüdisser, J., & Traugott, M. (2023). Urban-driven decrease in arthropod richness and diversity associated with group-specific changes in arthropod abundance. *Frontiers in Ecology and Evolution*, *11*, 980387.

Christensen, M., Seeley, R., Ungos, J., Lyman, Z., & Ingley, S. J. (2025). Sustainable restoration: addressing critical challenges through university-led projects. *Restoration Ecology*, *33*(3), e14337.

Cousquer, G., Norris, E., Lurz, P., Gurnell, J., & Vandermeer, E. (2024). Hedgerows for hedgehogs and campus biodiversity: A prickly challenge for universities. *Journal of Awareness-Based Systems Change*, *4*(1), 101-126.

Faeth, S. H., Bang, C., & Saari, S. (2011). Urban biodiversity: patterns and mechanisms. *Annals of the new York Academy of Sciences*, *1223*(1), 69-81.

Franz, Y., Tausz, K., & Thiel, S.-K. (2015). *Contextuality and Co-Creation Matter: A Qualitative Case Study Comparison of Living Lab Concepts in Urban Research*. *5*(12).

Hughes, J., & Macdonald, D. W. (2013). A review of the interactions between free-roaming domestic dogs and wildlife. *Biological Conservation*, *157*, 341–351. https://doi.org/10.1016/j.biocon.2012.07.005

Kabisch, N., Frantzeskaki, N., & Hansen, R. (2022). Principles for urban nature-based solutions. *Ambio*, *51*(6), 1388–1401. https://doi.org/10.1007/s13280-021-01685-w

Kien, C., Nußbaumer, B., Thaler, K. J., Griebler, U., Van Noord, M. G., Wagner, P., & Gartlehner, G. (2014). Barriers to and facilitators of interventions to counter publication bias: Thematic analysis of scholarly articles and stakeholder interviews. *BMC Health Services Research*, *14*(1), 551. https://doi.org/10.1186/s12913-014-0551-z

Klaus-Rosińska, A., & Iwko, J. (2023). Success of research projects. Prediction and assessment from the point of view of project stakeholders thereby taking into account a sustainability approach. *Operations Research and Decisions*, *33*(4). https://doi.org/10.37190/ord230406

Leal Filho, W., Aina, Y. A., Dinis, M. A. P., Purcell, W., & Nagy, G. J. (2023). Climate change: Why higher education matters?. *Science of The Total Environment*, *892*, 164819.

Lerew, R. (2024). The Impacts of 'No-Mow'Areas on Floral Diversity: A Case Study at the University of Otago. *Pūhau ana te rā: Tailwinds*, *2*(2).

Lewin, K. (1946). Action Research and Minority Problems. *Journal of Social Issues*, *2*(4), 34–46. https://doi.org/10.1111/j.1540-4560.1946.tb02295.x

Liu, J., Zhao, Y., Si, X., Feng, G., Slik, F., & Zhang, J. (2021). *University campuses as valuable resources for urban biodiversity research and conservation. Urban For. Urban Green. 64, 127255*.

Martínez-Acosta, M., Vázquez-Villegas, P., Mejía-Manzano, L. A., Soto-Inzunza, G. V., Ruiz-Aguilar, K. M., Kuhn Cuellar, L., ... & Membrillo-Hernández, J. (2023). The implementation of SDG12 in and from higher education institutions: universities as laboratories for generating sustainable cities. *Frontiers in Sustainable Cities*, *5*, 1158464.

Martinez-Conde, S. (2016). Has Contemporary Academia Outgrown the Carl Sagan Effect? *Journal of Neuroscience*, *36*(7), 2077–2082. https://doi.org/10.1523/JNEUROSCI.0086-16.2016

Mouratidis, K., & Yiannakou, A. (2022). What makes cities livable? Determinants of neighborhood satisfaction and neighborhood happiness in different contexts. *Land Use Policy*, *112*, 105855. https://doi.org/10.1016/j.landusepol.2021.105855

Mulder, I. (2012). Living Labbing the Rotterdam Way: Co-Creation as an Enabler for Urban Innovation. *Technology Innovation Management Review*, *2*(9), 39–43.

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan—a web and mobile app for systematic reviews. *Systematic reviews*, *5*(1), 210.

Peng, C., & Xu, H. (2024). Universities and cities: The impact of higher education on urban innovation, entrepreneurship, and economic growth. *Asian Economic Papers*, *23*(2), 33-56.

Pereira, H. M., Martins, I. S., Rosa, I. M., Kim, H., Leadley, P., Popp, A., ... & Alkemade, R. (2024). Global trends and scenarios for terrestrial biodiversity and ecosystem services from 1900 to 2050. *Science*, *384*(6694), 458-465.

Piano, E., Souffreau, C., Merckx, T., Baardsen, L. F., Backeljau, T., Bonte, D., ... & Hendrickx, F. (2020). Urbanization drives cross-taxon declines in abundance and diversity at multiple spatial scales. *Global change biology*, *26*(3), 1196-1211.

Ramassa, P., Avallone, F., & Quagli, A. (2024). Can "publishing game" pressures affect the research topic choice? A survey of European accounting researchers. *Journal of Management and Governance*, *28*(2), 507–542. https://doi.org/10.1007/s10997-023-09667-8

Rose, K. M., Markowitz, E. M., & Brossard, D. (2020). Scientists' incentives and attitudes toward public communication. *Proceedings of the National Academy of Sciences*, *117*(3), 1274–1276. https://doi.org/10.1073/pnas.1916740117

Ryan-Fogarty, Y., Carlin, C. M., Kirakowski, T., Kirrane, M. J., Lysaght, L., & Reidy, D. T. (2022). Evaluating the use of intervarsity bioblitz as an engagement and reporting tool for biodiversity in green and blue spaces on urban campuses: A case study of irish universities. In *Biology and Environment: Proceedings of the Royal Irish Academy* (Vol. 122, No. 3, pp. 181-200). Royal Irish Academy.

Tercanli, H., & Jongbloed, B. (2022). A Systematic Review of the Literature on Living Labs in Higher Education Institutions: Potentials and Constraints. *Sustainability*, *14*(19). https://doi.org/10.3390/su141912234

Zhang, G., & He, B.-J. (2021). Towards green roof implementation: Drivers, motivations, barriers and recommendations. *Urban Forestry & Urban Greening*, *58*, 126992. https://doi.org/10.1016/j.ufug.2021.126992

Zhang, Y., Jiang, C., Chen, S., Zhang, Y., Shi, H., Chen, B., & Mao, L. (2021). Effects of landscape attributes on campuses bird species richness and diversity, implications for eco-friendly urban planning. *Sustainability*, *13*(10), 5558.

Reviews of the first version of the systematic review

Review 1.

This manuscript presents a systematic review of biodiversity-supporting interventions implemented on university campuses. The topic is relevant and timely, as universities are increasingly viewed as important actors in urban sustainability and biodiversity conservation. The review addresses a clear gap in the literature by focusing on interventions rather than simply documenting biodiversity patterns on campuses.

The manuscript has several strengths. The research question is well motivated, the systematic review approach is appropriate, and the authors successfully identify major trends in the literature. In particular, the findings reveal a strong geographic concentration of studies in the Global North, a predominance of institutional policy-driven interventions, and a focus on plants and insects as target taxa. These observations are useful for understanding current research priorities and identifying knowledge gaps.

The paper is generally well structured and follows a logical progression from introduction to discussion. The figures and tables effectively summarize the main findings, and the manuscript remains concise despite covering a relatively broad topic.

However, several issues should be addressed.

First, the search strategy appears very broad and may have generated many irrelevant records. The authors note that including terms such as “university” produced numerous unrelated results. A more critical discussion of how the search strategy may have influenced the final sample would strengthen the paper.

Second, the exclusion of articles due to restricted access deserves attention. The manuscript states that a substantial proportion of studies were excluded during full-text screening because they were inaccessible. The authors could specify how many papers were excluded for this reason and discuss the potential bias introduced by this decision.

Third, the classification of interventions as successful, partially successful, or unsuccessful requires additional methodological clarification. The criteria used to assign these categories are not fully explained, and the assessment appears partly subjective. A clearer description of the evaluation procedure would improve transparency and reproducibility.

The Discussion could also be strengthened by moving beyond descriptive summaries. The review identifies common intervention types, but it would be valuable to discuss whether any interventions appear particularly promising or consistently effective. This would increase the practical relevance of the study.

A number of minor issues should also be corrected. There are some typographical and stylistic errors throughout the manuscript. Consistent terminology should be used when referring to biodiversity interventions.

Overall, this manuscript provides a useful synthesis of an emerging research area and highlights important gaps in the literature on campus biodiversity interventions. While some methodological details require clarification, the study offers valuable insights for researchers and practitioners interested in biodiversity conservation on university campuses.

Review 2.

This manuscript presents a systematic review of biodiversity-related interventions implemented on university campuses. I think the topic is interesting and relevant, especially considering the growing interest in biodiversity conservation and sustainability in higher education institutions. While many studies focus on biodiversity patterns on campuses, fewer seem to examine actual interventions, so I think this review addresses a useful gap in the literature.

Overall, I found the manuscript well organized and easy to follow. The objectives are clearly stated, and the use of a systematic review approach together with the PRISMA framework makes the methodology transparent. The figures and tables are also helpful and allow the reader to quickly understand the main patterns identified in the reviewed studies.

One aspect that I particularly liked was the overview of the different types of interventions implemented on university campuses. It was interesting to see that green roofs, habitat restoration, and vegetation management were among the most commonly reported actions. I also found the geographical bias towards the United States and other countries of the Global North noteworthy, as it highlights an important gap in the existing literature. The discussion of campuses as living laboratories was also valuable and fits well with the broader role of universities in sustainability initiatives.

At the same time, I have a few comments that could help strengthen the manuscript.

First, I found the classification of intervention success somewhat problematic. The authors acknowledge that many studies did not provide clear criteria for defining success or failure. Because of this, categorizing interventions as successful, partially successful, or unsuccessful seems at least partly subjective. In my opinion, this limitation should be emphasized more clearly in the Discussion section.

Second, some parts of the Discussion appear to go beyond the results of the review itself. For example, the sections concerning publication pressure, academic incentives, and institutional barriers are interesting, but these issues were not directly investigated in the reviewed studies. I think it would be useful to make it clearer that these are possible explanations proposed by the authors rather than conclusions that emerge directly from the analysed literature.

I also noticed a few minor language issues and typographical errors throughout the manuscript. They do not affect the overall quality of the paper, but a careful proofreading would improve readability.

Despite these comments, I believe the manuscript provides a useful overview of biodiversity interventions on university campuses and identifies several important trends and knowledge gaps. The study has practical relevance and may be useful both for researchers and for university stakeholders interested in biodiversity management.

Overall, I think this is a valuable contribution on an interesting topic. I recommend the manuscript for publication after minor revisions.

Review 3.

The presented systematic review highlights the importance and role of university campuses as possible biodiversity hotspots in urban areas. Posing as examples for students and city residents, university campuses might be considered as living labs where the implementation of biodiversity intervention actions should be well visible. Authors address a gap in the literature related to biodiversity interventions on campuses. I find this systematic review to be valuable and important work worth publishing after modifications.

The introduction section provides a rationale and state of the art for undertaking this research problem. Its advantage is that it is concise and supported with bibliography records from mainly the last five years. I have a few concerns regarding Methods section:

- I did not find information about a protocol that should be written before conducting a systematic review. Was it done? Access should be provided.
- I would suggest moving to the protocol or PRISMA diagram informations about the inclusion criteria.
- Also, I do not see the point of presenting the PICO table in the manuscript, as comparators are not applicable for answering the research question and the logic of building the search string is clear.
- Please, add the exact date of the article search.
- It is not clear how full-text screening was done. Authors are claiming in lines 92-93: "Articles that fulfilled the inclusion criteria were imported to Zotero for the full-text screening, which was done independently by four researchers.". Does it mean that each article has been read four times?

The result section is written clearly and to the point. However, I have concerns about the way of results visualization. The main problem I see is providing values per cent without the raw number of papers, which might be misleading. Table 2. could be two separate tables but the results that are shown there will probably be easier to follow and compare in the form of a bar plot. Especially, that Figure 2E repeats information from Table 2. Two additional editorial notes – do not break the table between pages, and do not use the shortcut for Figure (Fig.) in its description when you use the full word for a Table.

I would consider moving parts of the Discussion section to the Introduction, especially lines 165-170. In my opinion, this systematic review is not a good place for divagations from lines 178-186. Despite this, I find the Discussion well written. I also have one comment to the Bibliography section: correct citations starting in lines 282, 298, and 301, as the full list of authors is not provided.

Taking into account the time limitation that the authors had, in my opinion, the provided manuscript insightfully attempts to fill the gap in knowledge. I would suggest publication after minor corrections.

Review 4.

Collaborative pro-environmental initiatives launched as Living Labs concept are of significant importance for the restoration of biological diversity. And university campuses in particular should implement environmental practices on their grounds that are consistent with established scientific principles. Therefore, this study is well aligned with current, significant research issues. This paper includes all the standard sections typical of this type of manuscript with requirements manuscripts followed the structure of Biology Letters, with the limit of 2500 words and a maximum of 4 displays.

The title and abstract accurately reflect the content of the article. In the introduction, the authors emphasize the vital role of campuses as key urban oases of biodiversity, the loss of which represents one of the most pressing environmental challenges of the 21st century. Thanks to their ecological value and educational mission, campuses can also serve as “living laboratories” where the issue of biodiversity loss is integrated into teaching, research, and restoration efforts, directly connecting students and the broader community with nature.

The aim of this systematic review was identification the biodiversity interventions implemented on university campuses, examination management practices used to maintain campus biodiversity and assessing ecological and social outcomes associated with these interventions.

The authors used Rayyan, a free mobile app that helps with the initial screening of abstracts and titles. As part of their final search, they collected articles on efforts to protect and promote biodiversity on university campuses, including habitat restoration, reducing mowing frequency, and planting native species. The authors searched two databases, Scopus and Web of Science, using exactly the same search terms, which, in my opinion, could have been described without repetition. As a result, they obtained 8,876 records, and ultimately, after applying four additional criteria and thanks to the well-planned work of the team of co-authors, they analyzed in detail 50 scientific articles recently published in English. Based on a well-selected range of scientific literature, they demonstrated that these activities primarily had ecological objectives, which accounted for 45% of all reported objectives. Human or social objectives accounted for 29%, while management or infrastructure objectives accounted for 26%.

Interestingly, they found habitat creation or restoration and vegetation or landscape management as a most common intervention type followed by green infrastructure. Measures to support species were the least frequently reported.

This systematic review synthesizes the current state of knowledge regarding biodiversity conservation efforts and management practices on university campuses in the Global North, assesses their ecological impacts, and identifies research gaps and directions for future research. As the authors rightly note, the effectiveness of many measures cannot be definitively assessed, as measurable results often require a long observation period, and evaluating them after such a short time is impossible. Therefore, it is not enough to simply implement eco-friendly measures; monitoring changes and impacts must also be taken into account. In conclusion, the authors also suggest that researchers are reluctant to transform local ecosystems. This highlights the important role of popularization activities within the scientific community as well.

Overall, the literature has been handled correctly, and all relevant references have been cited, with one exception (Winkler et al., 2021), which was mentioned in the introduction but not listed in the bibliography.

The language used in the manuscript is correct, which is likely the result of the text being checked by the Deepl translator.

Throughout the text, I found a few typos in lines 54, 175, 210, and 308 (respectively: “synthesize,” “favorable,” “concerning,” and “Irish”), which can easily be corrected.

Review 5.

The article “Biodiversity Interventions and Management Practices on University Campuses: A Systematic Review” provides a comprehensive synthesis of literature about different types of biodiversity interventions across university campuses. The authors show that there is a lack of studies documenting proactive approaches to conserve biodiversity at campuses, as most studies screened by them focus on describing existing biodiversity without proposing any interventions to protect it. They argue that researchers are encouraged to publish novel theoretical results rather than focus on applied research. This is an interesting commentary that adds to the discussion about the management of campus biodiversity – who should be responsible for deciding about biodiversity protection on campuses? These results could provide a call for action and show the need to appoint experts that could devote their time to such actions. By analyzing the aggregated data, the authors reveal that the current research landscape is heavily skewed toward the Global North, with a particularly high concentration of studies originating in the United States. Furthermore, the evaluation of these campus initiatives exhibits a taxonomic bias, focusing predominantly on plants and insects while leaving vertebrates and soil organisms largely unexamined. When interventions are actually documented, they most frequently take the form of habitat restoration, vegetation management, and green infrastructure, with green roofs emerging as the single most popular structural practice. The methods used by the authors are correct and standard for a systematic review. They are clearly stated, and the chosen keywords are relevant to the topic of the review. There seemed to be an issue with the search string word “universit*”, which was matching with a lot of articles not meeting the authors' criteria. This, however, was hard to avoid as it is a necessary keyword here. Another option could be to exclude non-scientific articles, because a lot of actions on campuses can be documented through other sources of media or locally published by students (or in their theses). The results are presented very comprehensively and then followed by an engaging discussion. There is a clear limitation due to the low number of papers included in this systematic review, although it may be interpreted as a result itself (not many records of successful management practices). This review shines a light on the problem of biodiversity management on university campuses, the lack of universal approaches to protecting biodiversity, and several biases such as geographical and species biases. Overall, everything is clearly written and shows the authors' dedication to this very relevant topic.

Final version of the systematic review

Biodiversity Interventions and Management Practices on University Campuses: A Systematic Review

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Summary

University campuses can serve as important urban biodiversity refuges and living laboratories for sustainability, yet little is known about the interventions implemented to preserve or enhance the biodiversity within these settings. To fill this gap, we conducted a systematic review of biodiversity-focused interventions on university campuses.

The literature was concentrated in the Global North, particularly the United States. Institutional policies were the most common governance mechanism, while habitat restoration, vegetation management, and green infrastructure were the dominant intervention types. Green roofs emerged as the single most frequently reported intervention. The papers focused primarily on ecological objectives and outcomes, with plants and insects receiving the greatest attention. Social outcomes and several taxonomic groups, including vertebrates and soil organisms, were comparatively underrepresented. Although more than half of the studies reported successful interventions, the evidence base was highly heterogeneous in terms of intervention types, evaluation methods, and outcome measures.

Overall, university campuses demonstrate considerable potential as living laboratories for biodiversity conservation and sustainable urban development. However, the literature remains fragmented, geographically biased, and focused on a limited range of interventions and taxa.

Introduction

University campuses are valuable parts of cities. By providing knowledge, entrepreneurship, education, and employment opportunities, they contribute significantly to urban development (Leal Filho et al., 2023; Peng & Xu, 2024). However, their role in building educated and resilient societies extends beyond these functions. University-owned spaces can also serve as models for sustainable urban development (Martínez-Acosta et al., 2023).

Global biodiversity has declined substantially and is expected to continue decreasing in the future (Pereira et al., 2024). Although urban areas may support increased abundance and species richness for some taxa, such as birds and plants (Faeth et al., 2011), biodiversity in other groups has declined (Piano et al., 2019; Chatelain et al., 2023). University campuses are often characterised by surprisingly high levels of biodiversity (Liu et al., 2021), frequently exceeding those found in other parts of the city (Zhang et al., 2021). As a result, campuses can function as important urban biodiversity refuges. Owing to both their ecological value and educational mission, campuses can also serve as living labs where biodiversity is integrated into teaching, research, restoration practice, and citizen science, directly connecting students and the wider public with nature.

As socially responsible institutions, universities bear a responsibility to conserve biodiversity and enhance the ecological value of their green and blue spaces (Ryan-Fogarty et al., 2022). Consequently, many universities have implemented a range of biodiversity-focused interventions on their campuses. These initiatives are typically designed to promote local biodiversity and take various forms, including reduced mowing frequencies (Lerew, 2024), the creation of small habitats and the cultivation of native plant species (Winkler et al., 2021), the integration of restoration projects into curricula (Christensen et al., 2025), and support for local wildlife (Cousquer et al., 2024).

Despite growing interest in campus biodiversity, most scientific literature focuses on biodiversity patterns and species composition on campuses rather than on interventions aimed at enhancing biodiversity (e.g., Liu et al., 2021; Arjona et al., 2023). To address this gap, we conducted a systematic review to identify and synthesise biodiversity interventions implemented on university campuses and reported in scientific literature. In addition to providing a systematic overview of the knowledge within this field of research, the insight gained in this study has practical implications for sustainable management of university campuses.

Methods

Search strategy

Our search string was designed to retrieve papers related to the interventions aimed at supporting biodiversity at university campuses (e.g. habitat restoration, reducing mowing frequency, tree planting).

On 11.05.2026 we searched two academic databases, Scopus and Web of Science, using the following search string:

((("fauna" OR "flora" OR "Wildlife") AND (("rich") OR ("abundan*") OR ("divers*"))) OR ("diversity" AND (biolog* OR ecolog* OR habitat*)) OR (biodivers* OR "biological divers*" OR "species divers*" OR "species richness" OR "species abundance")) AND (universit* OR campus* OR "college*" OR "higher education" OR "academic institution*") AND (intervention* OR manage* OR policy OR policies OR conservat* OR planning OR "restorat*" OR "practice*" OR "treatment*")

Screening process

In total, we obtained 8876 records. All of them were imported to Ryyan (Ouzzani, 2016) for duplicate removal and the abstract screening. The abstract screening process was done by two teams of two researchers each with following inclusion criteria applied:

1. Papers published in English,
2. Peer reviewed empirical research papers,
3. Studies describing any type of intervention aimed at supporting biodiversity,
4. Intervention has to concern local biodiversity at university campuses.

Articles that fulfilled the inclusion criteria were imported to Zotero and equally distributed among four researchers for the full-text screening. In order to efficiently conduct the full-text screening we created a form to collect the data regarding: (1) country of the campus; (2) campus setting (urban, suburban or rural); (3) governance of the intervention (institutional policy, bottom-up initiative, research experiment); (4) stated objective of the intervention (ecological, social or infrastructural objectives); (5) type of the intervention; (6) studied groups of organisms; (7) measured outcomes (ecological, social or infrastructural outcomes) and their assessing method type (quantitative or qualitative); (8) success or failure of the intervention

declared by the authors. Approximately 40% of articles were excluded at this stage, either because they failed to meet the inclusion criteria (61 articles), or due to the restricted access (6 articles). In total, 50 articles were included in the systematic review. The exact numbers of articles included and excluded at each stage of the systematic review are presented on the PRISMA diagram (Figure 1)

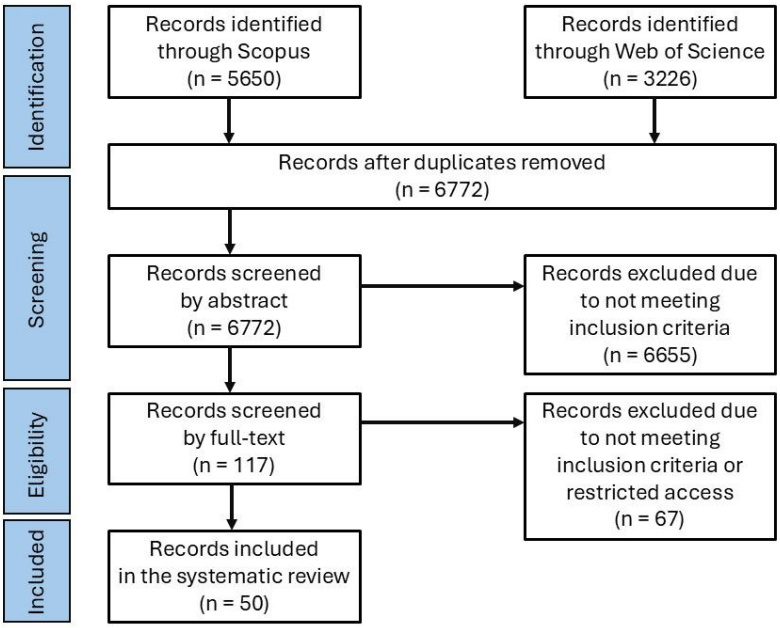

Figure 1. PRISMA diagram presenting each step of our systematic review.
n – number of articles.

Results

The studies included were geographically concentrated in the Global North, which represented 58% (29 papers) of the sample. By country, the United States accounted for the largest share, with 30% (15 papers) of the studies, followed by Spain, with 10% (5 papers), and Japan, with 6% (3 papers). Other countries, including the United Kingdom, India, Taiwan, China, Canada and Mexico, each represented 4% of the sample (2 papers for each country). At the regional level, Asia accounted for 22% of studies (11 papers), Latin America for 12% (6 papers), Africa for 6% (3 papers), and Australia for 2% (1 paper) (Figure 2A.).

Most interventions were implemented in urban campuses, which represented 44% of the studies (22 papers). Suburban campuses accounted for 18% (9 papers), while the campus setting was not specified in 38% (19 papers) of the cases (Figure 2B.). Regarding governance, interventions were most often framed as institutional policies, representing 43% (23 papers) of the sample.

Research experiments accounted for 25% (13 papers), whereas bottom-up initiatives represented 9% (5 papers). Governance was not specified in 23% (12 papers) of the studies (Figure 2C.).

The interventions primarily pursued ecological objectives, which represented 45% (35 papers) of all reported objectives. Human or social objectives accounted for 29% (22 papers), while management or infrastructure objectives represented 26% (20 papers) (Figure 2D.). The most common intervention types were habitat creation or restoration and vegetation or landscape management, each accounting for 27% (17 papers each) of intervention types. These were followed by green infrastructure (25% - 16 papers), monitoring or research activities (11% - 7 papers), and species-support interventions (9% - 6 papers) (Figure 2E.).

At the level of specific interventions, green roofs were the most frequent, representing 16% (8 papers) of studies. Green policy or management accounted for 10% (5 papers), while forest restoration and wetland construction or restoration each represented 8% (4 papers). Stormwater management accounted for 6% (3 papers). Other interventions, such as wildlife conflict management, native plantings, pollinator gardens, reduced mowing, invasive species management, bird houses and bee nests, were less frequent and each represented between 2% (1 paper) and 4% (2 papers) of the sample (Table 1.).

The taxonomic focus of the literature was uneven. Plants were the most frequently studied group, representing 37% (23 papers) of the reported taxa, followed by insects, with 19% (12 papers). Birds accounted for 3% (2 papers), while fish, amphibians, reptiles and soil organisms each represented 2% (1 paper). In addition, the targeted taxa were not specified in 21% (13 papers) of the studies. This suggests that campus biodiversity interventions have been evaluated mainly through plant and insect related indicators, while other taxonomic groups remain underrepresented (Table 2.).

Most papers included some form of outcome evaluation, with 92% (46 papers) reporting evaluated outcomes and 8% (4 papers) not reporting any evaluation. Ecological outcomes were the most common, representing 56% (32 papers) of outcome categories. In contrast, human or social outcomes relied more often on qualitative approaches, which accounted for 62% (8 papers), while quantitative methods represented 38% (5 papers). Management or infrastructure outcomes were also mostly assessed quantitatively, with quantitative methods representing 69% (11 papers) of assessments.

Finally, 52% (26 papers) of the studies classified the intervention as successful, while 14% (7 papers) reported partially successful interventions and 6% (3 papers) classified the intervention as unsuccessful. However, intervention success was not specified in 28% (14 papers) of the studies. Overall, the evidence suggests that campus biodiversity interventions are generally reported as successful or partially successful, although this conclusion should be interpreted cautiously given the heterogeneity of interventions, outcomes and evaluation methods.

Taken together, the literature is concentrated in Global North and urban campus contexts, is frequently driven by institutional policies, and focuses mainly on ecological objectives through habitat restoration, vegetation management, and green infrastructure. The evidence is strongest for plants and insects, while other taxonomic groups remain underrepresented.

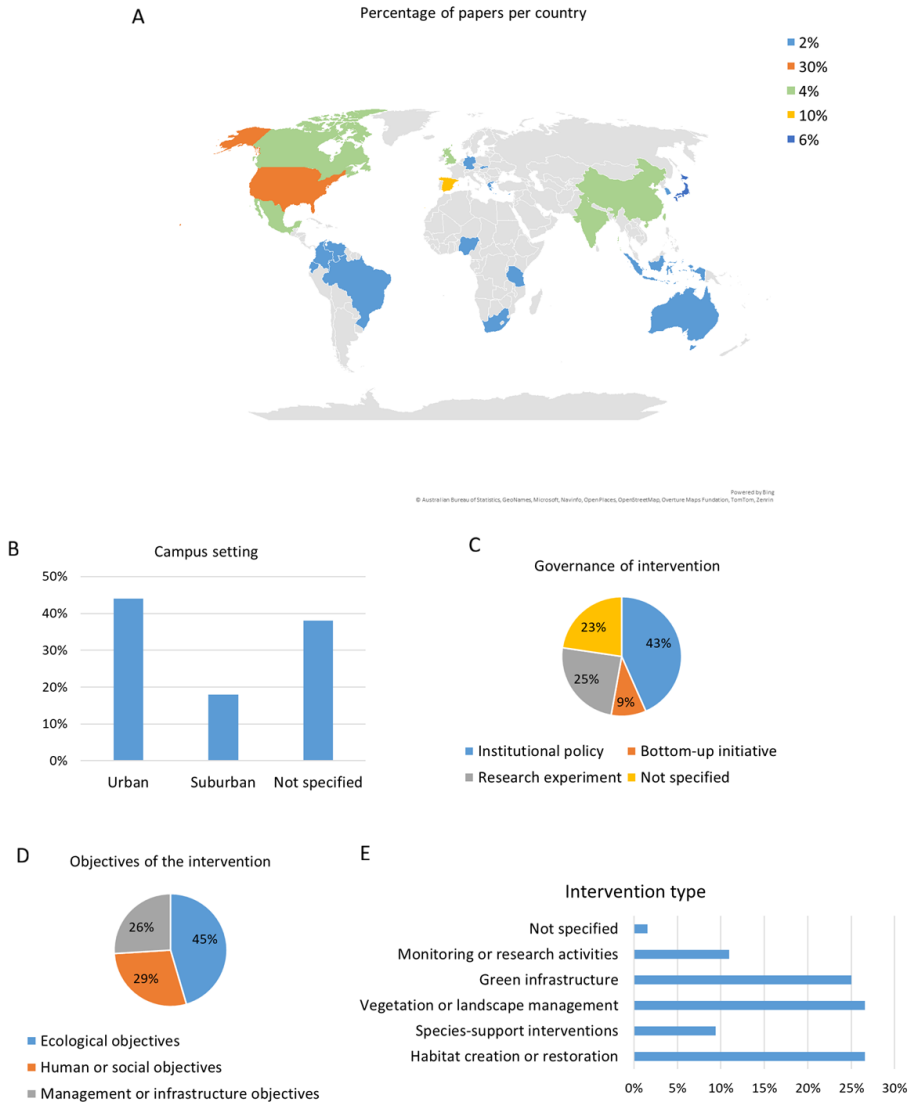

Figure 2. Systematic review results. (A) the geographic distribution of the articles; (B) setting of the campus where intervention was conducted; (C) the governance of the intervention; (D) the stated objectives of the interventions; (E) the types of implemented interventions.

Table 1. Frequency of biodiversity intervention types in the reviewed papers.

Intervention type	Number of papers	Percentage of papers
Green roofs	8	16%
Green policy / management	5	10%
Forest restoration	4	8%
Wetland construction / restoration	3	6%
Stormwater management	3	6%
Native plantings	2	4%
Forest management	2	4%
Pollinator gardens	2	4%
Citizen science	2	4%
Stray cats / dogs control	2	4%
Invasive / non-native speciel management	2	4%
Water bodies management	2	4%
Wildlife conflicts management	1	2%
Greywater irrigation	1	2%
Landfill restoration	1	2%
Meadow restoration	1	2%
Reduced mowing	1	2%
Community gardens	1	2%
Rain garden	1	2%
Ecogarden	1	2%
Introducing species supporting ecosystem	1	2%
Riverbank restoration	1	2%
Small botanical refuges	1	2%
Bird houses	1	2%
Bee nests	1	2%
Ecosystem restoration	1	2%

Table 2. Frequency of taxonomic groups studied in the reviewed papers.

Taxa studied	Number of papers	Percentage of papers
Plants	23	37%
Insects	12	19%
Non-insect invertebrates	5	8%
Mammals	4	6%
Birds	2	3%
Fish	1	2%
Amphibians	1	2%
Reptiles	1	2%
Soil organisms	1	2%
Not specified	13	21%

Discussion

Our aim in this study was to present an overview of the state of the art in the field of biodiversity-supporting interventions on university campuses. The concept of science in action is not new (Lewin, 1946); moreover, it was renewed lately by the accelerated emergence of the living lab methodology (Bajgier et al., 1991). The idea began to gain more traction when the European Union introduced the Living Lab concept in its policy in 2006, when the Finnish EU Presidency launched the European Network of Living Labs (ENoLL, 2024) and the European Commission began funding living labs (Franz et al., 2015; Mulder, 2012).

Despite the advantages that university campuses offer as sites for living laboratories and biodiversity interventions, such as proximity, familiarity with the management structure and the possibility of student engagement (Tercanli & Jongbloed, 2022), our review identified a relatively small number of studies describing actual biodiversity-supporting interventions. The overall number of retrieved papers after abstract screening was ~2%. The most often recurring exclusion reason after full-text screening was the lack of a real intervention in the study (52%). This observation may suggest that translating research interest into practical action on university campuses remains challenging, although the reasons behind this pattern cannot be assumed directly from the reviewed studies.

One possible explanation is methodological, as it is the effect of of including the “University” keyword in the search string, which generated a high number of studies that mentioned their

affiliation in the abstract. Another possible explanation is of a broader, metascientific nature. Although these issues were not directly investigated in the present review, previous studies have suggested that researchers engaged in action-oriented or participatory research may face institutional and structural barriers, including institutional inertia, funding constraints and pressures associated with the publish-or-perish system (Rose et al., 2020; Becker & Luka, 2023). Similarly, other studies suggest that scientists are recognized for their contributions to theoretical foundations, and actively engaged individuals are often perceived as less serious than their colleagues (Martinez-Conde, 2016). Moreover, journals seek novel theoretical results, which are difficult to achieve while implementing existing frameworks (Kien et al., 2014). Scientific work is therefore governed by the flow of funding and publishing trends (Ramassa et al., 2024). These broader factors may partially explain the publication patterns observed in our review, including the relatively high proportion of studies focused on institutional policies (43%), although further research would be needed to assess their role more directly.

The resulting publication landscape poses a substantial challenge for performing a systematic review (Chapman et al., 2023). The effectiveness of many interventions could not be conclusively assessed at the time of publication, as measurable outcomes often require extended monitoring periods or are inherently difficult to evaluate in the short term. Consequently, several studies reported only preliminary or partial evidence of success. Where intervention outcomes were assessed, evaluation was predominantly based on biological and ecological indicators, including biodiversity indices, species richness, abundance measures, and plant survival rates. In contrast, although many authors emphasized potential benefits for human well-being and user experience, these dimensions were assessed considerably less frequently and with less methodological rigour. The final decision on the success of the study was highly subjective. Often there was no criteria of success or failure provided, therefore our data on this matter should be treated with caution, supporting the need for uniform procedure of evaluation for action-oriented research (Chapman et al., 2023; Klaus-Rosińska & Iwko, 2023).

The only tendency that can be established among the chosen types of intervention is the low representation of species-support interventions, which might not be well perceived in the context of biodiversity-focused interventions. Examples of the interventions reviewed lack unification or significant replication, with 55% of cases appearing incidentally solely once or twice. The only type of intervention that received higher consideration was the green roof (8 examples, described in 16% of papers). A possible reason behind this is the ease of

implementation by campus governance when ground-level space is a limiting factor (Zhang & He, 2021). Beyond the establishment of vegetated roof surfaces, several studies investigated approaches to enhance their functional performance. These included modifications to substrate composition aimed at improving thermal regulation while maintaining suitable conditions for plant growth and survival.

The majority of the identified interventions targeted plants. Insect-related interventions, particularly those concerning pollinators, constituted another noteworthy category of biodiversity-enhancement strategies. Notably, two studies addressed the management of free-ranging cat and dog populations. Although less common than habitat-based interventions, such measures are particularly relevant due to the direct impacts that unmanaged animal populations can have on local biodiversity (Hughes & Macdonald, 2013).

Furthermore, many studies framed biodiversity interventions within a broader sustainability context, emphasizing their multiple co-benefits (Kabisch et al., 2022). In addition to supporting biodiversity conservation, green infrastructure measures were frequently associated with improvements in user well-being, enhanced campus management, and increased operational resilience (Mouratidis & Yiannakou, 2022). Examples included interventions designed to mitigate flooding risks, reduce local temperatures, and improve overall environmental quality within campus settings.

The authors tend to notice that urban biodiversity remains one of the essential problems to address and recognize the importance and the special place of university campus in the urban context, yet the resulting publication landscape is chaotic and barren. However, a crucial limitation that has to be considered while assessing the conclusions of this review is the lack of grey literature inclusion, which might prove to be essential in discovering which biodiversity interventions are really practised on academic campuses.

To prepare this report, we used DeepL for grammar corrections.

Bibliography:

Arjona, J. M., Ibáñez-Álamo, J. D., & Sanllorente, O. (2023). Mediterranean university campuses enhance butterfly (Lepidoptera) and beetle (Coleoptera) diversity. *Frontiers in Ecology and Evolution*, *11*, 1130557.

Bajgier, S. M., Maragah, H. D., Saccucci, M. S., Verzilli, A., & Prybutok, V. R. (1991). Introducing Students to Community Operations Research by Using a City Neighborhood as a Living Laboratory. *Operations Research*, *39*(5), 701–709.

Becker, A., & Lukka, K. (2023). Instrumentalism and the publish-or-perish regime. *Critical Perspectives on Accounting*, *94*, 102436. https://doi.org/10.1016/j.cpa.2022.102436

Chapman, A., Rankin, N. M., Jongebloed, H., Yoong, S. L., White, V., Livingston, P. M., Hutchinson, A. M., & Ugalde, A. (2023). Overcoming challenges in conducting systematic reviews in implementation science: A methods commentary. *Systematic Reviews*, *12*(1), 116. https://doi.org/10.1186/s13643-023-02285-3

Chatelain, M., Rüdisser, J., & Traugott, M. (2023). Urban-driven decrease in arthropod richness and diversity associated with group-specific changes in arthropod abundance. *Frontiers in Ecology and Evolution*, *11*, 980387.

Christensen, M., Seeley, R., Ungos, J., Lyman, Z., & Ingley, S. J. (2025). Sustainable restoration: addressing critical challenges through university-led projects. *Restoration Ecology*, *33*(3), e14337.

Cousquer, G., Norris, E., Lurz, P., Gurnell, J., & Vandermeer, E. (2024). Hedgerows for hedgehogs and campus biodiversity: A prickly challenge for universities. *Journal of Awareness-Based Systems Change*, *4*(1), 101-126.

Faeth, S. H., Bang, C., & Saari, S. (2011). Urban biodiversity: patterns and mechanisms. *Annals of the new York Academy of Sciences*, *1223*(1), 69-81.

Franz, Y., Tausz, K., & Thiel, S.-K. (2015). *Contextuality and Co-Creation Matter: A Qualitative Case Study Comparison of Living Lab Concepts in Urban Research*. *5*(12).

Hughes, J., & Macdonald, D. W. (2013). A review of the interactions between free-roaming domestic dogs and wildlife. *Biological Conservation*, *157*, 341–351. https://doi.org/10.1016/j.biocon.2012.07.005

Kabisch, N., Frantzeskaki, N., & Hansen, R. (2022). Principles for urban nature-based solutions. *Ambio*, *51*(6), 1388–1401. https://doi.org/10.1007/s13280-021-01685-w

Kien, C., Nußbaumer, B., Thaler, K. J., Griebler, U., Van Noord, M. G., Wagner, P., & Gartlehner, G. (2014). Barriers to and facilitators of interventions to counter publication bias:

Thematic analysis of scholarly articles and stakeholder interviews. *BMC Health Services Research*, *14*(1), 551. https://doi.org/10.1186/s12913-014-0551-z

Klaus-Rosińska, A., & Iwko, J. (2023). Success of research projects. Prediction and assessment from the point of view of project stakeholders thereby taking into account a sustainability approach. *Operations Research and Decisions*, *33*(4). https://doi.org/10.37190/ord230406

Leal Filho, W., Aina, Y. A., Dinis, M. A. P., Purcell, W., & Nagy, G. J. (2023). Climate change: Why higher education matters?. *Science of The Total Environment*, *892*, 164819.

Lerew, R. (2024). The Impacts of 'No-Mow'Areas on Floral Diversity: A Case Study at the University of Otago. *Pūhau ana te rā: Tailwinds*, *2*(2).

Lewin, K. (1946). Action Research and Minority Problems. *Journal of Social Issues*, *2*(4), 34–46. https://doi.org/10.1111/j.1540-4560.1946.tb02295.x

Liu, J., Zhao, Y., Si, X., Feng, G., Slik, F., & Zhang, J. (2021). *University campuses as valuable resources for urban biodiversity research and conservation. Urban For. Urban Green. 64, 127255*.

Martínez-Acosta, M., Vázquez-Villegas, P., Mejía-Manzano, L. A., Soto-Inzunza, G. V., Ruiz-Aguilar, K. M., Kuhn Cuellar, L., ... & Membrillo-Hernández, J. (2023). The implementation of SDG12 in and from higher education institutions: universities as laboratories for generating sustainable cities. *Frontiers in Sustainable Cities*, *5*, 1158464.

Martinez-Conde, S. (2016). Has Contemporary Academia Outgrown the Carl Sagan Effect? *Journal of Neuroscience*, *36*(7), 2077–2082. https://doi.org/10.1523/JNEUROSCI.0086-16.2016

Mouratidis, K., & Yiannakou, A. (2022). What makes cities livable? Determinants of neighborhood satisfaction and neighborhood happiness in different contexts. *Land Use Policy*, *112*, 105855. https://doi.org/10.1016/j.landusepol.2021.105855

Mulder, I. (2012). Living Labbing the Rotterdam Way: Co-Creation as an Enabler for Urban Innovation. *Technology Innovation Management Review*, *2*(9), 39–43.

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan—a web and mobile app for systematic reviews. *Systematic reviews*, *5*(1), 210.

Peng, C., & Xu, H. (2024). Universities and cities: The impact of higher education on urban innovation, entrepreneurship, and economic growth. *Asian Economic Papers*, *23*(2), 33-56.

Pereira, H. M., Martins, I. S., Rosa, I. M., Kim, H., Leadley, P., Popp, A., ... & Alkemade, R. (2024). Global trends and scenarios for terrestrial biodiversity and ecosystem services from 1900 to 2050. *Science*, *384*(6694), 458-465.

Piano, E., Souffreau, C., Merckx, T., Baardsen, L. F., Backeljau, T., Bonte, D., ... & Hendrickx, F. (2020). Urbanization drives cross-taxon declines in abundance and diversity at multiple spatial scales. *Global change biology*, *26*(3), 1196-1211.

Ramassa, P., Avallone, F., & Quagli, A. (2024). Can "publishing game" pressures affect the research topic choice? A survey of European accounting researchers. *Journal of Management and Governance*, *28*(2), 507–542. https://doi.org/10.1007/s10997-023-09667-8

Rose, K. M., Markowitz, E. M., & Brossard, D. (2020). Scientists' incentives and attitudes toward public communication. *Proceedings of the National Academy of Sciences*, *117*(3), 1274–1276. https://doi.org/10.1073/pnas.1916740117

Ryan-Fogarty, Y., Carlin, C. M., Kirakowski, T., Kirrane, M. J., Lysaght, L., & Reidy, D. T. (2022). Evaluating the use of intervarsity bioblitz as an engagement and reporting tool for biodiversity in green and blue spaces on urban campuses: A case study of Irish universities. In *Biology and Environment: Proceedings of the Royal Irish Academy* (Vol. 122, No. 3, pp. 181-200). Royal Irish Academy.

Tercanli, H., & Jongbloed, B. (2022). A Systematic Review of the Literature on Living Labs in Higher Education Institutions: Potentials and Constraints. *Sustainability*, *14*(19). https://doi.org/10.3390/su141912234

Winkler, J., Jeznach, J., Koda, E., Sas, W., Mazur, Ł., & Vaverková, M. D. (2021). Promoting biodiversity: vegetation in a Model Small Park located in the Research and Educational Centre. *Journal of Ecological Engineering*, *23*(1), 146-157.

Zhang, G., & He, B.-J. (2021). Towards green roof implementation: Drivers, motivations, barriers and recommendations. *Urban Forestry & Urban Greening*, *58*, 126992. https://doi.org/10.1016/j.ufug.2021.126992

Zhang, Y., Jiang, C., Chen, S., Zhang, Y., Shi, H., Chen, B., & Mao, L. (2021). Effects of landscape attributes on campuses bird species richness and diversity, implications for eco-friendly urban planning. *Sustainability*, *13*(10), 5558.