Abstract Booklet for the Ecological Forecasting Initiative 2026 Annual Conference

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Keynote Speaker Abstracts

Pandemic decision-making with modelling: the models and the data needs?

Caroline Colijn

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In the COVID-19 pandemic, models were often at the forefront of decision making and public discussion. Models helped with case projections, estimating the impacts of non-pharmaceutical interventions, estimating real-time measures of transmission (like Rt, the effective reproduction number). Models helped us think about the vaccine rollout, to project healthcare burden in the context of evolution of new variants, and to reason about what might happen next. Our network of infectious disease modellers collected the questions that decision-makers asked. I will describe a selection of these chronologically, describing new models that were developed to help support decision-making, the data needs that this raised, and challenges related to communicating uncertainty to decision-makers and the public.

Response velocity evaluates vulnerability through climate sensitivity combined with rates of climate change: applications to North American and European forests

James S. Clark

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To survive climate change forest trees will have to shift seed production poleward. However, warming will not stimulate tree fecundity in the north if it is limited by other habitat variables. Anticipating changes like this suggests the need for full uncertainty in process, parameters, and data using hierarchical state-space models. However, when there are tens of thousands of time series with dependence within and between trees, and the response is erratic, traditional forecasting with autoregressive terms (for example) cannot offer useful predictions. We evaluated the responses of tree fecundity to climate change for 292 tree species in North America and Europe, using response velocity, defined as climate sensitivity X climate change rate. The sensitivities to climate were estimated for each species and combined with rates of climate change to quantify how temperature, moisture deficits, and late freeze are influencing biogeographic shifts in tree reproduction. Results show that moisture deficit and late freeze, not annual temperature, drive changing seed production. Unlike annual temperature, which is increasing generally, change in these climate variables is not driving poleward shifts in seed production. Results do not challenge the expectation that forests might eventually shift poleward. Rather, they show why current efforts offer divergent interpretations. The changes happening now are not consistent with annual temperature trends. As warming continues, fecundity changes can best be anticipated from temperature interactions with precipitation and extremes that impact flowering and fruiting in winter and spring. Response velocity can exploit spatio-temporal information to anticipate how climate is driving ecological change where traditional methods fail.

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Oral Presentation Abstracts

When Behavior Matters: Linking Individual Behavior to Ecosystem Dynamics

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Individual behavior responds dynamically to environmental conditions, yet many ecological models rely on population averages that overlook structured behavioral variation. We develop a behaviorally structured modeling framework that treats behavior as a continuous trait and links individual-level responses to population-level ecological dynamics. The model integrates population dynamics with behavioral distributions, capturing feedback between environmental conditions and individual responses. Using analytical and numerical methods, we show that behavioral heterogeneity fundamentally reshapes system dynamics, including stability, transient responses, and the emergence of critical transitions. Our results reveal that changes in behavioral distributions can modify persistence and resilience, and can alter the onset and progression of regime shifts in ecological systems. These dynamics arise from feedback between environmental variation and behavior, which is absent in traditional mean-based approaches. This work establishes behavior as a central mechanism in ecological dynamics and provides a mathematically grounded framework for improving ecological prediction under environmental change.

Keywords: Ecological forecasting; Behavioral plasticity; Trait-structured models; Population dynamics; Regime shifts

Meteorological conditions predict questing tick densities across the eastern United States

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Tick-borne diseases (TBDs) are increasing globally due to factors such as climate and land use change. Accurate forecasting of questing tick densities can allow the public to make informed decisions to reduce the risk of TBD exposure. However, ticks have a multi-stage life cycle that can potentially be affected by factors such as the population dynamics of their small mammal hosts, weather, and land cover, making accurate forecasts difficult and computationally expensive. We addressed these problems using a hierarchical state-space model, which leverages data from tick surveys, small mammal surveys, and meteorological data across the eastern United States to forecast questing tick densities for each life stage up to a year in

advance. We applied the model to two tick species, Ixodes scapularis and Amblyomma americanum, which are vectors of TBDs in North America. We expected that population sizes of the small mammal host Peromyscus leucopus would impact the transition success rate between life stages, but mouse variables were generally poor predictors of questing tick densities based on the 95% CI. We found that several meteorological variables, especially precipitation and relative humidity, affected tick survival; however, their importance varied based on tick species, life stage, and geographic location. In particular, the survival of nymphs and larvae tended to have strong associations with relative humidity and precipitation, whereas these variables did not have clear associations with adult survival. Our modeling framework can assist in making public health decisions by predicting changes in tick questing activity in response to a changing climate.

Evaluation of the skill of probabilistic seasonal forecasts in predicting droughts with the hydrologic model ParFlow/CLM over central Europe

Alexandre Belleflamme, Suad Hammoudeh, Klaus Goergen, Stefan Kollet

Research Centre Jülich

Repeated droughts in recent years and their impacts on managed and natural ecosystems have stressed the need for seasonal forecasts of subsurface water resources, including their depletion and their recovery.

To address this need, we provide an experimental water resources bulletin with a 7-months forecast of the subsurface water storage anomaly from the surface to 60m depth at the beginning of each meteorological season.

Here, we evaluate the skill of eight spring forecasts, each initialised on March 1st between 2018 and 2025, that cover the vegetation period until the end of September. Each forecast consists of a 50-member ensemble simulating the terrestrial water cycle at the surface and subsurface with the physics-based integrated hydrologic model ParFlow/CLM over a central European model domain at 0.6km resolution. The ensemble is driven by the probabilistic seasonal weather forecast SEAS5 from the European Centre for Medium-Range Weather Forecasts.

Overall the seasonal forecast clearly outperforms a simple climatological outlook. However, the normalized Spread Skill Score indicates an underdispersed ensemble, especially under abnormally dry conditions, suggesting that the ensemble as a whole has difficulties to represent droughts, confirmed by the Cumulative Rank Probability Skill Score. Nevertheless, a closer look at the ensemble tail (lower quintile and tercile) with the Relative Operating Characteristics Skill Score yields good results, meaning that droughts are well included in the seasonal forecast ensembles.

With this system we explore the hydrologic forecasting possibilities strand as part of and towards a high-resolution European ecosystem reanalysis using the latest high performance computers in Europe.

Keywords: seasonal hydrologic forecasts, drought, subsurface water resources, hydrologic model ParFlow

Another Rain Song: Evaluating the performance of zero-shot forecasting using a foundational AI model as a surveillance tool for the emerging One Health issue of Legionellosis in Ontario, 2013-2024

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Legionellosis or Legionnaires' disease is a serious form of pneumonia caused by Legionella bacteria, and is an emerging One Health problem in Ontario and globally. Forecasting is an important aspect of disease surveillance since forecasts of the expected incidences provide a baseline against which observations can be assessed in support of an early warning system for disease outbreaks.

Traditionally, forecasts were derived from statistical time series analysis, the most prominent being the SARIMA model. Machine learning and artificial intelligence (AI) offer additional solutions, including the application of neural network algorithms and, more recently, pretrained foundational models for forecasting.

This case study analyzed monthly Legionella incidence reports from Ontario, 2013-2024, using four time series forecasting methods, including automated SARIMA modeling as a benchmark and zero-shot forecasting using TimeGPT. The fully pre-trained transformer based TimeGPT model is a foundational time series model based on the GPT large language model. Forecasts were visualized and further compared using two accuracy measures: RMSE and MAD.

Time series exploration of the legionellosis incidence by STL revealed an increasing trend and a strong seasonal pattern with summer peaks. The legionellosis incidence increased with rising ambient temperatures.

In conclusion, zero-shot forecasting using a foundational AI model is not necessarily a golden bullet that offers a window into the future with less uncertainty. There is no best model or method that is consistently outperforming its competitors. However, it is certain that legionellosis is an emerging One Health issue of public health concern requiring sustained environmental and public health surveillance.

Keywords: Legionnaires' disease; forecasting; artificial intelligence; surveillance; evaluation

Using interpretable AI to forecast species distributions and inform marine spatial planning

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Ocean ecosystems are undergoing rapid transformation that is driving redistribution of highly mobile marine species. Anticipating these changes is critical for sustainable fisheries management and effective marine spatial planning, yet many existing species distribution model frameworks are not designed specifically for near-term forecasting and decision support. Here, we integrate satellite remote sensing, high-resolution oceanographic model outputs, fisheries observer data, and biologging observations from highly mobile predators (e.g., sharks and tunas) within a spatially explicit AI/ML model framework to generate short-term forecasts of species' distributions in the Northwest Atlantic Ocean. We implement an interpretable AI approach and use transparent evaluation metrics to identify key environmental drivers and improve confidence in operational forecast tools. By comparing model predictions to observed target and incidental catch, we evaluate forecasts in a year-ahead hindcast framework and develop decision-relevant metrics that quantify both target species encounter probability and bycatch risk, including the unrealized benefits of using near-term forecast tools for decision making on the water. By combining model predictions across target and non-target species, we generate dynamic maps of fishing opportunity and ecological risk to inform adaptive management. Our results demonstrate how interpretable forecasting models can predict spatiotemporal overlap between fisheries and vulnerable species and support dynamic spatial measures by empowering fisher decision-making and/or supporting time-area management mechanisms. This work highlights the potential for interpretable AI to advance proactive and transparent decision support for spatial planning and resource use applications in dynamic ocean systems.

Toward comparative forecasting of zoonotic arbovirus systems

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University of Florida

Forecasting zoonotic vector-borne disease systems remains a persistent challenge for public and veterinary health. These systems are difficult to predict because they often involve multiple vectors and multiple hosts, and a pathogen, each with intrinsic population dynamics influenced by external environmental conditions. Despite substantial investment, surveillance programs often detect hazards after cases in humans or other animals, leading to reactive rather than proactive control. We developed hierarchical spatiotemporal models for two mosquito vector–avian host arbovirus systems in Florida, USA. West Nile virus (WNV) is a generalist involving multiple primary mosquito vectors, and eastern equine encephalitis virus (EEEV) is a specialist with a single primary vector. Models were fitted to 20 years (WNV) and 15 years (EEEV) of Florida Department of Health sentinel chicken seroconversion data. We incorporated nonlinear landscape and lagged climate covariates with spatiotemporal random fields (GMRF-SPDE, AR1) in the 'sdmTMB' R package and evaluated model performance using out-of-sample predictions at monthly and seasonal horizons. Both systems demonstrated potential for operational ecological forecasting. Monthly WNV models outperformed seasonal models. Seroconversion increased with higher precipitation and minimum temperatures at a two-month lag and declined under higher maximum temperatures during the sampling month. EEEV seroconversion increased with intermediate precipitation at a 12-month lag, elevated 1-month lagged minimum temperature, and intermediate forest and wetland cover. Correlations between eBird-derived avian host dynamics and predicted EEEV activity suggest this data stream may improve realized predictability. Next steps include comparative analyses of intrinsic predictability and identifying where strategic data integration can advance operational forecasting.

Keywords: zoonotic arboviruses, predictability, multisource data streams

Will climate change boost boreal forest's primary productivity? Continental-scale process-based forecasts for the Canadian boreal forest

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The boreal forest provides essential ecosystem services, including timber resources, wildlife habitat, carbon storage, and climate regulation. The persistence of these services depends on how climate change reshapes disturbance dynamics, land covers, and forest productivity. Here, we focus on forecasting primary productivity responses across the entire Canadian boreal forest. We parameterized and applied the process-based ecophysiological model Biome-BGC to generate spatially explicit predictions of potential primary productivity at continental scale. Such large-scale, mechanistic forecasts remain rare in predictive ecology, where projections often rely on correlative or statistical approaches. Model predictions showed strong agreement with independent gross primary productivity estimates from flux tower observations distributed across Canada. Projecting forward to 2100 under climate change scenarios, we predict large spatial heterogeneity in productivity responses. Most regions are expected to experience substantial increases in productivity, particularly areas currently constrained by low temperatures, where projected gains sometimes exceed 100% relative to historical baselines. Our simulations also indicate a fundamental shift in limiting factors: much of the boreal forest, presently temperature-limited, is projected to transition toward water or light limitation by the end

of the century. These results suggest that increases in primary productivity may partially offset rising carbon emissions associated with intensifying disturbances such as wildfire, insect outbreaks, and permafrost thaw. By providing one of the first process-based, wall-to-wall forecasts of boreal potential productivity at national scale, this work advances our capacity to mechanistically predict ecosystem responses to climate change.

Keywords: Process-based modelling; Primary productivity; Boreal forest; Ecological forecast; Ecosystem model

Attractor and transient periodicities are invariant to seasonal transmission patterns in epidemic models

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Childhood diseases, such as measles and whooping cough, exhibit cyclical behaviour, and the frequencies of their recurrent epidemics change over decades or centuries. A key mechanism underlying these epidemic cycles is seasonal variation in contact rates stemming mainly from school terms (known as "term-time forcing"). Early mechanistic models represented seasonality with a simple sine wave for mathematical convenience, which raises the question: to what extent do inferences about transitions in epidemic cycles stemming from mechanistic models depend on accurate representation of the seasonal forcing function's shape?

Papst and Earn addressed this question by introducing a family of functions smoothly connecting sinusoidal and term-time forcing. They showed that the asymptotic epidemic dynamics predicted by these models can be mapped onto one another, enabling comparison of historical periods with different seasonal patterns. However, their method relies on adjusting the amplitude of forcing by following a period-doubling bifurcation in the system. This key bifurcation does not occur for all diseases, notably whooping cough, limiting the method's applicability.

Papst and Earn focused on asymptotic epidemic behaviour; here, we turn our attention to the transient dynamics in order to extend their method to diseases like whooping cough. We show that the transient periods of damped oscillations onto cyclical attractors can also be made invariant across different seasonal forcing schemes, and so invariance is a more general principle in these systems. This finding supports the ongoing search for a more general framework for understanding shifts in epidemic frequencies observed in childhood infectious diseases.

Keywords: Childhood infectious diseases, mechanistic modelling

An Update on American Meteorological Society Ecological Forecasting Committee Activities – the Need for an Interdisciplinary Perspective.

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The American Meteorological Society (AMS) Committee on Ecological Forecasting was chartered in 2014 to recognize the urgent need to accelerate connections between weather, water, ocean, coastal, and terrestrial forecasting and the emerging modeling and forecasting capabilities in the ecological and environmental communities. In January 2024 the AMS adopted a Statement on The Future of Ecological Forecasting to generate broader awareness of this need within the AMS. In March 2026 members of the AMS Committee published a paper entitled "Ecological Forecasting for Readiness, Resilience, and Response" in the Bulletin of the American Meteorological Society (BAMS) to call attention to and elaborate on the Statement by providing additional background, motivation, and examples to support the Statement. This talk at EFI 2026 will give an overview of the BAMS paper with a focus on the importance of interdisciplinary collaboration across the weather, water, and climate forecasting community and the ecological forecasting community. We will address the intersection of weather and climate with ecosystem impacts; our common interest in providing actionable information to support decision-making to mitigate and respond to impacts across diverse domains including agriculture, fisheries and related of food and medicine supply chains, power grid stability, infrastructure damage, human health, and many more; areas for joint interdisciplinary research and development that benefit both of our communities; and, the role of professional societies in coordinating transdisciplinary efforts. We will also present an overview of the activities of the AMS Committee on Ecological Forecasting.

Keywords: Interdisciplinary collaboration societies

Evolution of the National Weather Service Modeling Suite

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Weather forecasts produced by the National Weather Service (NWS) are widely used in the ecological forecasting community to provide atmospheric inputs to ecological forecasts. Temperature, humidity, precipitation, wind, wave action, coastal inundation, inland flooding and other parameters affect a broad range of ecosystems from microbiology community dynamics to public health, with extreme weather events being particularly impactful. Many ecological forecasts using deterministic inputs have not been reliable enough for decision making, however, ensemble models provide uncertainty quantification that can enhance ecological

forecasts. The next several years will see important evolution of the NWS modeling suite that includes multiple models spanning time and space scales. This evolution is driven by the Unified Modeling System (UFS), a community developed, simplified modeling suite, that will be more cost effective to maintain and improve. The advancement of the NWS modeling suite is also driven by the modeling "moonshot" which envisions a global convection allowing models running at 3 kilometer resolution with a variable mesh capability to run regions at even higher resolution resulting in more ecologically applicable data streams. This talk will present an overview of the NWS modeling roadmap, including the evolution of the Global Forecast System and Global Ensemble Forecast System (GFS and GEFS) models from the FV3 dynamical core to the Model for Prediction Across Scales (MPAS) core and the replacement of some rapid refresh, high resolution and regional models such as the North American Mesoscale (NAM) model and their ensemble versions with the new Rapid Refresh Forecast System (RRFS).

Keywords: Weather ensemble roadmap global regional

From national ecological monitoring to local forecasts and adaptive management

Christian Damgaard

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Predictions of plant community dynamics under different management scenarios are made for different heathland habitat types using 20 years of national monitoring data from 40-100 sites. The empirical spa-tial and temporal modelling assumes a structural equation model of the driving factors in a temperate heathland ecosystem, and the model is fitted using hierarchical Bayesian methods to separate sampling and process errors.

The observed change in plant species cover is explained well by the temporal model (>95% of the variance explained).

Local 5-year forecasts are used in an adaptive management process at specific heathland ecosystems in collaboration with local managers and stakeholders.

Keywords: Heathland ecosystems, time-series data, plant cover, adaptive management

Forecasting invasive insect spread and management outcomes for improved decision-making

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Invasive species pose significant threats to biodiversity, ecosystem services, and local economies, necessitating tools that can anticipate spread and evaluate management strategies. The Asian long-horned beetle (Anoplophora glabripennis; ALB) is a destructive wood-boring insect that has caused major concern in Ontario due to its ability to kill a wide range of hardwood tree species, leading to costly eradication efforts and urban canopy loss. We developed a spatially explicit state-and-transition simulation model (STSM) to forecast ALB invasion dynamics across heterogeneous landscapes in Ontario, Canada. Using the STSM framework within SyncroSim, we simulated a historical infestation in Mississauga and a hypothetical invasion in Muskoka under alternative management scenarios.

The model represents invasion as transitions among discrete landscape states, capturing infestation progression, detection, dispersal, and management. Simulations show that early detection combined with aggressive removal can achieve rapid eradication but with short-term loss of host tree cover. In contrast, delayed or absent intervention leads to widespread infestation and near-complete loss of susceptible host species. Landscape context influenced outcomes, with more connected, host-rich environments amplifying spread and impact.

These results highlight trade-offs between immediate management costs and long-term ecological consequences, emphasizing the importance of early intervention to mitigate biodiversity loss. Our work demonstrates how spatial forecasting tools can support invasive species management by quantifying risks, evaluating interventions, and identifying vulnerable landscapes, providing a transferable framework for biodiversity conservation under increasing invasion pressure.

Keywords: Ecological forecasting, invasive species, state-and-transition models, biodiversity conservation, decision support

Forecasting disease occurrence by 2050 following urban densification, habitat connectivity loss, and climate change

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An increase in wildlife disease has been identified in urban areas; however, the drivers of this increase remain unknown. Leveraging multi-city biomonitoring efforts across North America, we assessed whether greater disease occurrence was correlated with urban characteristics, habitat connectivity loss, and climate change. We focused on sarcoptic mange (Sarcoptes scabiei), an emerging panzootic disease, using coyote (Canis latrans) camera trap images. Locally, disease occurrence was greater at sites with higher urban intensity and in proximity to connectivity corridors, and at the continental scale, disease occurrence was greater in cities with higher human population density and fewer connectivity corridors. Following our findings, we forecast an increase in mange occurrence across cities by 2050, most prominently at northern latitudes following a combined effect of urban densification and milder winters affecting host space use overlap and host and mite survival. Urban planning for supporting habitat connectivity and proactive disease management policies can improve wildlife welfare and limit the economical effects of zoonosis.

Keywords: One Health, Sarcoptic mange, Bayesian statistics, Urban Wildlife, Disease Ecology

Forecasting dryland resilience via resource-driven dung beetle facilitation

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Dryland ecosystems are highly vulnerable to global warming and increasingly prone to desertification, yet their resilience often hinges on complex biotic interactions. At the center of these interactions are dung beetles, acting as potential ecosystem engineers. Local experiments have demonstrated their powerful ability to buffer warming impacts—significantly reducing warming-induced shrub growth loss and mortality, while also reversing density-dependent plant competition. Crucially, this plant-facilitation mechanism is strictly dependent on the presence of ungulates, which provide the essential resource (dung) that fuels beetle populations. Forecasting how this multi-trophic cascade (ungulate-beetle-shrub) will perform under higher risks of extreme weather events remains a critical challenge for landscape management.

Here, we present a predictive framework that integrates this complex ecological cascade with Bayesian modeling to forecast ecosystem resilience in two dryland systems. To power these forecasts, we synthesize a multi-layered dataset integrating biotic interactions alongside key abiotic drivers: spatial distribution and abundance monitoring of ungulates (resource availability), constant-effort pitfall trapping of dung beetles (population dynamics monitoring), and field experiments of shrub growth under dung-beetle activity. Crucially, our experiments show that dung beetles completely reverse density-dependent growth suppression, shifting a 9.6% competitive penalty into a 3.1% net facilitation, and strongly buffer plant mortality, sustaining high survival rates between 88.5% and 91.8%. By integrating this robust empirical

data into our Bayesian models, we can effectively scale individual-level processes to landscape-level dynamics.

Keywords: Dryland ecosystems; Dung beetles; Bayesian modeling; Ecosystem resilience; Global warming

How much is enough? Optimizing Sampling thresholds for reliable ecological forecasts

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Terrestrial Ecosystem Research Network (TERN)

Monitoring vegetation dynamics is critical for understanding ecological change and informing conservation under accelerating climate and land-use pressures. Long-term monitoring, however, is often constrained by various management practices and limited field resources. Using Terrestrial Ecosystem Research Network AusPlots point-intercept data from 174 plots across four Major Vegetation Groups (MVGs) in Australia, we examined how variation in plot size and sampling intensity influence vegetation metric accuracy and sensitivity. We applied two strategies: (1) six nested subplots within 1-ha plots and (2) reduced sampling intensities (1⁄4, 1⁄3, 1⁄2 points) with resampling for robust inference.

Generalized linear mixed-effects models were fitted for Shannon diversity, Simpson diversity, species richness, and upper-storey fractional green cover. Results show that optimal plot size and sampling intensity thresholds are community- and metric-specific. Shannon and Simpson diversities vary significantly across plot sizes and MVGs. Eucalypt Woodlands, Tussock Grasslands and Chenopod Shrublands achieve steady diversity estimates at 80 × 80 m plots, whereas Acacia Forests stabilize above 50 × 50 m. Species richness declines progressively with decreasing plot size. Reduced sampling intensity significantly affects Shannon diversity and species richness across MVGs, while Simpson diversity is robust in Eucalypt Woodlands (1⁄3 points) and Acacia Forests (1⁄4 points). Upper-storey fractional green cover remains consistent under both design modifications but differs among MVGs.

These results demonstrate that sampling design directly influences biodiversity baselines, trend detection, and forecast performance. Incorporating community-specific sampling thresholds reduces model bias and enhances early detection of ecosystem change, strengthening the reliability and comparability of ecological forecasts across heterogeneous ecosystems.

Keywords: Terrestrial ecosystem, biodiversity monitoring, plot size, sampling intensity, vegetation metrics

Guidance and tools for quantitative and qualitative context-specific evaluations of species distribution models

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Species distribution and abundance models (SDMs) frequently inform land and population management actions, including conservation planning, forest management, impact assessment, and recovery planning for species at risk. Sampling effort varies across large heterogeneous landscapes, and accurate spatial and/or temporal extrapolation is challenging, so model reliability varies across space and time. Models that extrapolate poorly can still remain useful for applications within well-sampled geographic or environmental space, but the risks associated with errors will vary with application. Evaluations of model reliability are therefore most useful when they are both spatially explicit and application-specific. Quantitative evaluation methods can help identify areas of extrapolation and variation in model reliability. Qualitative evaluations of SDMs by people who know the land, species, and/or sampling limitations provide additional, complementary benefits. To date, the process for integrating qualitative knowledge into model evaluation and interpretation has been ad hoc, variable, and often inefficient. Our goals are to develop tools and guidance to enable context-specific model evaluation informed by diverse expertise, and to facilitate effective communication among modelers, evaluators, and model users with these tools. We present: a prototype sdmEvaluationTool R Shiny app that enables both quantitative and qualitative spatially-explicit review and evaluation of models; and complementary guidance on how to do application-specific evaluation that helps clarify what questions to ask evaluators and how to interpret answers. We will continue to develop the tool and guidance as we use them to evaluate national, provincial, and regional boreal bird models for various applications.

Keywords: species distribution and abundance models; application-specific spatial model evaluation; R shiny app; expert elicitation

Spatial Resolution Shapes Forecast Utility for Decision-making

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Invasive pests threaten global food security and economies, making timely and accurate forecasts critical for effective management. Predicting the spread of generalist invaders is particularly challenging – these pests move rapidly across varied hosts and environments,

demanding models that capture both broad-scale patterns and fine-scale processes driving pest spread. Meeting these dual demands is computationally expensive, particularly for spatiotemporal analyses. One common way to mitigate these costs is to coarsen the spatial resolution, but this can compromise data quality, introduce errors, and affect utility for management.

Using the Pest or Pathogen Spread (PoPS) Forecasting System and Spotted Lanternfly as a case study, we generated hindcasts at five resolutions (100, 300, 500, 700, and 900 m) and compared performance, predicted infested area, and computational tradeoffs. We further examined how results varied spatially across invasion zones (core, front, edge) that reflect operationally distinct management contexts.

Performance changed modestly across resolutions. Intermediate-to-coarse hindcasts performed better, specifically in the invasion core. In the front and edge regions, finer-to-intermediate hindcasts performed similarly or better than coarser hindcasts, and substantially reduced the predicted infested area, creating opportunities for more targeted interventions. However, finer-grained forecasts require significantly more time and memory, potentially limiting their value during the early stages of an invasion when rapid action is paramount. Ultimately, choosing the right spatial resolution is not merely a technical detail—it shapes the real-world utility of forecasts. Choosing the right spatial resolution to align with management goals is vital for delivering forecasts that better inform on-the-ground actions.

Keywords: Invasive Species, Modeling, Scaling

Quantifying the cost of cultural bias in conservation decision making

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Human systems shape not only ecological data collection, but also perspectives and assumptions made during model building, generating uncertainty in how dominant value systems and cultural bias limit ecological inference. Understanding how this uncertainty propagates in conservation decision making requires translation beyond abstract statistical measures and toward performance on real-world objectives. Here we develop a quantitative framework combining uncertainty quantification and decision theory to understand the value of reducing uncertainty generated by cultural bias for a conservation decision maker. We demonstrate this framework in the context of decision making in the Columbia River Basin (CRB), where the Pacific lamprey – an ancient, foundational species in the CRB – modulates salmonid ocean survival both as a parasite of salmonids and a predation buffer against marine mammals. The Pacific lamprey, however, has faced a precipitous decline in the last century,

largely stemming from Euro-American cultural bias, which has led to asymmetric measurement error and observation of local, rather than global, properties of the system. We show that multiple functional forms of this three-species dynamical system are statistically indistinguishable yet result in very different optimal management actions because of differences that lie outside the range of observed data. We use methods from decision theory to quantify the cost of lamprey uncertainty in units relevant for a decision maker, demonstrating that the value of information around overlooked species can be considerable. These results highlight how Situated Modeling in ecological management can be used to interrogate how modeling as a process and practice is contextualized.

Keywords: decision theory; value of information; Bayesian statistics; cultural bias

Scalable Parameter Calibration for Land Surface Models Using Ensemble Kalman Inversion

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Terrestrial ecosystem models play an important role in ecological forecasting, but their predictive accuracy is often limited by poorly constrained parameters that cannot be directly observed. These parameters are typically inferred by calibrating model outputs against observations such as leaf area index (LAI) and aboveground biomass (AGB), but traditional Markov chain Monte Carlo (MCMC) methods can be computationally prohibitive because they require many expensive forward model evaluations, and gradient-based methods are often impractical because model derivatives are unavailable or costly to compute. We present a scalable parameter calibration framework based on ensemble Kalman inversion (EKI) with likelihood tempering. We apply this approach to the SIPNET ecosystem model across >200 FLUXNET and NEON sites, calibrating a influential parameters identified through sensitivity analysis, against a combination of bottom-up (e.g., NEE, LE) and remotely-sensed (e.g., LAI, AGB) observations. In our experiments, accurate calibration was achieved with relatively small ensembles (~50). Relative to the prior ensemble, calibrated parameter ensembles improved representation of seasonal canopy dynamics and aboveground biomass across sites. EKI results also showed increasing agreement with posterior distributions obtained by MCMC over tempering iterations. Across sites, calibration reduced median seasonal amplitude error in LAI by 43%, indicating improved representation of the annual canopy cycle. For AGB, calibration reduced median CRPS by 67% and RMSE by 78%. Calibrated ensembles were also sharper, with median interval width reduced by 66% while maintaining coverage of the nominal 90% interval. These results demonstrate that our framework provides a scalable approach for parameter inference in complex ecosystem models.

Keywords: Data assimilation, Bayesian calibration, Uncertainty quantification, Terrestrial carbon cycling

Phenological shifts of marine top predators in a rapidly changing ocean region

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Changes in phenology–the seasonal timing and distribution of life history events–are a common response to environmental change, yet remain poorly understood for highly migratory marine species. In pelagic systems, phenology is closely linked to the seasonal availability of suitable habitat, but understanding and predicting temporal shifts in habitat have received far less attention than spatial redistribution. Here, we use species distribution models for twelve ecologically and economically important pelagic predators to characterize historical habitat phenology in the Northwest Atlantic Ocean and project future changes under end-of-century oceanographic conditions. We define phenology as the seasonal distribution of modeled suitable habitat ("habitat phenology"), which serves as a proxy for species occurrence. Using this framework, we identify three general phenological archetypes–warm-migratory, resident, and cold-migratory–based on the timing and concentration of seasonal habitat. Projected climate-driven habitat changes alter both the timing and seasonal concentration of suitable habitat, with responses varying across species and archetypes. While some species exhibit minimal shifts in peak timing, many show reduced seasonality or expanded seasonal habitat, and several are predicted to transition between archetypes, including shifts toward more resident or winter-dominated patterns. These results demonstrate that climate-driven redistribution will reshape not only where species occur, but also when suitable habitat is available. Such temporal shifts have important implications for fisheries, conservation, and marine spatial planning, highlighting the need to integrate phenological dynamics into forward-looking, dynamic ocean management.

Keywords: phenology, species distribution model, highly migratory species, climate change, dynamic ocean management

Predictive validation improves forecast quality: re-finding the best models for caribou movement

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Statistical estimation methods in ecology are prone to overfitting, yet our field has long relied on within-sample goodness-of-fit metrics that inherently favour overly complex models. More recently, cross-validation using held-out data has become common practice, but this approach does not necessarily align with the forecasting demands typical of applied ecological decision making. When the goal is to inform planning—making decisions today to achieve desired outcomes tomorrow—models must be evaluated in the same way they will be used: to forecast. We argue that appropriate – and the specific best – model complexity can only be identified when the validation strategy mirrors the temporal structure of the forecasting problem. Using caribou GPS collar movement data, we demonstrate that Unseen Future Validation and Testing—validation on data that occur strictly temporally after all training data—identifies "best" models that generalize better and avoid the overfitting that both within-sample fit and conventional cross-validation fail to detect. Our results illustrate that predictive, temporally aligned validation consistently identifies a different set of best movement models than other model scoring procedures: we believe this is doing a better job at correcting for overfitting. We conclude that ecological models intended to support real-world planning and policy should adopt a predictive validation framework as standard practice to ensure that model selection reflects true forecasting performance and leads to better-informed decisions for ecological systems.

Keywords: Predictive validation, Predictive Ecology, Caribou, Movement, Neural Nets

Forecasts reveal divergent seasonal and regional responses of forage fish in a changing Northwest Atlantic Ocean

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Forage fish are small, schooling species that transfer energy from plankton to higher trophic levels and comprise a large proportion of biomass in many productive coastal ocean ecosystems. Yet their spatiotemporal distributions remain poorly resolved and difficult to predict. We used 30 years (1993–2023) of catch data from the Northeast Fisheries Science Center bottom trawl survey to develop season-specific, spatially explicit models for key forage species: Atlantic herring (Clupea harengus), Atlantic butterfish (Peprilus triacanthus), sand lance (Ammodytes spp.), and alewife (Alosa pseudoharengus). We compared model-predicted habitat suitability under contemporary conditions (1993–2002) to near term decadal forecasts (2025–2034) derived from the NOAA Modular Ocean Model 6 to quantify projected shifts across regions of the Northwest Atlantic. Our results reveal strong season- and region-dependent responses to future ocean conditions across species. Suitable habitat is projected to generally increase in fall, whereas spring responses are mixed and species-specific. These findings demonstrate that forage fish responses to changing ocean conditions are not uniform, reflecting the importance of seasonal dynamics and species-specific adaptive capacity in shaping forage fish distributions. Accounting for this heterogeneity will be critical for improving ecosystem-based management and anticipating impacts on predators, fisheries, and coastal communities.

Keywords: Gulf of Maine, Georges Bank, Marine protected areas, Fisheries

Exploring hypothetical-yet-plausible pandemic pathogens: a dual-model forecasting framework

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Following the COVID-19 pandemic, the Public Health Agency of Canada (PHAC) is updating Canada's Pandemic Influenza Plan into a broader Canadian Pandemic Preparedness Plan (CPPP), creating a need for modelling frameworks that support forecasting and decision-making across diverse and uncertain pathogen characteristics. To address this, the PHAC Modelling Hub developed a dual-model framework that enables rapid scenario exploration without precluding more detailed analyses.

We paired a deterministic, age-structured compartmental model with a stochastic, agent-based model to simulate outbreaks of five "hypothetical-yet-plausible" respiratory diseases based on profiles of real respiratory pathogens of pandemic potential. Using Canadian demographic and contact data with literature-derived epidemiological parameters, we generated forecasts under baseline conditions and intervention scenarios, focusing primarily on the first 100 days of an outbreak, but also exploring longer-term outcomes.

Disease transmissibility drove the timing and magnitude of epidemic peaks, while virulence determined healthcare burden. The agent-based model produced spatially heterogeneous, often multimodal epidemic trajectories, revealing uncertainty not captured by more homogeneous models. The compartmental model identified critical timing–effort trade-offs, with early, moderate contact reductions substantially reducing hospitalizations; agent-based simulations supported these findings while highlighting variability linked to population structure.

These results demonstrate how complementary models can improve early outbreak forecasting, quantify uncertainty, and identify time-sensitive intervention opportunities to support pandemic preparedness objectives.

Keywords: time series forecasts; pandemic preparedness; decision-making; public health

Forecasting non-breeding distributions of thick-billed murre populations to inform conservation of Atlantic populations

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Effective management of migratory wildlife populations, especially those that traverse multiple jurisdictions, requires accurate estimates of the spatio-temporal distributions of specific populations. Thick-billed murres (Uria lomvia), a pan-Arctic colonial breeding seabird, are experiencing declines across much of their North Atlantic breeding range. Murres from colonies across the North Atlantic migrate to subarctic waters in winter to avoid sea ice and polar night. Multinational tracking efforts have documented short and long-range migratory movements of murres throughout the North Atlantic basin. Birds from breeding populations in one jurisdiction may encounter risks from anthropogenic activities while in the territorial waters of other countries. For instance, murres migrating across the North Atlantic are exposed to harvest in Canada, Greenland, and Iceland. We developed a dynamic species distribution model (SDM) to predict and forecast murre distributions across the Atlantic at weekly intervals. The SDM can generate near real-time distribution estimates using oceanographic forecast models, providing valuable insights to inform harvest management, environmental impact assessments, and emergency response planning.

Keywords: Seabirds, Species Distribution Model, Marine Ecology

Conformal Prediction quantifies the current and future uncertainty of Species Distribution Models

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Providing accurate estimates of uncertainty is key for the analysis, adoption, and interpretation of species distribution models. In this manuscript, through the analysis of data from an emblematic North American cryptid, I illustrate how Conformal Prediction allows fast and informative uncertainty quantification. I discuss how the conformal predictions can be used to gain more knowledge about the importance of variables in driving presences and absences, and how they help assess the importance of climatic novelty when doing future predictions.

Forecasting Mountain Pine Beetle Infestations with Multi-Paradigm Models

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Accurate ecological forecasts provide useful insights to inform policy and management, but building models to produce these forecasts is challenging. Modelling approaches can vary from mechanistic models that attempt to capture the underlying ecological processes to purely phenomenological or statistical models fit to data with limited – or no – mechanism. These different approaches are likely to have different strengths depending on the metric being predicted, the amount of data for training, and the time horizon of the prediction. In particular, too strong reliance on past data may lead to incorrect inferences about the future of ecosystems under novel conditions, such as those induced by climate change and anthropogenic disturbances. Here, we evaluate several models from different paradigms, including neutral models, to predict Mountain pine beetle (MPB) infestations in Alberta, Canada. During a recent hyperepidemic (~2005–2019) in neighbouring British Columbia, MPB was able to overcome the natural barrier of the Rocky Mountains and spread into Alberta. Alberta dedicated extensive resources to monitor and control this spread, including helicopter surveys of infested trees. We use this data to study the predictive accuracy of several models that range in complexity and mechanistic basis. We discuss general trends in model performance with the aim of providing practice advice about the types of models that may achieve the greatest predictive accuracy given different data availability, target year, and forecast horizons.

Keywords: Ecological forecasting; model comparison; neutral models; mountain pine beetle

From importation to transmission: Modelling the potential for autochthonous dengue virus transmission in Canada via imported travellers

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Each year, hundreds of cases of dengue are imported into Canada via travellers from endemic countries. However, this is subject to underreporting and misclassification due to lack of awareness of this domestically uncommon disease.

The threat of autochthonous mosquito-borne disease transmission in Canada is growing. Aedes albopictus, a vector for dengue virus, has become established in southern Ontario. As the Canadian landscape for vectors and vector-borne pathogens evolves due to climate change, it is imperative to understand the potential for local transmission initiated by imported cases.

A compartmental SEIR-SEI model was developed to explore dengue transmission in Windsor, Ontario. The model introduces dengue cases into the population to explore the possibility of an autochthonous outbreak during a limited period of the year. The model accounts for temperature and precipitation drivers of mosquito development and was calibrated on mosquito population data from Windsor.

As no locally acquired human cases of dengue have ever occurred in Canada, outbreak data from the Pesaro and Urbino province in Italy with similar meteorological conditions to Windsor was used to model a potential outbreak in Canada.

Our results indicate the importance of timing of introduction events. The model shows the highest outbreaks occurring when cases are introduced in July and August with a median outbreak size of 62 cases per 100,000 people in 1000 simulations. The findings highlight the growing local risk of mosquito-borne diseases in Canada and the importance of increasing awareness of exotic pathogens.

Keywords: Aedes albopictus, compartmental model, forecasting, mosquito, One Health

A guided tour through the cyberinfrastructure that supports the NEON Ecological Forecasting Challenge

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Ecological forecasting challenges have emerged as an effective mechanism for advancing predictive capacity in ecology by coordinating community efforts to generate, evaluate, and refine near-term forecasts of yet-to-be-collected data. The NEON Ecological Forecasting Challenge exemplifies this approach, having processed more than 82 million individual forecasts across 81 sites since 2021. We present the design principles, implementation, and lessons learned from the cyberinfrastructure developed to support the NEON Challenge, with an emphasis on its applicability to future forecasting initiatives. The platform is a serverless, open-source system that automates the core forecasting workflow, including target data generation, probabilistic forecast ingestion and validation, evaluation using proper scoring rules, and dissemination of results. The infrastructure relies on cloud-native, vendor-agnostic technologies, including object-based storage, continuous integration workflows, and containerized execution, to ensure scalability, reproducibility, and long-term maintainability. Its modular architecture facilitates adaptation to new forecasting targets, data sources, and observatories, enabling rapid deployment for emerging ecological forecasting challenges.

Keywords: NEON, Challenges, cyberinfrastructure

When data deficiencies matter: a tale of forecasting two ecotypes of caribou

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Data deficiencies are a fact of life for ecologists, but forecasting can highlight when these matter and when they do not. Managers need to make decisions about the future based on data from the past, which is inherently an out-of-sample data problem for current models, highlighting the role of validation for models, especially those with data deficiencies. We present examples from northern mountain caribou and boreal caribou (Rangifer tarandus caribou), in the far north and boreal Canada respectively, habitat selection analyses that highlight when some data deficiencies matter and when they do not. Our results highlight how model complexity relates to data deficiencies and when they matter in models when forecasting both spatially and/or temporally. Based on these findings, we developed a method that provides a scalable framework for estimating population status in data-deficient contexts and may be broadly applicable to other species of conservation concern. In the case of managed species that cross jurisdictional boundaries, this study also provides evidence for improved predictions when data outside jurisdictions are used together.

Keywords: validation, spatio-temporal forecasting, habitat selection, demography

Where Climate Change and Sampling Bias Collide: Challenges of Predicting and Validating Biodiversity Change in Canada

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Anticipating biodiversity change is critical in rapidly warming regions, yet challenging because these areas often coincide with poor sampling. Data gaps are widely understood to interfere with species distribution models (SDMs), so bias-correction methods are generally trusted to account for this. However, when faced with real-world data gaps and climate change, it is unclear if these methods are reliable, as this is difficult to measure with biased data. To better understand SDMs in this context, we 1) measure performance with a new occurrence-checklist-range (OCR) validation, and 2) evaluate prediction discrepancy across space and time. We found: 1) bias-correction improves model performance against independent (checklist and range) data, but not against typical occurrence cross-validation, 2) predicted richness differed among methods (up to 2.7-fold), especially in the north, and 3) counterintuitively, future projections varied less (by 28%) because well-sampled climate space will shift north. Our findings suggest potential widespread overconfidence in SDM predictions for the unevenly

sampled world, with implications for the growing reliance on biodiversity estimates for planning and policy. OCR validation and methodological discrepancy measurements are relatively easy ways to address this.

Keywords: SDMs, Sampling bias, Validation, Uncertainty

Poster Presentation Abstracts

Lessons learned from Jamaica Bay: Leveraging a decade of data to inform best practices in the design, monitoring, and management of urban salt marsh restorations

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Globally, over 50% of coastal salt marshes have been lost to human-induced stressors such as coastal land-use development, altered hydrology, sea-level rise, and eutrophication. In urban areas, rates of loss can be much higher. Jamaica Bay (New York, NY, USA) has lost over 92% of its marshes over the past century. Multiple large-scale restoration efforts have attempted to reverse rates of marsh loss and restore ecosystem services for coastal human communities. However, post-project monitoring and quantitative assessment of restoration success lags far behind investment in marsh construction. Here we conduct a condition assessment of restored salt marsh islands in Jamaica Bay using monitoring data collected from permanent plot locations on five restored marsh islands, as well as a reference site, from 2005-2017. Data included point-intercept percent coverage of vegetation, stem density and height, aboveground and belowground plant biomass, density and richness of benthic and nektonic fauna, and marsh surface elevation. We are using these data to address important management questions that will inform future restoration practices in urban estuaries: 1) Which restoration techniques applied to Jamaica Bay have been most successful in restoring marshes? 2) Do current sampling metrics provide effective indicators for detecting a response to salt marsh restoration? 3) Was sampling frequency and duration appropriate? Results of this project will be available to help inform salt marsh restoration planning, design, and monitoring in northeastern USA marshes.

Keywords: nature-based solutions, green infrastructure, sea-level rise, coastal resilience

Building Predictive Confidence: Evaluating forecast reliability in spatio-temporal species distribution models

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Understanding and predicting species distributions under changing ecosystem conditions is essential for anticipating the ecological and management consequences of marine species redistributions. Spatio-temporal mixed-effects models are widely used for this purpose, combining fixed effects for measured environmental drivers with spatial or spatio-temporal random fields representing unmeasured processes. However, how these models behave when used for forecasting, particularly under potentially novel conditions, remains poorly understood. To address this, we developed a simulation framework with explicit control over the spatial structure, temporal dynamics, and relative influence of measured versus unmeasured drivers to examine prediction reliability across three contrasting scenarios: (1) stationary baseline conditions, where both drivers remain stable; (2) trending measured driver conditions, where progressive environmental change moves beyond the range observed during model fitting; and (3) compound stressor conditions, where trending measured drivers combine with regime shifts in unmeasured drivers, representing realistic climate change scenarios. Using this framework, we characterize how prediction reliability changes across scenarios as a function of driver structure and model complexity. We then apply this framework to species distribution data from the Northwest Atlantic as a worked diagnostic example, illustrating how it can inform real-world forecasting decisions. Together, these results provide a conceptual foundation and practical diagnostic workflow for evaluating forecast reliability in spatio-temporal species distribution models, with direct relevance to ecological forecasting and conservation planning under global change.

Keywords: Gaussian Markov random field, mixed effects modeling, climate change projections, environmental novelty, non-stationarity

The OA2O Project: Integrating Short-Term Ocean Acidification into NOAA's Operational Ocean and Weather Forecasting Systems

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Ocean Acidification Program (OAP), NOAA Research

There is a significant opportunity to establish an operational forecasting system for ocean acidification (OA) at NOAA, which will greatly benefit coastal communities and industries reliant on marine ecosystems. Building from more than 15 years of biogeochemical modeling research

sponsored by NOAA's Ocean Acidification Program (OAP) , the Ocean Acidification to Operations (OA2O) initiative seeks to transition mature, community-developed BGC and OA forecast models from research-based systems into NOAA's 24/7 operational infrastructure. This transition addresses a critical gap in reliability and accessibility of research-funded models.

The OA2O initiative will leverage existing operational hydrodynamic models from NOAA's National Ocean Service (NOS) as a foundation for new, dependable OA forecast products. The initiative has a two-pronged implementation path: first, adapting existing research BGC and OA models for integration with NOS operational systems; and second, developing a generalized, hydrodynamic-core-agnostic BGC/OA module that can interface with various hydrodynamic cores used by the Unified Forecast System (UFS) and NOS ocean forecast systems. Ultimately, the OA2O initiative empowers the ocean acidification community to better address the needs of stakeholders in coastal industries, fisheries, and aquaculture sectors with timely, actionable forecasts, fostering a robust Research-to-Operations-to-Research (R2O2R) feedback loop.

Keywords: ocean acidification modeling short-term forecasting

Integrating Community-Based Waste Management and Ecological Forecasting to Enhance Urban Resilience in Bukavu, DRC *(cancelled)*

Joseph Bahati

Anansoft Foundation

Rapid urbanization in Bukavu, South Kivu, Democratic Republic of Congo, has intensified challenges in waste management, with negative impacts on public health, freshwater ecosystems, and urban resilience. Women of Africa, a local NGO, implements community-based waste collection, recycling, and environmental education programs targeting vulnerable populations, particularly women and youth. However, the effectiveness of these interventions is constrained by unpredictable seasonal flooding, climate variability, and limited infrastructure.

This study explores the integration of ecological forecasting tools into local waste management practices to improve planning and responsiveness to environmental changes. Using participatory mapping, local knowledge, and environmental monitoring data, we co-developed decision-relevant forecasts that predict waste accumulation hotspots, flooding risks, and areas vulnerable to contamination. These forecasts inform community mobilization, strategic placement of collection points, and targeted awareness campaigns.

Preliminary results indicate that forecast-informed interventions significantly reduce waste accumulation in high-risk zones and enhance community engagement in sustainable practices. By combining grassroots initiatives with ecological forecasting, our approach strengthens urban resilience, protects freshwater systems, and promotes inclusive environmental governance.

This work demonstrates that integrating scientific forecasts with local knowledge and community-led interventions is critical for addressing environmental and public health challenges in rapidly urbanizing, resource-constrained contexts. Lessons from Bukavu can inform similar initiatives across sub-Saharan Africa and contribute to global discussions on sustainable waste management, climate adaptation, and urban ecological resilience.

Keywords: Waste Management, Ecological Forecasting, Urban Resilience, Community-Based Interventions, South Kivu

Building an agent-based modeling framework to forecast freshwater phytoplankton blooms

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Forecasting the emergence of phytoplankton blooms is a critical need in aquatic ecology and water management due to their scums, toxins, and risks to human health. However, forecasting blooms remains a significant modeling challenge for multiple reasons. For example, phytoplankton dynamics are governed by functional relationships with changing environmental conditions that cannot be directly represented by machine learning and statistical modeling approaches. Meanwhile, deterministic models of phytoplankton blooms typically include only a subset of relevant functional relationships due to limitations in data and computational power, and are inherently limited in capturing the diversity of phytoplankton responses to environmental drivers. In contrast, agent-based models (ABMs) are specifically designed to tractably study collective phenomena (e.g., phytoplankton blooms) that emerge from many functional relationships while explicitly accounting for heterogeneity in responses among individuals. Here, we describe a novel agent-based model for individual phytoplankton particles coupled to an existing modeling framework linking the Aquatic EcoDynamics (AED) water quality modules to the one-dimensional hydrodynamic General Lake Model (GLM). The resulting GLM-AED-ABM modeling environment allows individual phytoplankton particles to both respond to and alter the thermal and chemical characteristics of the water column. These feedbacks allow the model to exhibit realistic and ecologically relevant phenomena not previously captured by phytoplankton models, such as nutrient fluxes between phytoplankton and the water column and attenuation of light in the water column by phytoplankton. Future work will leverage this framework to incorporate bloom predictions into decision support tools, ultimately improving our ability to forecast water quality and ecosystem health.

Keywords: phytoplankton blooms, agent-based modeling, water quality, GLM-AED

Adding Biological Soil Crust Representation to the CLASSIC Terrestrial Biosphere Model to Improve Dryland Carbon Flux Predictions

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Despite drylands covering ~41% of Earth's land surface, their carbon fluxes are poorly simulated by all major terrestrial biosphere models. This is problematic, as these models form the terrestrial component of the larger earth system models used to predict future climate change scenarios. However, all terrestrial biosphere models currently omit representation of biological soil crusts, which cover ~30% of dryland soils. Biological soil crusts are complex surface assemblages composed of both non-vascular cryptogams and surface heterotrophs, with these crusts exhibiting unique carbon flux behaviours compared to the vascular plants currently represented within terrestrial biosphere models. Thus, I will be adding biological soil crust representation to the Canadian Land Surface Scheme Including Biogeochemical Cycles (CLASSIC) and evaluating how the addition of these crusts alters the simulation of dryland carbon fluxes compared to real-world observations.

Keywords: Biological Soil Crust, Dryland, Carbon Cycling, Terrestrial Biosphere Model

The impact of trophic state and spatio-temporal scale on predictability of water quality

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How predictable are temperate freshwater ecosystems? We can look at predictability in one of two ways, as the ability of our models to mimic observations (realized) or as the complexity or stochasticity of the observed data (intrinsic). Intrinsic predictability is often considered to be a guide for what variables may be more easily forecast, because it is correlated with realized predictability. Environmental differences and spatial and temporal aggregation of variables can strongly influence how predictable they are. Using multiple years of observations on two lakes, one eutrophic and one oligotrophic, we assessed intrinsic and realized predictability of chlorophyll a, phycocyanin, dissolved oxygen, turbidity, fluorescent dissolved organic matter, conductivity, pH, and temperature. In addition to comparisons across lakes, we explored differences within lakes and at multiple levels of spatio-temporal aggregation. Contrary to our expectations we found that intrinsic predictability was often higher in the eutrophic system than the oligotrophic lake. Despite differences in predictability, forecast performance of multiple

statistical models was similar across both lakes. In both lakes there was no consistent difference between predictability of chlorophyll at the daily or hourly timescale, but daily temperatures were more predictable than hourly. It remains an open question whether intrinsic predictability can usefully guide forecasting under realistic environmental monitoring in temperate lakes.

Keywords: freshwater, intrinsic predictability, realized predictability

Evaluating the scientific output of long-term ecological monitoring programs using NSF grant records

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Long-term monitoring programs provide some of the most valuable empirical data in ecology, but their establishment and maintenance can be costly. To assess the scientific output of long-term monitoring programs, we compared Long Term Ecological Research (LTER) grants and individual principal investigator NSF Division of Environmental Biology (DEB) grants in the United States. Specifically, we evaluated whether LTER grants were associated with greater publication output and whether publications arising from LTER grants differed in citation rates.

We compiled all relevant grants that had expired between 2016 and the present and identified their associated publications using NSF's Public Access Repository and Web of Science. Publications were included only if the associated grant number was referenced in the article. We then quantified the number of publications associated with each grant and the citation performance of those publications.

Overall, we found that LTER grants were associated with approximately 2.7 times more publications than individual DEB grants after accounting for funding amount and time since the grant began. In contrast, we found no evidence that publications arising from LTER grants differed in citation rate from those arising from individual DEB grants. These findings suggest that large-scale long-term monitoring programs can generate substantially greater publication output without an apparent reduction in citation performance. Importantly, our estimates likely underestimate the full value of LTER programs because publications that use freely available LTER data often do not cite the grant numbers that supported data collection, preventing their inclusion in our analysis.

Keywords: Open data, Funding evaluation, Research impact

Current and future distribution of timber species of the genus Manilkara Adans. in the Amazon region.

Emeli Susane Costa Gomes

Universidade Federal de Santa Catarina

Abstract not available at this time.

Analysis of Corn Earworm long-term monitoring data informs initial conditions uncertainty and predictability

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Corn earworm (Helicoverpa zea) is a major pest of row crops and vegetables in the United States. Descriptive spatial statistics and temperature-driven models have advanced management of this species, however these models have not coupled long-term monitoring data with these mechanistic understandings to forecast seasonal spread. I will build a spatiotemporal spread model to predict H. zea infestations that will allow stakeholders to plan, test, and apply multiple scenarios which are needed to improve control. We use the long-term monitoring dataset from Lawton et al., (2022), to create a data-model that will allow us to better understand the uncertainty in the recorded historical species distribution. We apply a Bayesian hierarchical model of weekly adult corn earworm abundance at 1,974 pheromone and black light traps from 1990–2021 to assess changing population dynamics. Weekly uncertainty bands are computed and the model achieves reasonable results on 89,970 observations with $R2 = 0.800$ (0.799, 0.802) and RMSE = 0.785 (0.783, 0.788). Peak timing, week of year of maximum abundance, is derived from 1,000 draws from the posterior distribution. We use this analysis to inform yearly estimates of abundance at the trapping locations, paying close attention to the distribution of peak timing across overwintering and non-overwintering zones. Over the 32-year period, we observe heterogeneity in the peak timing among zones. This analysis will inform seasonal abundance estimation and help to understand which locations are predictive of non-overwintering zone population dynamics to be used as initial conditions for our spread model.

Keywords: Corn earworm, Bayesian, predictability, uncertainty, initial conditions

Forecasting shifts in coastal distribution for a marine species-at-risk with seasonal ties to terrestrial habitat

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Marbled murrelet (Brachyramphus marmoratus) is a species-at-risk with heightened conservation focus because of its reliance on nesting habitat in old growth forests. Habitat selection depends on marine conditions influencing foraging success year-round, and proximity to terrestrial nesting habitat during the breeding season, creating pronounced temporal variation in habitat requirements across seasons. High-resolution predictions of year-round critical habitat is of utmost importance for the conservation of this species, as is forecasting how distributions will shift into the future. We leveraged extensive, seasonal at-sea survey data, as well as high-resolution suitable nesting habitat data from 1990 to the present to assess critical habitat distribution along the coast of British Columbia. Using the period with the highest quality survey data (2000-2025), we used a combination of Bayesian Additive Regression Tree (BART) and decision tree models to predict present day critical habitat, as well as hindcast to the 1990s, with earlier survey data used in ground-truthing. Further, we used climate and forest stock projection models to forecast critical habitat distribution into the future, allowing us to assess decadal shifts in distribution from the 1990s to the 2050s. Ongoing tracking efforts using satellite tags during the breeding and non-breeding season may be integrated to further refine these models. These results are important for critical habitat assessment and risk management under economic growth projections, and offer an opportunity to further develop data integration methods in ecological forecasting.

Keywords: species-at-risk; coastal habitat; seabird; marine biodiversity; old growth forest

Accounting for crop susceptibility and landscape context in biological invasion forecasts improves pest management treatment outcomes

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Threats from invasive species are significant and increasing, causing billions of dollars in annual damages. Determining both when and where to invest in management efforts is difficult due to limited budgets and complexity of spread dynamics across heterogeneous social-ecological landscapes. Modeling the spread of invasions can improve decision-making by identifying which locations will see the greatest management benefits. Two approaches are often used: process-

based models of population growth and spatiotemporal spread, and bioeconomic models with economic, ecological, and treatment cost parameters to determine optimal management locations. These model types have rarely been combined, despite the potential benefits of leveraging their different strengths and combining their outputs to select management locations. We integrated these two modeling approaches to simulate the spread and management of Spotted Lanternfly (SLF), an invasive planthopper, for 31 years in the continental United States. We used three scenarios to allocate management locations: 1) treating the most highly infested locations using the process-based model's outputs that show forecasted spread, 2) selecting locations utilizing a bioeconomic pest management model, and 3) combining approaches 1 and 2 to select optimal management locations. Our results suggest that selecting management locations based on outputs from both model types yields the fewest crop damages and the smallest overall invasion extent and intensity. This underscores the benefits of accounting for economic damages and landscape context in addition to propagule pressure when selecting management locations for invasive species. We recommend combining these model types when making management decisions for other invasive species.

Keywords: Invasive species, Spatio-temporal forecasting

Forecasting range expansion of blue crabs in the Gulf of Maine using crowdsourced observations

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Blue crabs (Callinectes sapidus) are expanding their range northward from the mid-Atlantic into the Gulf of Maine (GoM), where they may cause a variety of ecosystem impacts from competing with non-native crabs to preying on shellfish reefs. Observations of blue crabs in the GoM spiked following a decade of unprecedented warming. This study uses crowdsourced observations of blue crabs to: (1) evaluate potential drivers of blue crab expansion into the GoM in the past two decades and (2) to quantify the rate of this expansion. Crowdsourced data combines observations from many sources and enables us to model abundance across a wider geographic range than any single survey. However, crowdsourced data requires rigorous bias correction. We use a Bayesian modeling approach to account for sampling bias in crowdsourced observations. We hypothesize that the model will predict a strong effect of year, indicating rapid expansion, in addition to significant effects from both degree death days (cumulative temperatures below 3°C in the wintertime), sediment type, and depth. We anticipate that the model presented here will serve as a tool to forecast further range expansion into the GoM.

Keywords: Blue crab; range expansion; Gulf of Maine; species distribution model; crowdsourcing

Forecasting Highly Pathogenic Avian Influenza using Mallard Dynamics

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Highly Pathogenic Avian Influenza (HPAI) reached Canada in 2021, causing ongoing mortalities in a wide range of avian and mammal species. Waterfowl have been particularly affected. In contrast, mallard ducks have a high tolerance to HPAI and are suspected to drive HPAI dynamics through their seasonal migration and behaviors. Using mallard observations from eBird, and HPAI data from Canada's Interagency Surveillance Program for Avian Influenza Virus in Wild Birds, we developed a short-term forecasting model that uses mallard relative abundance to predict HPAI mortality dynamics in waterfowl. First, we modelled weekly estimates of mallard relative abundance using an adaptive spatiotemporal model. Using this relative abundance, we then conducted a wavelet coherence analysis to quantify the time lag between mallard dynamics and HPAI detections in waterfowl. We found an annual, recurrent relationship with mallard relative abundance leading HPAI outbreaks by around 4-8 weeks. Finally, we created ARIMA models using lags of 4-8 weeks to generate short-term forecasts and used a rolling window approach to compare them to two baseline models. We found that a second order autoregressive model with mallards lagged at 5 weeks was the optimal model to forecast HPAI mortality in waterfowl. We show that mallard duck dynamics can be useful for HPAI forecasting and could provide advanced warning of high-risk periods of outbreaks in waterfowl.

Keywords: Avian influenza, HPAI, Forecasting, Wildlife Surveillance

Geoengineering the Climate: Modeling the Effects of Stratospheric Aerosol Injection on the Distribution of Disease Vectors and Public Health Risk

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Solar radiation modification, particularly through stratospheric aerosol injection (SAI), has been proposed as a strategy to offset global warming. However, its potential impacts on climate-sensitive disease systems remain poorly understood. In this study, we assess how SAI-driven climate changes may alter the spatial distribution of disease vectors of public health importance in Mexico, in comparison with a conventional climate change scenario (SSP2-4.5). We use a unique, high-resolution dataset derived from a National Atlas of Infectious Diseases, consisting of georeferenced records of vectors with confirmed pathogen presence. These include

mosquitoes associated with dengue, triatomines transmitting Chagas disease, ticks linked to Lyme disease and rickettsiosis, and phlebotomine sandflies responsible for leishmaniasis. Using a spatially explicit Bayesian modeling framework, we integrate these occurrence data with climate projections under both SAI and SSP2-4.5 scenarios to estimate changes in environmental suitability, depending on species-specific ecological niches. Our approach explicitly accounts for uncertainty and enables probabilistic inference of species-specific responses to altered temperature and precipitation regimes. Preliminary results indicate heterogeneous and vector-specific shifts in potential distributions under SAI, differing in magnitude and spatial pattern from those projected under SSP2-4.5. These findings highlight that climate geoengineering interventions may reshape the geography of vector-borne disease risk in complex ways. Incorporating eco-epidemiological responses into the evaluation of climate intervention strategies is essential to anticipate unintended public health consequences and inform decision-making.

Keywords: Solar Radiation Modification, Vector-Borne Diseases, Bayesian Spatial Modeling, Climate Change, Public Health Risk

Identifying the role peak productive days and/or growing season length play in the inter-annual carbon cycle variability of globally distributed drylands

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The mechanisms driving inter-annual net terrestrial carbon cycle variability are not well understood. This is particularly the case for dryland ecosystems given their unique biophysical and biogeochemical processes that respond to and regulate water availability. Drylands are ecologically complex and varied across the globe, making up 40% of the world's terrestrial surface. While studies have recently demonstrated that drylands are a dominant contributor to global net carbon (C) fluxes; to better understand what is driving the inter-annual variability there is a need to examine which intra-annual periods of carbon flux are responsible. Two such intra-annual periods to consider are 1) days within the year that are the most productive (i.e., peak C flux days) and 2) the length of the carbon uptake period (i.e., the growing season). Using data from flux towers provided by Fluxnet Shuttle, the number of peak productivity days and the length of the growing season within a given year were quantified for a globally distributed range of dryland sites. The strength of the relationships between the number of days for each process and the annual total net and gross CO2 fluxes were quantified to ascertain the relative importance of each. Overall, it seems that peak flux days better explain annual CO2 flux variability compared to growing season length. A more accurate understanding of the inter-annual variability of dryland carbon cycling can help to improve the performance of process-based dynamic vegetation models, climate change projections, and eventually, assessments of climate solutions.

Keywords: Carbon fluxes, Drylands, Peak Productivity Days, Growing Season

Integrating generative AI into Log-Gaussian Cox Process species distribution models to help forecast emerging disease threats

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Emerging wildlife diseases present a serious threat to the health of animals, the wider environment, and even humans. These diseases can negatively impact our agriculture, economy, and national security. Understanding where there is high risk from new emerging wildlife diseases is crucial for stakeholders making policy and management decisions. To accurately model disease risk spatially, we need to understand where susceptible species are located at different times of the year. However, in the rapidly changing emerging disease landscape, the species of interest can also change rapidly. This presents challenges for species distribution models (SDMs), since the consensus view is that expert knowledge of the biology and ecology of the target species is necessary to accurately model its distribution, but gathering this knowledge from subject matter experts on a quickly changing list of target species is not feasible. We propose using a generative AI researcher agent to assist in this effort. We developed a general SDM framework with a log-gaussian Cox process backbone to produce forecasts of species presence and associated spatial uncertainty surfaces across the continental United States. We tested implementations of this framework on multiple species, comparing the performance of SDMs fit using covariates selected by species experts with SDMs fit using covariates selected by our AI researcher agents that reviewed relevant scholarly articles on the target species. Our results will offer insights into the feasibility of utilizing AI agents to help rapidly generate SDMs for various target species that incorporate expert knowledge of relevant species biology and ecology.

Keywords: Species distribution modeling, Spatial modeling, Uncertainty, Generative AI, Log-Gaussian Cox process

Lightning-Driven Wildfire Risk and Forest Loss in Six Rivers National Forest

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Forest ecosystems are critical for maintaining biodiversity, stabilizing soils, and regulating hydrological processes, yet they are increasingly threatened by wildfires and prolonged drought.

Six Rivers National Forest in Humboldt County, California, is particularly vulnerable due to dense biomass, dry summer conditions, and forests dominated by coast redwood (Sequoia sempervirens), Douglas fir (Pseudotsuga menziesii), and tanoak (Notholithocarpus densiflorus). This study applies remote sensing and geospatial analysis to investigate patterns of forest loss and wildfire activity, with an emphasis on lightning-induced fires. Forest loss data from Hansen et al., wildfire perimeter and severity data from CAL FIRE and MODIS burned area products, and environmental indicators including the Palmer Drought Severity Index (PDSI) and Normalized Difference Vegetation Index (NDVI) were integrated to evaluate spatial and temporal relationships between wildfire severity and forest degradation.

Results indicate strong spatial overlap between areas of high wildfire severity and observed forest loss. Analysis of wildfire ignition sources reveals a pronounced shift in fire causation over time, with lightning becoming the leading ignition source in Six Rivers National Forest after 2000. This shift suggests increasing vulnerability to climate-driven ignition processes rather than primarily human-caused fires. Although machine learning models have not yet been implemented, these results establish a strong empirical foundation for future predictive modeling. Identifying lightning as a dominant driver of wildfire-related forest loss highlights the importance of integrating ignition source data with vegetation and drought metrics to support proactive forest management and wildfire mitigation under changing climate conditions.

Keywords: Remote Sensing; Wildfire Severity; Lightning-Induced Fires; Forest Loss; Climate Change

A Digital Twin of a German Agricultural Landscape for Forecasting Avian Populations

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Ecological forecasting in agricultural systems is challenged by strong seasonality, spatial interactions, weather variability, heterogeneous land use, and management interventions such as mowing, harvest, and pesticide applications. We present a simulation-based digital twin of a German agricultural landscape that integrates these processes within a spatially explicit and controllable framework. The simulation represents heterogeneous fields, crop rotations, weather conditions, and management events, and generates daily population dynamics of farmland bird species across space and time.

The framework is designed to capture key characteristics of agricultural ecosystems while producing synthetic datasets with known underlying processes. It includes species with contrasting temporal patterns, from resident birds with year-round presence to migratory birds with seasonal occurrence, enabling the analysis of how shared environmental conditions can lead to different population responses. The resulting spatio-temporal datasets provide a

controlled basis for studying avian population dynamics and for evaluating ecological forecasting models under known environmental and management conditions.

The poster presents the structure of the digital twin, the ecological processes and simulation parameters it represents, and the resulting data products. It illustrates how such simulation environments can support ecological forecasting by providing controlled testbeds for method development, workflow validation, and later transfer to observational biodiversity data.

Keywords: digital twin, ecological forecasting ,spatio-temporal simulation, synthetic ecological data, population dynamics

Forecasting the Impacts of Climate Change on Coastal Ecosystems and Sustainable Tourism in the Caspian Sea Region

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Coastal ecosystems of the Caspian Sea are increasingly exposed to climate-driven variability, sea-level fluctuations, altered precipitation regimes, and intensified anthropogenic pressures. These dynamics threaten biodiversity, ecosystem services, and the socio-economic sustainability of communities dependent on eco-tourism and coastal livelihoods. This study investigates the coupled impacts of climate change and human activity on coastal ecological integrity and sustainable tourism development in the Caspian Sea region.

The research employs an integrated ecological forecasting framework that combines remote sensing analysis, climate projection scenarios, ecosystem service assessment, and sustainability indicators. Using predictive ecological modeling and scenario-based simulations, the study evaluates potential trajectories of habitat condition, biodiversity distribution, and tourism capacity under varying climate and management pathways. Particular emphasis is placed on identifying early-warning indicators of ecosystem degradation and assessing the resilience of coastal habitats under adaptive governance strategies.

In addition, environmental accounting tools are incorporated to quantify trade-offs between conservation priorities and tourism-driven economic development. Stakeholder-informed governance models are examined to assess how ecosystem-based management and community participation can enhance adaptive capacity and long-term sustainability.

Findings highlight that proactive ecological forecasting, when integrated with policy planning and participatory management, can significantly reduce environmental risk while supporting climate-resilient tourism strategies. By linking predictive ecological science with governance and socio-economic planning, this study provides actionable insights for policymakers, conservation

practitioners, and regional planners seeking to balance environmental protection with sustainable development in vulnerable coastal systems.

Keywords: Ecological Forecasting, Climate Change Impacts, Coastal Ecosystems, Sustainable Tourism, Ecosystem Services

What can long-term data show us about uncertainties in forest models?

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One of the most important priorities for improving forecasts of forests is understanding what processes dominate uncertainty in forecasts. One way to incorporate data and process uncertainty into predictions is to iteratively test forest models against data from real forest stands. This entails generating an ensemble of model runs across parameter values and input data and iteratively stopping those model runs, checking how well the ensemble of model runs agrees with observed data, adjusting the ensemble to be consistent with observed data, and restarting the ensemble. Each of these steps presents a non-trivial technical and ecological challenge that is tailored to the specific model that is being run and the site that is being modeled. For instance, generating a reasonable ensemble of model runs for data assimilation to act on requires detailed parameterization of all present species as well as the disturbance history of the site and updating the model state requires understanding how each state variable is updated and interconnected in the model's internal logic. We have set up a data assimilation framework to run the forest model LPJ-Guess with observed above ground biomass from Harvard Forest in Massachusetts, USA. We found that generating a reasonable ensemble requires incorporating a detailed understanding of the disturbance history of a site and successful adjustments to above ground biomass in the system require adjusting not only the biomass of individuals but also the density of individuals within each cohort.

Keywords: Data Assimilation, Forest Modelling

Bayesian Modeling Approach for Forecasting Eastern Equine Encephalitis Virus in Horses

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Eastern Equine Encephalitis virus (EEEV) is a mosquito-borne alphavirus that causes a rare but potentially severe neurological disease in horses and humans.

Despite a considerable amount of EEE published research, forecasting of EEE, particularly in horses, remains limited due to sporadic, strong environmental heterogeneity, and climate-sensitive, non-stationary transmission dynamics.

In our study, we applied Bayesian generalized nonlinear models to characterize the relationship between environmental factors and equine infection risk. The modeling framework accounted for zero-inflated, temporally structured outcomes and nonlinear covariate effects, enabling probabilistic inference under high uncertainty. We fit a zero-inflated negative binomial distribution to manage overdispersion, structural zeros, and rare event counts. Seasonal patterns were modeled using harmonic functions with varying numbers of Fourier components. Temporal dynamics were evaluated using autoregressive terms, lagged counts, exponentially weighted moving averages, positivity rates, and year-specific random intercept. Among the candidate models, a specification integrating two seasonal harmonic components and a harmonic long-term trend provided the best predictive performance, yielding the lowest prediction error (RMSE = 0.45, MAE = 0.12).

The proposed Bayesian framework provides a flexible approach for forecasting rare EEEV outbreaks and identifying environmental drivers associated with equine infection risk.

Keywords: Eastern Equine Encephalitis virus, equine, Bayesian generalized nonlinear models, zero-inflated counts, time series

Functional outlier detection for air quality forecasting: identifying anomalous PM2.5 daily patterns and their predictive value for special air quality statements in Ontario

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Air pollution poses significant public health risks, with elevated PM2.5 concentrations linked to adverse respiratory and cardiovascular outcomes. Accurate detection of anomalous pollution episodes is critical for timely environmental forecasting and early warning systems. This work applies functional data analysis to continuous PM2.5 monitoring data in Ontario, treating daily concentration profiles as functional observations to capture their full temporal structure.

We compare several depth-based outlier detection methods — spanning shape, magnitude, and amplitude anomalies — under simulated heterogeneous contamination scenarios, evaluating their robustness and sensitivity across diverse outlier compositions. We then apply insights from the simulation to hourly PM2.5 concentrations observed across Ontario. Detected and classified

functional outliers are linked to Special Air Quality Statements (SAQS) issued by Air Quality Ontario between 2023 and 2024, allowing us to assess the predictive value of anomalous PM2.5 profiles for regulatory air quality events.

Our findings offer a principled, data-driven framework for integrating functional anomaly detection into ecological forecasting, with implications for air quality surveillance and robust inference.

Keywords: Outlier detection, Statistical Depth, Functional Data, Air Quality

Integration of SEEA Ecosystem Accounting with State-and-Transition Simulation Models for Policy-Oriented Coastal Ecosystem Forecasting: A Case Study of Central Java, Indonesia

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Universitas Diponegoro

Recently, the United Nations adopted the System of Environmental-Economic Accounting Ecosystem Accounting (SEEA EA) as a standard for environmental accounting, gaining increasing attention not only in terrestrial systems but also in coastal and marine environments. While the framework is primarily designed to report past ecosystem conditions, there is a growing need to assess how ecosystem values may change under future management scenarios. This study develops an integrated approach to project future ecosystem conditions and values using State-and-Transition Simulation Model (STSM).

The coastal region of Central Java, Indonesia, was used as a case study. Historical land-cover data from 2015 to 2025 were used to parameterize transition probabilities derived from satellite-based classifications. These transitions were then simulated to 2045 under three scenarios: business-as-usual, conservation-oriented management, and development-driven intervention. Scenario assumptions were implemented through a combination of probability-based transitions and area-based management actions.

Preliminary results indicate that coastal dynamics, particularly inundation processes and proximity to settlements, play a significant role in shaping mangrove trajectories. Conservation-oriented scenarios show increased potential for mangrove expansion, while the business-as-usual scenario reflects persistence of historical land-use patterns. The integrated framework further enables the translation of simulated land-cover changes into monetary ecosystem values, allowing comparison of long-term economic implications across scenarios.

This study demonstrates the potential of integrating STSM with SEEA EA to support forward-looking ecosystem accounting, providing a basis for policy evaluation and coastal management planning.

Keywords: Ecosystem Accounting, Coastal, STSM, Scenario Modelling, LULC

An AI-Driven Decision Support System for Integrated Surveillance and Avian Influenza Outbreak Risk Prediction

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The increasing complexity of infectious disease dynamics highlights the need for integrated and proactive surveillance systems. Current approaches to avian influenza monitoring often rely on a limited set of data sources and focus on confirmed cases, which can delay detection and limit the ability to respond in a targeted way. This gap motivates the need for systems that combine multiple sources of information and provide a more complete view of how outbreak risk develops over time and across regions. In this work, we present an AI-driven Decision Support System (DSS) for spatiotemporal disease modeling, developed using avian influenza surveillance in Canada. The system integrates diverse data sources, including environmental factors, historical outbreak records, and online activity, to support more timely and reliable outbreak risk assessment.

The proposed DSS is structured around three main components. A digital surveillance module analyzes online activity to capture early signals that may indicate changes in outbreak risk. A spatiotemporal risk prediction module models geographic variation in outbreak risk by combining environmental and epidemiological data. These outputs are brought together in an interactive dashboard that presents both descriptive patterns and predictive insights in a user-centered interface. Preliminary findings show that combining digital signals with spatiotemporal analysis can help identify early changes associated with increased outbreak risk, often before official reports become available. Overall, the system is designed to support policymakers and emergency responders by enabling more informed, timely, and targeted decisions for managing AIV outbreak risk.

Keywords: Decision Support System, Disease Modeling, Avian Influenza, Spatiotemporal Surveillance, Social Media Analytics, Public Health AI

Energy first: Using thermodynamics to forecast consequences of environmental change on size and energy balance in birds

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Coincident with biodiversity loss and climatic warming, vertebrates across the globe are declining in average body size, and despite decades of investigation, the causes and future implications of these declines (i.e. for individual and species persistence) are yet unresolved. Using a novel Price Equation, we recently showed that contemporary size declines in birds are predominantly plastic in origin. However, whether this plasticity is driven by changes in local climate or resource access remains unknown; so too do its implications for energy balance within individuals. To address these gaps, we derived the first base-principles model – rooted in thermodynamics – describing how environmental temperature shapes the mature body size of individuals to balance energy budgets in active, thermoregulating animals. After validating this model against existing data, we use it to predict how avian body size will respond to future climate and resource-change scenarios. We then assess: (i) how such changes alter energy allocation within individuals and among species, (ii) which physiological process (e.g. activity, thermoregulation) present energetic bottlenecks in these scenarios, and (iii) what the risks of energetic disequilibrium and death are if size remains unchanged (i.e. simulating a plasticity limit). Together, our model offers a new perspective on the consequences of current and future environmental change for endothermic species, specifically, by highlighting outcomes for energy flow.

Keywords: Energetics, Environmental Physics, Physiology, Body Size, Plasticity

Causal modelling of a freshwater ecosystem: many-to-one and one-to-many

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Reliable ecological forecasting requires not just predictive accuracy, but an understanding of the mechanisms generating observed patterns. While machine learning approaches have become popular in ecological modelling, they are primarily predictive and do not inherently recover causal structure. Without an explicit causal framework, such models may misrepresent ecosystem drivers and offer limited guidance for management, where effective interventions depend on understanding cause and effect.

We present three case studies demonstrating how Convergent Cross Mapping (CCM) and Bayesian Networks analysis can construct directed causal networks as the foundation for mechanism-informed forecasting.

The first examines a "one-to-many" scenario: how water residence time (RT) influences multiple freshwater quality indicators in Lake Kinneret. CCM-derived networks integrated with Pearl's causal mediation framework disentangle direct and indirect pathways. Exploration by the climate

regime reveals how RT effects shift across environmental conditions, with implications for forecasting under climate change.

The second addresses a "many-to-one" scenario: the collapse of Peridinium gatunense blooms in Lake Kinneret after 1995. CCM identifies candidate drivers, Extended CCM captures temporal causal structure, and Bayesian network analysis explores plausible ecological scenarios. Proteomics and metabolomics data ground the causal structure in physiological mechanisms. The third introduces CEcBaN, a generalizable CCM-based causal Bayesian network framework, demonstrated across three processes: nitrification, phytoplankton succession, and heat transfer to surface water.

Together, these cases illustrate a workflow that moves beyond correlative forecasting toward models capable of anticipating ecosystem responses to perturbation and management.

Keywords: Freshwater; Causality; Ecosystem; CCM; Bayesian Network

Comparing carbon flux dynamics in forest and grassland ecosystems

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Understanding how ecosystems exchange carbon with the atmosphere is important for predicting how the effects of climate change, such as drought, will impact future vegetation-atmospheric interactions. Carbon flux, measured as net ecosystem exchange (NEE), shows whether an ecosystem acts as a carbon sink or a carbon source. This study examines how climate disturbances such as drought affect ecosystem carbon flux differently in grassland and forest systems. Using data from National Ecological Observatory Network (NEON) and a set of climate predictors (temperature, precipitation, and drought indices), we compare NEE variation across grassland and forest ecosystem types. Results are expected to show that grasslands are more sensitive to short-term changes in precipitation and temperature, while forests exhibit more complex, multi-layered responses with lower short-term sensitivity but greater vulnerability to severe drought. We plan to examine differences in ecosystem resilience and carbon sink reliability, offering insights for ecological forecasting, and broader applications in understanding carbon cycling under changing environmental conditions.

Keywords: carbon cycle, drought, NEON, climate change, grasslands

Understanding lake ecosystem dynamics using spatial synchrony

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Ecosystem management is subject to increasing challenges under climate change and other anthropogenic stressors, one of which involves untangling and modeling various drivers of ecosystem change. Synchrony can be utilized to identify possible shared drivers between ecosystems at local and regional scales, as coherent behavior can be indicative of shared forcing. Muskegon Lake and Lake Macatawa (MI), two of roughly two dozen drowned river mouth lakes lining the eastern shoreline of Lake Michigan, are separated by approximately 50 km and experience similar regional climate patterns. Management of these unique systems, which play a vital role in tourism, navigation, and habitat, requires understanding the drivers that shape them. Both lakes have been the subject of targeted restoration efforts—Muskegon Lake was recently delisted as a Great Lakes Area of Concern, and Lake Macatawa's Project Clarity has coordinated restoration for over a decade—and long-term monitoring efforts have yielded 13 years of similarly structured seasonal data, including measurements of nutrients, temperature, and chlorophyll a. This study uses correlation to identify periods of coherent behavior between the two lakes. Results show that synchrony varies by season. Surface total phosphorus (TP) levels behave coherently in spring but less so in other seasons, suggesting regional conditions dominate early-season TP dynamics before giving way to localized influences. In contrast, nitrate concentrations are most synchronous in summer, and synchrony in chlorophyll a varies interannually. This approach leverages combined data from both lakes to provide insights that are not readily found in either dataset alone.

Keywords: synchrony; long-term monitoring; inland lakes

A macroecological framework for assessing biodiversity risks under solar geoengineering

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Due to inadequate international efforts to reduce emissions, the likelihood of exceeding the Paris Agreement limits of 1.5°C and 2°C is rising. A temperature overshoot could trigger irreversible changes, including large-scale melting of the Antarctic and Greenland ice sheets. Unconventional methods such as solar radiation management (SRM) are being studied to cool the planet quickly. However, it remains unclear how SRM could affect biodiversity. Here, we adopted a macroecological framework to quantify the impacts of the SRM scenario on the spatial distribution of terrestrial vertebrate species richness. We compiled data for 27,345 species to generate models predicting richness changes under an SRM scenario starting in 2035 and ending in 2070, compared with two mitigation scenarios (SSP2-4.5 and SSP1.2.6). We developed risk metrics to measure the magnitude, speed, and abruptness of species richness loss under SRM deployment across the entire implementation trajectory. If SRM is deployed, it would be associated with earlier and more synchronous emergence of grid cells exceeding a given loss threshold. It would accelerate diversity loss in many tropical regions, including northern and eastern South America, sub-Saharan Africa, South and Southeast Asia, Indonesia, and Australia. The emergence of abrupt changes was patchy and taxon-specific: birds and mammals showed the most spatially extensive responses, whereas amphibians and reptiles exhibited more localized hotspots. Our results suggest that an SRM strategy may exacerbate biodiversity loss among terrestrial vertebrates not only in magnitude but also in speed and abruptness compared with other mitigation scenarios in most tropical regions.

Keywords: macroecology, climate risks, ARISE-SAI, solar geoengineering, climate change