

# AI & Ecology: From Tool to Transformation

*Sara Beery*

Ten years ago, I built AI models to automate specific labeling tasks: species identification from camera traps, individual identification in citizen science imagery, counting trees in aerial surveys. Field ecologists incorporated these tools into their workflows and decreased processing times from years to days. I saw AI as a powerful assistant and set out to further improve its efficiency, generalizing AI methods to new species and ecosystems while strategically incorporating expert feedback.<sup>1</sup>

But through the years, my work in this field has evolved toward something both more participatory and more exploratory: building AI methods that enable scientists to explore vast databases, discover hidden ecological patterns, and integrate knowledge across different data modalities to understand how species are distributed, how they move through the environment, and how they interact with each other, with humans, and with a changing climate.<sup>2</sup> This shift from AI-assisted labeling to AI-enabled discovery represents more than a technical evolution; it reflects a transformation in how we practice, conceive, and organize ecological science.

The most obvious changes AI has brought to ecology are practical. Computer vision algorithms now automatically process everything from camera trap images to bioacoustic recordings to satellite imagery – detecting species, behaviors, life stages, and even individual animals with remarkable precision.<sup>3</sup> The efficiency of AI, paired with increasing availability and decreasing costs of environmental monitoring sensors, has enabled us to cost-effectively monitor ecosystem processes at scales previously impossible.

The deeper transformation I've seen is conceptual. The availability of vast datasets and AI tools to process them has fundamentally expanded the questions we can pursue. Problems that seemed intractable – like monitoring rare species across continental scales or tracking ecosystem responses to climate change in real time – are now within the realm of feasibility.<sup>4</sup> Perhaps most intriguing of all, AI-supported systems are enabling ecologists to discover patterns that sometimes challenge ecological intuition and demand new theoretical frameworks.<sup>5</sup> This evolution has forced our community to confront fundamental questions about uncertainty and

robustness. My work, and that of many others working at the intersection of artificial intelligence and ecology, now centers on developing systems and methods that incorporate strategic human oversight to gracefully detect and handle errors, adapt to a changing world, and capture uncertainty. These systems prioritize efficient human-AI collaboration, focusing on continuous refinement instead of (error-prone) full autonomy.<sup>6</sup> This reflects something ecologists have long understood: that imperfect observations, if modeled correctly, can still enable robust probabilistic understanding of complex systems.

This cultural transformation extends beyond individual research practices. Progress demands partnerships between field ecologists, computer scientists, and domain experts in remote sensing or bioinformatics, requiring us to break traditional academic silos.<sup>7</sup> Graduate programs increasingly balance field skills with computational literacy, and initiatives like the Computer Vision Methods for Ecology (CV4Ecology) Workshop provide ecologists with specialized AI training.<sup>8</sup> Research culture has shifted toward large collaborative papers; increased data standardization, sharing, and publication; and ever-faster hypothesis testing and refinement enabled by automated literature reviews, real-time data processing, and AI-assisted software development.

Yet these changes raise critical equity considerations. Access to large, standardized data infrastructure, AI tools, computational resources, and capacity building remains unevenly distributed, concentrating research capacity in technologically advanced regions while marginalizing insights from biodiversity hotspots in developing nations.<sup>9</sup> The global divide in AI capabilities could fundamentally alter whose ecological knowledge, and whose conservation priorities, shapes both our understanding of planetary systems and what actions we take to protect them.

Looking forward, the biggest bottleneck isn't computational power or algorithmic sophistication, it's the fundamental mismatch between the questions ecology must answer and the data ecologists can collect. We need to understand ecosystem resilience, predict tipping points, and guide restoration across decades and continents. But our observational networks remain fragmented, our temporal baselines short, and our causal understanding limited.<sup>10</sup> AI can be used to discover new patterns from vast amounts of data, but it cannot be used to reliably create information that doesn't exist.<sup>11</sup> It *can* help us maximize the value of data we have already collected, identify key remaining knowledge gaps, and strategically prioritize new data collection to fill them.<sup>12</sup> However, this requires key investments in data collection and infrastructure, recognizing raw information itself – not just its analysis – as fundamental to planetary understanding.

By 2035, I envision ecological research in which AI systems help synthesize literature, test hypotheses, optimize experimental designs, and develop scientific software – while scientists provide vital context, creativity, verification, and ethical

judgment. Realizing this vision will require solving much harder problems than pattern recognition. We need AI-enabled systems that can reason about causation in complex systems, integrate knowledge across scales from genes to ecosystems, and robustly quantify data and knowledge gaps and identify and address systemic biases.

Ecology's future lies not in choosing between human expertise and artificial intelligence but in developing mature partnerships that amplify our collective capacity to understand and protect the natural world – while remaining vigilant about who has access to these new capabilities and whose priorities shape our understanding of planetary systems. Our challenge is to navigate this transformation intentionally, ensuring that as we gain new powers of analysis and prediction, we maintain the observational skills, theoretical depth, and humble wonder that make ecological science both rigorous and meaningful.

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#### ABOUT THE AUTHOR

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#### ENDNOTES

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