THE UNIVERSITY OF TENNESSEE KNOXVILLE

Journal of Applied Sport Management

Volume 17 | Issue 4 Article 2

12-30-2025

Artificial intelligence as a catalyst for systemic sport ecology

Ugo Arbieu
Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Société Evolution, Gif-sur-Yvette, France, ugo.arbieu@universite-paris-saclay.fr

Laís Carneiro
Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Société Evolution, Gif-sur-Yvette, France, lais.carneiro@universite-paris-saclay.fr

Sonia Tieo
Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Société Evolution, Gif-sur-Yvette, France, sonia.tieo@universite-paris-saclay.fr

Franck Courchamp
Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Société Evolution, Gif-sur-Yvette, France, franck.courchamp@cnrs.fr

Recommended Citation

Arbieu, Ugo; Carneiro, Laís; Tieo, Sonia; and Courchamp, Franck (2025) "Artificial intelligence as a catalyst for systemic sport ecology," *Journal of Applied Sport Management*: Vol. 17 : Iss. 4.
https://doi.org/10.7290/jasm1766SS
Available at: https://trace.tennessee.edu/jasm/vol17/iss4/2

Journal of Applied Sport Management
https://doi.org/10.7290/jasm-2023-V15-I4-DZax
Vol. 17, No. 4
https://trace.tennessee.edu/jasm/vol17/iss4/2

Artificial Intelligence as a Catalyst for Systemic Sport Ecology

Ugo Arbieu
Lais Carneiro
Sonia Tieo
Franck Courchamp

Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Société Evolution, Gif-sur-Yvette, France

Please send correspondence to Ugo Arbieu, ugo.arbieu@universite-paris-saclay.fr.

Abstract

Artificial intelligence (AI) is reshaping both sport management and environmental science, yet these developments have largely evolved in parallel. AI can serve not merely as a technical tool but also as a catalyst for systemic sport ecology, a field that integrates sport, digital innovation and environmental sustainability. Advances in discriminative, generative and agentic AI enable the synthesis of complex ecological and sport-related data, improving monitoring, forecasting, resource efficiency, policy design, and decision-making across scales. In doing so, AI offers a pathway beyond fragmented sustainability interventions and can support holistic approaches to the interconnected crises of climate change, pollution, and biodiversity loss. However, the catalytic potential of AI depends on responsible implementation, equitable access to data, and attention to environmental costs. In short, AI can drive systemic transformations by enhancing the collection and integration of social-ecological data, fostering governance innovation and operational sustainability within the sport sector.

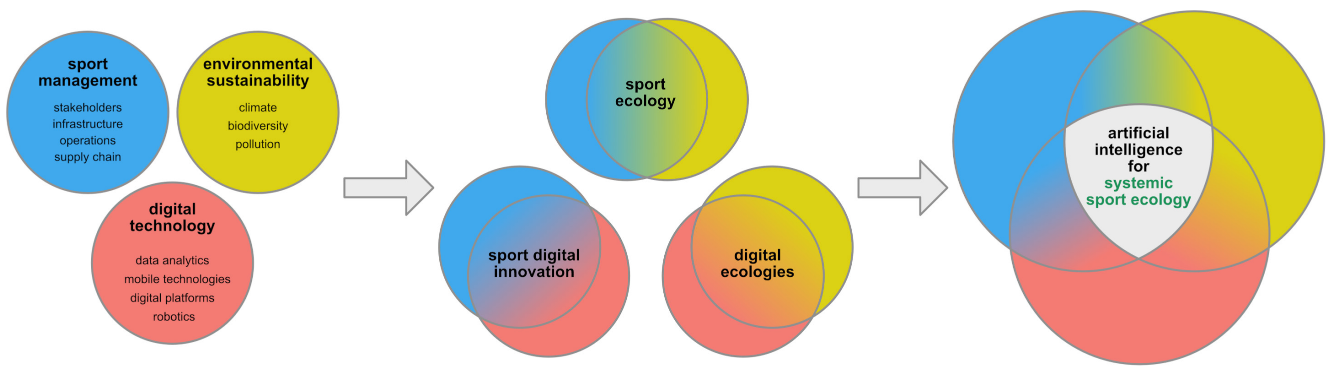
Keywords: biodiversity, digital innovation, environment, sustainability, sport management

Introduction

Sport management, environmental sciences, and digital technologies have each evolved as independent scholarly fields. Over time, interdisciplinary approaches have led to the emergence of digital innovation in sport, digital ecologies, and sport ecology as distinct and increasingly mature domains (see Figure 1). Yet these research fields have largely developed in parallel rather than in convergence. While sport management has recently recognized environmental sustainability as a critical concern alongside economic and social responsibility, and while environmental sciences increasingly address the impacts of human activities, there is a timely need to integrate these applied research fields in a holistic manner. This is essential to understand the complex, reciprocal, and dynamic relationships between sports, technological systems, and the natural environment, to pave the way towards "systemic sport ecology". The focus of this piece is how artificial intelligence (AI) methods and approaches may help address common challenges in applied sport ecology (i.e., limited resources, lack of expertise, biases towards climate action) and provide opportunities to boost the development of systemic sport ecology in fundamental and applied ways.

Figure 1

Flowchart Showing the Emergence of Interdisciplinary Fields of Research and Innovation Across Sport Management, Digital Technologies, and Environmental Sciences



Artificial Intelligence in a Nutshell

AI broadly refers to computational techniques that enable machines to perform tasks traditionally associated with human intelligence, including perception, reasoning, pattern recognition, synthesis and decision-making (Gassert et al. 2025). The conceptual foundations of AI were articulated in the mid-20th century and unfolded through successive technological waves. The most recent leap has been the advent of large language models powering discriminative and generative AI systems like ChatGPT in 2022 (Jebara 2012). Discriminative AI focuses on classification, prediction, and pattern detection from data. Their outputs are typically labels, probabilities, segmentations, or numerical forecasts (Christin et al. 2019). Generative AI models the underlying statistical distribution of the data to produce new, synthetic content, to create e.g. artificial ecological datasets, simulate scenarios, generate maps or images, or transform numerical and textual descriptions into novel representations.

Digital Innovation and Sports

Digital innovation has transformed sport management by reshaping sport performance, fan engagement, accessibility, video broadcasting, operations and security, and resource efficiency (Glebova et al. 2023). At the performance level, AI-powered predictive analytics support coaches and managers by evaluating athletes' historical and real-time data and preventing injuries (Rahmani et al. 2024). Digital technologies are also commonly used to enhance the spectator experience: in an era of „sportainment" (Glebova & Desbordes 2021), emotional engagement is enhanced through virtual and augmented reality environments enabling remote immersion for global audiences. On the operational side, natural language processing helps sport organizations monitor online sentiments to improve customer satisfaction and automate sales processes with dynamic ticket pricing (Naraine & Wanless 2020). Logistics and security of sport events have also been improved by automatic recognition systems and blockchain solutions for secured and transparent financial transactions. AI-powered automatic cameras reduce broadcasting costs while tailoring communication emotionally across cultural contexts (Desai 2024). Resources are being more efficiently used through the implementation of automatic sensors, wearables, computer-vision systems and real-time data collection and analyses. As environmental sustainability is a growing concern in sports, digital facility management technologies are emerging to enforce preventive maintenance or weather-related damage assessments of sport equipment and infrastructure (Orr & Ross 2022). Automated systems for sampling soil, irrigation, or mowing improve resource efficiency and reduce environmental impact. Drones are used for turfgrass and field management, feeding AI systems to enable precise identification of nutrient or water stress, infestations, and disease.

Digital Technology and Sport Ecology at a Crossroads

The progressive uptake of environmental sustainability in sport management has given rise to the emerging field of sport ecology (McCullough et al. 2020), which studies the reciprocal relationship between sport and the natural environment. Sport ecology encompasses research on sustainability in sport (Mallen & Chard 2011), climate vulnerability and adaptation (McCullough et al. 2020), the dependence of sport on natural resources, and the ways in which environmental conditions affect the sport sector. This field is increasingly positioned within the wider nexus of the "triple planetary crisis", i.e. climate change, pollution, and biodiversity loss (de Castañeda et al. 2023). However, the focus has primarily been put on climate issues, including the carbon footprint of sport and adaptation strategies for climate impacts (Orr et al. 2022), leaving pollution (Watanabe et al. 2023) and biodiversity loss (Arbieu et al. 2025) comparatively underexplored, despite their equal importance in environmental decline.

As a consequence, if digital technology is increasingly being mobilized for sport ecology purposes (Orr & Ross 2022), many of these developments focus on climate-related monitoring and adaptation. Digital systems now track weather and environmental hazards that affect sport participation and infrastructure. Automatic sensors monitor temperature, humidity, atmospheric pressure or precipitation, providing early warnings to anticipate damages to facilities and event cancellations linked to extreme weather (Orr & Ross 2022). Similar technologies are applied to air quality management, where air pollution metrics are used to protect practitioners' health and inform adaptation strategies such as delaying play, shifting events indoors or modifying game schedules. Digital tools further help monitor conditions in outdoor sport environments, support citizen science data collection, and link sport participation to climate or sustainability initiatives (Orr & Ross 2022).

Sport Ecology and the Quest for Systems Thinking

Most current applications of digital innovations remain concentrated in climate adaptation, with limited integration of the most recent advances in digital ecologies (Jarić et al. 2020; Turnbull et al. 2022). This could become a lost opportunity, as digital technology has become a major driver of innovation in environmental management (Borowiec et al. 2022; Christin et al. 2019), addressing complex nature conservation challenges at multiple spatial and biological scales. Recent advances in remote sensing and automation using AI-driven audio analysis, camera traps or drones have expanded the frontiers of biodiversity monitoring (Borowiec et al. 2022; Besson et al. 2022), while neural networks can now estimate key population-genetic parameters such as mutation or recombination rates (Flagel et al. 2019). At broader geographic scales, AI can map environmental degradation (Gassert et al. 2025), including drivers of deforestation (Wilson 2024), global fishing pressure, oil spills or soil pollution.

Therefore, it has become evident that there is a timely need for more integrated approaches geared towards systems thinking (Voulvoulis et al. 2022), which acknowledges the interconnections between sport, human health, ecosystem health and AI developments (Lemarchand et al. 2025). Systems thinking helps move beyond fragmented responses towards more holistic strategies that reflect the intertwined nature of environmental challenges, including climate, pollution and biodiversity jointly (Trendafilova & Ziakas 2025), and offers tools for identifying leverage points across complex social-ecological systems (Voulvoulis et al. 2022). Recent AI developments could thus be seen as opportunities to address the main constraints that sport ecology is currently facing and foster integration across disciplines and scales. Persistent obstacles in sport ecology include the lack of strategic approaches, limited human and financial capacity for sustainability implementation, unequal capacities among stakeholders (from resource-intensive multinational brands to under-resourced organizations), knowledge and expertise gaps regarding both environmental issues and digital solutions, fragmented and unstandardized data sources, and the difficulty of monitoring and reporting environmental impacts across multiple dimensions.

AI as a Catalyst for Systemic Sport Ecology

AI may help sports embrace "twin transformation", i.e. the simultaneous pursuit of digitalization and environmental responsibility as complementary strategic priorities (Hammerschmidt et al. 2025). Twin transformation represents a process of compounded value creation in which each transformation strengthens the transformative potential of the other, thereby enabling organizations to adopt systemic sport ecology, which addresses evolving operational, social, and environmental goals in an integrated manner.

AI has the potential to design and address systemic sport ecology objectives: enhancing fan engagement and digital literacy, reducing system complexity, strengthening environmental monitoring and reporting, improving operational and cost efficiency, and embedding sustainability principles in sport management. Hence, increasingly connected stadium allows spectators to access multiple services (even from outside stadiums) through digital applications. For example, interactively helping sort waste items for better recycling which, coupled with automatic sentiment analysis, enhances fan engagement in sustainability while improving operational efficiency and customer satisfaction. AI systems can also help synthesize heterogeneous and unstructured data, including ecological surveys, remote-sensing time series, climate projections, and socio-economic information (Gassert et al. 2025). Large language models help extract, analyze, and make sense of unstructured data to improve traceability, flag environmental risks, forecast social-ecological processes and support policy processes (AlMahri et al. 2024; Gassert et al. 2025). Generative AI can further fill data gaps and augment scarce environmental datasets through synthetic data generation or by enhancing existing records (Rafiq et al. 2023), improving stakeholder capacity to forecast ecological responses and model complex interactions between people, sport, and nature (Rafiq et al. 2023).

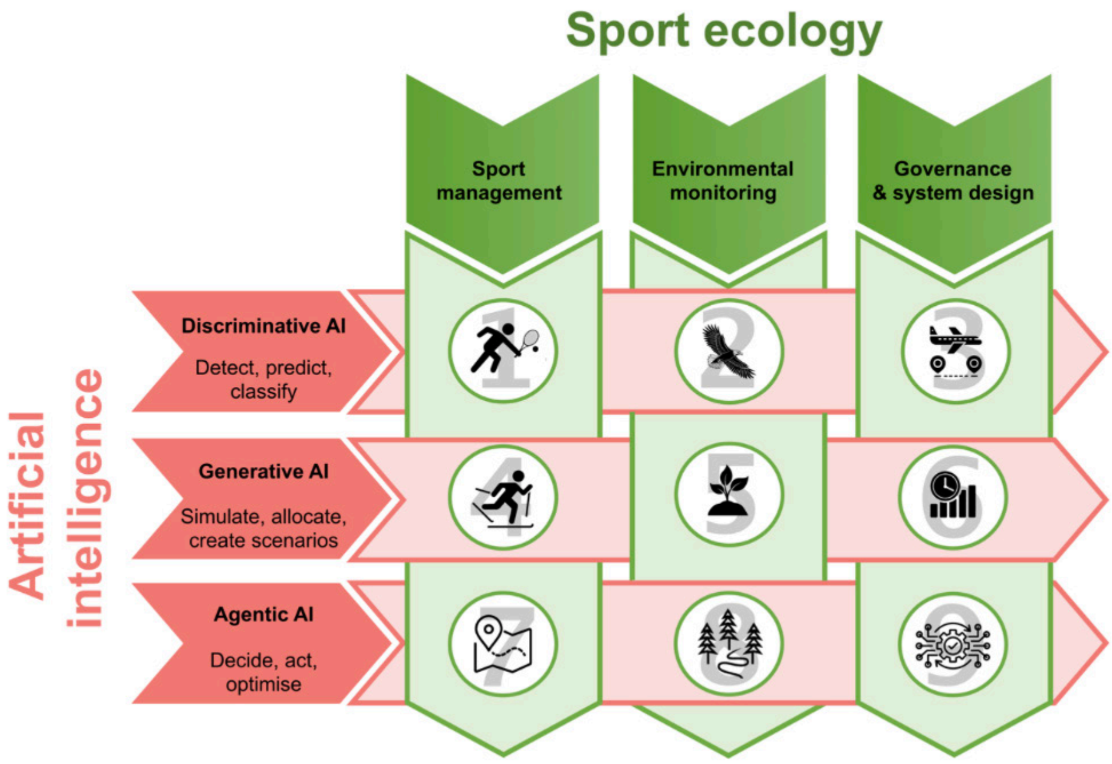
A particularly transformative development is agentic AI (Acharya et al. 2025), which refers to systems capable of autonomously setting goals, adapting to uncertainty, and operating in dynamic and complex environments. Drawing on advances in reinforcement learning, adaptive control and goal-oriented architectures, agentic AI can plan, react, and reallocate resources across highly variable conditions, from disaster management and infrastructure resilience to customer interaction, and health monitoring. Reinforcement learning and agent-based models are particularly promising for sport ecology because they simulate dynamic, multiscale interactions between sport participants, wildlife, and ecosystems under changing environmental conditions (McKee et al. 2022). These models can reproduce congestion, disturbance, competition, or cooperation scenarios, offering an unprecedented opportunity to explore leverage points for sustainability interventions.

Ultimately, the success of AI-powered systemic sport ecology is contingent on careful design and implementation. Systemic sport ecology will require identifying key stakeholders and expertise, defining targets that reflect both environmental and sport-management priorities, and building the infrastructure needed to feed AI systems, which performance depends on the availability of high-quality, reliable, labelled and standardized datasets (Christin et al. 2019). AI should therefore be seen not only as a tool that improves prediction or data-processing capacity, but as a catalyst for systems thinking: a mechanism for connecting multiple datasets at various scales, disciplines, and stakeholders to steer sport organizations toward systemic sport ecology.

To illustrate these arguments, discriminative AI models could analyse the correlations and interdependencies between athlete physiological data, spectator mobility patterns, environmental conditions gathered from multiple sources (e.g., soil microbiome health, pollen concentration) and ecological impacts of sport activity (e.g., soil erosion, wildlife disturbance). These analyses can provide actionable feedback to practitioners and event organizers to adjust training routes, reduce trail erosion, adapt rest periods to preserve turfgrass and reduce water use, or monitor long-term trends in ecosystem health tied to local sport practice, thus bridging across health, performance and ecological resilience. Combined with a generative simulation model, such information could help design adaptation scenarios (e.g., "if the Ironman triathlon event is delayed by 45 minutes and the route is shifted 2km west, the heat stress will be reduced by 18%, air pollution by 22% and disturbance to denning carnivores by 65%"). Now, integrating agentic AI systems would go one step further, as they would integrate competing interests (e.g. athlete experience, fan safety, ecosystem health, economic concerns) to trigger actions dynamically, like redirecting fan crowds to avoid sensitive areas, activate shade systems to reduce heat stress, modify lighting, or automatically adjusting game timing or aid stations. Seen this way, AI can genuinely act as a facilitator of human–nature co-existence through sport (Figure 2).

Figure 2

Illustration of How the Three Major Types of AI can Support Systemic Sport Ecology



Note. **1.** Heat-stress detection: automatic analysis of athlete physiology combined with weather data during a tennis tournament; **2.** Biodiversity impact of sport trails: computer-vision analysis from camera traps to identify wildlife disturbance from runners; **3.** Unsustainable fan mobility: classification of fan origin-destination patterns to identify carbon emissions hotspots around a world cup event; **4.** Synthetic climate-performance datasets: generation of training-performance datasets to improve Nordic skiing training in mountain areas. **5.** Ecosystem response simulation to sport events: simulation of erosion and environmental adaptation over successive yearly races of cross-country horse riding; **6.** Policy outcome generator: automated scenario building for the reduction of air pollution exposure of a marathon race; **7**. Real-time adaptive event management: real-time adjustment of shade systems and hydration point locations during a triathlon; **8**. Wildlife-aware dynamic crowd routing: automatic real-time rerouting of spectators away from migrating herbivores near a mountain biking event ; **9.** Full-system twin optimization: integral optimization of carbon footprint and environmental damage reduction, fan safety and operational costs to select alpine skiing world cup sites.

Challenges in Deploying AI for Sport Ecology

Despite its transformative potential, the deployment of AI in sport ecology faces significant challenges arising from environmental, epistemic, and socio-technical limitations. First, AI systems have an ecological footprint: their growth is tied to water consumption from power plants and data centers (Siddik et al. 2021), carbon emissions (Crawford 2024), and the extraction of raw materials for hardware manufacturing (Rafiq et al. 2023). There will be trade-offs between environmental costs and ecological benefits associated with AI implementation (Orr & Ross 2022). Furthermore, digital technologies carry the risk of deepening disconnection from nature if they substitute rather than enhance direct engagement with nature (Soga & Gaston 2016). Epistemic risks involve the issues of hallucinations from generative models and data misinterpretations (Gassert et al. 2025). As models can only learn from the data on which they are trained (Wilson et al. 2024), biases in data collections constrain applications to other social-ecological contexts which are data scarce.

Additional barriers include data security, privacy, a lack of interoperability between datasets, and domain-specific knowledge gaps where biodiversity data, infrastructural data, climate records and sport-performance analytics remain siloed, which further calls for academic interdisciplinarity. Finally, AI deployment raises ethical questions of inclusion and governance: who defines the targets, who controls the data, and who benefits from the models? These challenges do not diminish the promise of AI for systemic sport ecology; rather, they underline the need for responsible, interdisciplinary and context-sensitive implementation. When paired with collaborative governance and sustainability-driven design, AI can become a powerful catalyst of a systemic approach to sport ecology, one that integrates sport management constraints, ecosystem health and digital innovations.

References

Acharya, D. B., Kuppan, K., & Divya, B. (2025). Agentic AI: Autonomous intelligence for complex goals–a comprehensive survey. IEEe Access, 13, 18912-18936.

AlMahri, S., Xu, L., & Brintrup, A. (2025). Enhancing supply chain visibility with knowledge graphs and large language models. International Journal of Production Research, 1-32.

Arbieu, U., Bellard, C., Bradshaw, C.J., Correia, R.A., Courtois, P., Di Minin, E., Jarić, I., Leroy, B., Murfree, J., Orr, M., Roturier, S., Sartore-Baldwin, M., Veríssimo, D., & Courchamp, F. (2025). Professional sport organizations as potential champions of biodiversity conservation. Frontiers in Ecology and the Environment, e2862.

Besson, M., Alison, J., Bjerge, K., Gorochowski, T.E., Høye, T.T., Jucker, T., Mann, H.M., & Clements, C.F. (2022). Towards the fully automated monitoring of ecological communities. Ecology letters, 25(12), 2753-2775.

Borowiec, M. L., Dikow, R. B., Frandsen, P. B., McKeeken, A., Valentini, G., & White, A. E. (2022). Deep learning as a tool for ecology and evolution. Methods in Ecology and Evolution, 13(8), 1640-1660.

Christin, S., Hervet, É., & Lecomte, N. (2019). Applications for deep learning in ecology. Methods in Ecology and Evolution, 10(10), 1632-1644.

Crawford, K. (2024). Generative AI's environmental costs are soaring–and mostly secret. Nature, 626, 693.

de Castañeda, R.R., Villers, J., Guzmán, C.A.F., Eslanloo, T., de Paula, N., Machalaba, C., Zinsstag, J., Utzinger, J., Flahault, A., & Bolon, I. (2023.) One Health and planetary health research: leveraging differences to grow together. The Lancet Planetary Health, 7(2), e109-e111.

Desai, N. P. Transforming sports management: The impact of digital innovation on fan engagement in the Indian Super League. International Journal of Science and Research, 14(3), 15-24.

Flagel, L., Brandvain, Y., & Schrider, D. R. (2019). The unreasonable effectiveness of convolutional neural networks in population genetic inference. Molecular biology and evolution, 36(2), 220-238.

Gassert, F., Gawel, A., Harfoot, M., Mayer, A., Singhal, K., Stolle, F., & Vary, L. (2025). AI for nature: How AI can democratize and scale action on nature.

Glebova, E., & Desbordes, M. (2021). Identifying the role of digital technologies in sport spectators customer experiences through qualitative approach. Athens Journal of Sports, 8(2), 141-160.

Glebova, E., Gerke, A., & Book, R. (2023). The transformational role of technology in sports events. In Sports management in an uncertain environment (pp. 169-187). Singapore: Springer Nature Singapore.

Glebova, E., & Madsen, D. Ø. (2024). Twin transformation as a strategic approach in sport management: the synergy of digitalization and sustainability in sports. Frontiers in Sports and Active Living, 6, 1403793.

Hammerschmidt, J., Burtscher, J., Gast, J., Kraus, S., & Puumalainen, K. (2025). Navigating the twin transformation: how digitalization and sustainability shape the future. Strategic Change.

Jarić, I., Correia, R.A., Brook, B.W., Buettel, J.C., Courchamp, F., Di Minin, E., Firth, J.A., Gaston, K.J., Jepson, P., Kalinkat, G., Ladle, R., Soriano-Redondo, A., Souza A.T., & Roll, U. (2020). iEcology: harnessing large online resources to generate ecological insights. Trends in Ecology & Evolution, 35(7), 630-639.

Jebara, T. (2012). Machine learning: discriminative and generative (Vol. 755). Springer Science & Business Media.

Lemarchand, B., Marrauld, L., Dandrieux, P.E., Sarfati, M., & Edouard, P. (2025). Planetary health: why not empower the sports and exercise medicine community to play the game of life well? BMJ Open Sport & Exercise Medicine, 11, e002409.

Mallen, C., & Chard, C. (2011). A framework for debating the future of environmental sustainability in the sport academy. Sport Management Review, 14(4), 424-433.

McCullough, B. P. (2023). Advancing sport ecology research on sport and the natural environment. Sport Management Review, 26(5), 813-833.

McCullough, B. P., Orr, M., & Kellison, T. (2020). Sport ecology: Conceptualizing an emerging subdiscipline within sport management. Journal of Sport Management, 34(6), 509-520.

McKee, K. R., Leibo, J. Z., Beattie, C., & Everett, R. (2022). Quantifying the effects of environment and population diversity in multi-agent reinforcement learning. Autonomous Agents and Multi-Agent Systems, 36(1), 21.

Naraine, M. L., & Wanless, L. (2020). Going all in on AI: Examining the value proposition of and integration challenges with one branch of artificial intelligence in sport management. Sports Innovation Journal, 1, 49-61.

Orr, M., Inoue, Y., Seymour, R., & Dingle, G.W. (2022). Impacts of climate change on organized sport: a scoping review. Wiley Interdisciplinary Reviews: Climate Change, 13(3), e760.

Orr, M., & Ross, W. J. (2022). Digital technology and sport ecology. In The Routledge handbook of digital sport management (pp. 346-354). Routledge.

Rafiq, K., Beery, S., Palmer, M. S., Harchaoui, Z., & Abrahms, B. (2025). Generative AI as a tool to accelerate the field of ecology. Nature Ecology & Evolution, 9(3), 378-385.

Rahmani, M., Majedi, N., Hemmatinejad, M., & Jamshidi, A. (2024). Application of Artificial Intelligence in the sports industry: A review article. AI and Tech in Behavioral and Social Sciences, 2, 20-27.

Siddik, M. A. B., Shehabi, A., & Marston, L. (2021). The environmental footprint of data centers in the United States. Environmental Research Letters, 16(6), 064017.

Trendafilova, S., & Ziakas, V. (2025). Advancing sustainable sport event management and sport ecology: the missing links. Journal of Policy Research in Tourism, Leisure and Events, 17(4), 905-920.

Soga, M., & Gaston, K. J. (2016). Extinction of experience: the loss of human–nature interactions. Frontiers in Ecology and the Environment, 14(2), 94-101.

Turnbull, J., Searle, A., Hartman Davies, O., Dodsworth, J., Chasseray-Peraldi, P., von Essen, E., & Anderson-Elliott, H. (2023). Digital ecologies: Materialities, encounters, governance. Progress in Environmental Geography, 2(1-2), 3-32.

Voulvoulis, N., Giakoumis, T., Hunt, C., Kioupi, V., Petrou, N., Souliotis, I., Vaghela, C., & binti Wan Rosely, W.I.H. (2022). Systems thinking as a paradigm shift for sustainability transformation. Global Environmental Change, 75, 102544.

Watanabe, N., Yan, G. & McLeod, C. (2023). The impact of sporting events on air pollution: an empirical examination of national football league games. Sustainability, 15(6), 5568.

Wilson, N. (2024). Artificial intelligence helps drive new frontiers in ecology. BioScience, 74(5), 306-311.