Questionnaire

**ISEM symposium:**

Modelling integrated ecological (physical-ecological-social) systems: Challenges of establishing linkages to and from ecological components

Organizer: Hsiao-Hsuan “Rose” Wang (Ecological Systems Laboratory, Department of Wildlife and Fisheries Science, Texas A&M University, College Station, Texas, USA)

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**Motives and objectives:**

It is widely-recognized that models useful in addressing today’s most pressing environmental problems must be interdisciplinary. Assessment of potential impacts of changes in climate and policy on resilience and sustainability of the system-of-interest usually requires elicitation and integration of knowledge from the physical, biological, and social sciences, as well as from system stakeholders. Challenges associated with the integration of models from different disciplines also are widely-recognized. Existing reviews of these challenges, although excellent, tend to emphasis either technical aspects of integrating sophisticated models based primarily in the physical sciences (e.g., watershed models), or conceptual aspects of integrating human decision-making models based primarily in the social sciences (e.g., agent-based land use models). This symposium will focus on characterizing the nature of linkages to and from the ecological components included in integrated models with regard to (1) number of variables transferred, (2) directionality of transfer (one-way or two-way), and (3) degree of re-scaling of variables during transfer (aggregation and/or disaggregation).

**Instructions:**

Please select one of your studies as an example to answer the questions. Your presentation at ISEM is the preferred, but not necessarily required, example. There is no word limit on your answers, and please feel free use the writing style with which you are most comfortable. As I mentioned in the email, if I cannot understand anything due to my limited knowledge, I will communicate with you. If you would like to provide any materials in addition to the questionnaire (for example, figures, slide presentations), please feel free to email those to me as well.

**Questionnaire:**

Background information

1. Name, affiliation, and email address

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| Ex.: Hsiao-Hsuan “Rose” Wang. Ecological Systems Laboratory, Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas, USA. hsuan006@tamu.edu |
| Your information here: Alexander “Brad” Duthie. Biological and Environmental Sciences, University of Stirling, Stirling, Scotland, UK. |

1. Title of study (if published, please provide complete citation)

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| Ex.: Integrating physical, ecological, and social system components in a model representing impacts of wind-borne pests on producers of cereal grain crops in the Great Plains of the USA. |
| Your information here: Cusack, J. J., **A. B. Duthie**, I. L. Jones, J. Minderman, R. A. Pozo, O. S. Rakotonarivo, S. Redpath, and N. Bunnefeld. The impact of social conflict on sustainable wildlife harvesting. *Submitted*.  Also relevant: **Duthie, A. B.**, J. J. Cusack, J. Minderman, I. L. Jones, E. B. Nilsen, R. A. Pozo, O. S. Rakotonarivo, B. Van Moorter, and N. Bunnefeld. 2018. GMSE: an R package for generalised management strategy evaluation. Methods in Ecology and Evolution. 9:2396-2401 10.1111/2041-210X.13091. |

1. Objective of study

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| Ex.: To assess potential usefulness of a model that integrates the terrestrial life cycle and aeroecology of wind-borne insects (sugarcane aphids) to forecast regional patterns of infestations of field crops (grain sorghum). |
| Your information here: To derive general predictions regarding natural resource management sustainability in the presence of conflicts between stakeholders (in this case, between stakeholders that seek to harvest a resource and stakeholders that lobby for the conservation of the resource). |

1. Brief overview of the structure and dynamics of the ecological component of the integrated system as represented in your model. Please include brief descriptions of the temporal (length of simulations and time step) and spatial (extent and “grain” or “patch” size) scales, as well as the level of detail at which important processes are represented.

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| Ex.: The ecological component represents an area of ≈ 1,750,000 km2 divided into landscape cells measuring 0.5° latitude by 0.5° longitude (≈2500 km2). Simulations are run for 1 year using a daily time step. Within a landscape cell, a prototypical sorghum plant develops (through phenological stages) and grows (leaf area increases) as a function of air temperature. On a sorghum leaf, individual “super-aphids” (each super-aphid represents a cohort of identical individual aphids) develop through pre-reproductive, reproductive, and post-reproductive life stages, with some reproductive super-aphids undertaking a long-range migration. Reproduction, development, and mortality are temperature-dependent. Migration depends on plant phenology, with emigrating aphids dispersed by prevailing winds. Immigration and colonization of landscape cells depends on dispersal trajectories of migrants and the proportion of the potentially colonized cell (the cell receiving migrants) containing growing sorghum. |
| Your information here: The GMSE R package allows for flexible model selection that defaults to individual-based ecological and social components. We use GMSE to develop general social-ecological theory on how conflict affects population management, rather than modelling a specific social-ecological system of interest. In this study, the ecological component is a simple discrete logistic growth model with parameters of population density, carrying capacity, population growth rate, and total harvest (harvest is determined by social aspects of the model). Space is implicit. |

1. Brief overview of the physical component (as done above for the ecological component).

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| Ex.: The physical component consists of a meteorological model (HYSPLIT) developed by the U.S. National Oceanic and Atmospheric Administration (NOAA), which simulates air currents at various elevations above ground surface. The air currents carry and disperse inert particles (super-aphids, aphids are weak flyers) across the landscape cells. The physical component also includes time series of georeferenced (to the centers of landscape cells) minimum and maximum daily temperatures at the soil surface and in the air 2m above the soil surface, which are obtained from the NOAA Air Resources Laboratory. Spatial and temporal scales are the same as in the ecological component. |
| Your information here: Our model is a social-ecological model, and no physical processes such are explicitly simulated. |

1. Brief overview of the social component (as above).

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| Ex: The social component consists of geographically-aggregated (within landscape cells) groups of sorghum farmers who determine planting dates and type of sorghum to plant (lower-producing, aphid-resistant varieties or higher-producing, non-resistant varieties). |
| Your information here: The social component of our simulation models a situation of conflict between stakeholders. Social interactions include three separate parties: a manager of the population responsible for setting policy, harvesters, and conservationists. Managers attempt to keep the population of a managed species at some defined target density. This target, however, can be influenced by both groups of stakeholders through lobbying pressure. Harvesters seek to decrease the manager’s target and thereby increase harvesting quotas, while conservationists attempt to increase the manager’s target to decrease harvesting quotas and ultimately increase population density. Harvesters can also engage in illegal activity to increase their harvesting. Decision-making of managers and stakeholders is modelled through the use of an evolutionary algorithm to mimic goal-oriented human behaviour. Each stakeholder has some budget available to engage in actions, and acts in a way to further their own goals. Social and ecological conditions affect manager bias and harvester illegal activity. |

Linkages among ecological, physical, and social system components

1. Types of linkages (physical to ecological, ecological to physical, ecological to social, social to ecological) and number of variables transferred.

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| Ex.: Physical to ecological (5), ecological to physical (1), ecological to social (0), social to ecological (2). |
| Your information here: Physical to ecological (0), ecological to physical (0), ecological to social (3), social to ecological (3). |

1. (1) Variables transferred from physical to ecological component, including units of measure associated with each variable as it leaves the physical component and as it enters the ecological component.

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| Ex.: Individual super-aphids (or fractions thereof) are transferred from the meteorological model to landscape cells (potentially) each day. Minimum and maximum temperatures (°C) at the soil surface and in the air 2m above the soil surface are transferred to each landscape cell each day. |
| Your information here: No physical component to the model exists, so there is no transfer between physical and ecological components. |

1. (2) If rescaling during transfer is involved, describe how this is accomplished, noting important assumptions and sources of uncertainty associated with the rescaling process.

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| Ex.: Numbers of super-aphids are rescaled, temperatures are not rescaled. The number of super-aphids transferred on any given day to any given cell within the ≈ 1,750,000 km2 landscape is extremely small (on the order of 1x10-13). This small number is rescaled to equal 1 super-individual, which is assigned a cohort size of 1 reproductive aphid. That is, if colonization of the landscape cell is successful, we assume that 1 reproductive aphid colonizes the leaf of the prototypical sorghum plant in that cell. Field data on numbers of aphids initially colonizing sorghum fields do not exist. Aphids have an extremely high biotic potential and, unchecked, population levels can exceed economic thresholds for pesticide application within a few days. Thus, given the uncertainty associated with the probability of successful colonization on any given day and the potential for rapid population growth post-colonization, the precise number of aphids involved in the initial colonization is relatively unimportant in terms of its effect on model behavior. |
| Your information here: No rescaling occurs. |

1. (1) Variables transferred from ecological to physical component (described as above for physical to ecological transfers).

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| Ex.: Individual super-aphids are transferred from landscape cells to the meteorological model (potentially) each day. |
| Your information here: No variables transferred from ecological to physical component. |

1. (2) If rescaling during transfer is involved, describe (as above for physical to ecological transfers) how this is accomplished.

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| Ex.: No rescaling is involved. |
| Your information here: No transfer occurs, so no rescaling occurs. |

1. (1) Variables transferred from ecological to social component (described as above).

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| Ex.: No variables are transferred. |
| Your information here: Social and ecological components of the model are integrated, so no transfer is required. Some variables (e.g., population density) affect both social and ecological dynamics, but social and ecological components of the model make use of the same variables in the code. |

1. (2) If rescaling is involved, describe (as above) how this is accomplished.

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| Ex.: Not applicable. |
| Your information here: No rescaling is used or required. |

1. (1) Variables transferred from social to ecological component (described as above).

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| Ex.: Planting date (day of year) and type of sorghum planted (aphid-resistant or non-aphid-resistant) are transferred from each geographically-aggregated (within landscape cells) group of sorghum farmers to the corresponding landscape cell in the ecological component. |
| Your information here: See above – social and ecological components are integrated, so no transfer of variables is required. Some social components do affect both social and ecological dynamics (e.g., manager target population density), but the same variables within the code are used. |

1. (2) If rescaling is involved, describe (as above) how this is accomplished.

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| Ex.: No rescaling is involved. |
| Your information here: No rescaling is involved. |

Knowledge sources and model operationalization (computerization)

1. How would you characterize the knowledge bases upon which you drew to conceptualize the different components (physical, ecological, social) of your integrated model? That is, for each component, to what extent did you draw upon theory, data, and/or expert opinion (theoretical knowledge, empirical knowledge, and/or experiential knowledge)?

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| Ex.: Physical component: The meteorological model is based on theoretical and empirical knowledge. Temperatures are based on empirical knowledge. Ecological component: Reproduction and development of aphids and phenological development and growth of sorghum are based on empirical knowledge. Aphid migration, immigration, and colonization are based on experiential knowledge. Social component: Planting date and type of sorghum planted are based on empirical knowledge. |
| Your information here: The social component is based on knowledge of game theory, agent-based modelling, and evolutionary algorithms. The ecological component is based on foundational theory in population ecology. |

1. How did you (would you) operationalize (computerize) your model?

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| Ex.: We programmed the ecological and social components within the same spatially-explicit, individual-based modeling platform (NetLogo). We linked the ecological component to the physical component (the meteorological model HYSPLIT) via a customized algorithm that supports a daily dialog between NetLogo and HYSPLIT. |
| Your information here: Simulations are performed using the GMSE package in R (https://confoobio.github.io/gmse/). The code for GMSE is written in a combination of R and C. The model also integrates some custom R coding and makes use of the flexibility of GMSE’s `gmse\_apply` function. Social aspects of the model are agent-based, with a discrete number of stakeholders. Ecological aspects of the model are numerical. |