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What do tigers and backswimmers have in common? an analysis of structure and sensitivity in individual-based models

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Abstract

The sensitivity of outputs and structures of different individual-based models were compared across two different predator-prey systems; Panthera Population Persistence (PPP) and Backswimmer-Daphnia (Notonecta IBM) . The PPP model is spatially explicit, whereas in the food-uptake-submodel of the Notonecta IBM, distances are empirically included in differential equations. Both models differ significantly in their complexity and detailedness of process description. The PPP considers 29 parameters, whereas the backswimmer submodel (in its curent state) includes 8 parameters and is less complex. Extensive sensitivity analyses using improved Morris methods (PPP model) and/or the One Factor At A Time (OAT) screening technique (backswimmers) reveal that, in both models, the foragung radius is the most important factor beside all other factors and processes considered. A review of publications presenting various prey-predator models confirms this as a general pattern. The results suggest to carefully consider spaces within foraging models, independent of predator-prey-system and model type.

Keywords: predator-prey interaction; foraging radius; functional response; population persistence, ecological models

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1. Main text

Predator-prey interaction is one of classical ecological issues that has been extensively described by mathematical models and increasingly simulated by means of spatially-explicit, computer models. Current development in Individual-based model has opened new opportunities for testing the suitability of both theory and practical conservation in predator-prey system (Grimm, 1999). In the study presented, the structure and sensitivity of two individual-based models (IBMs) were compared across two different predator-prey systems: (1) the Panthera Population Persistence (PPP) model describing the dynamics of Sumatra tigers and their preys, and (2) Notonecta IBM model describing the interdependent dynamics of the backswimmers *Notonecta maculata* foraging on their zooplankton prey *Daphnia magna.* Both models differ significantly in the key aspects of predation behaviors and interactions which they describe as stochastic processes. Changes in the states of predators or prey that trigger the behaviors and interactions are considered in a dynamic manner appropriate to these changes.

The PPP model is a spatially explicit individual-based model to project the persistence of Sumatran tiger using parameterization of Tesso Nilo national park on Sumatra island. The model simulates the main behavior of tigers such as moving, foraging, reproduction and territorial defense (Imron et al., 2010). The sub-model simulates two different prey species; small and large prey. Both prey types are simulated through movement and reproduction behavior. Individual tigers are able to detect prey, mates, other individuals and environmental conditions, which leads to changing states in individual which behaves accordingly. The number of tigers and prey as well as the intrinsic time to extinction was measured for analyzing the persistence of population.

The Notonecta IBM was designed to assess food dependent population dynamics during larval development of the backswimmer *Notonecta maculata*. Within the model framework the uptake of food by juvenile specimens, foraging their zooplankton prey, is quantified by means of a mechanistic, process based submodel (Gergs & Ratte, 2009). The submodel describes the foraging process empirically on the base of a general predation cycle including four conditional events (encounter, attack, capture success, handling) instead of using classic functional response curves. Distances between predator and prey are empirically included in differential equations. For model parameterisation components of predation were directly observed by means of video experiments. Independent data of functional response and size selectivity experiments were used for model validation and proved the model outcome to be consistent with observations.

We used the *improved Morris* method (Compologo et al., 2007) which provides qualitative sensitivity measures, ranking the input factors in order of importance (Saltelli et al., 2004) for the PPP model. The number of tigers and prey were sensitive to hunting radius. The number of tigers was highly variable at a hunting radius from 100 m to 1,000 m and became unsurprisingly more stable at hunting radius > 1,000 m. The total number of prey was found to be sensitive to hunting radii smaller than 800 m, and was relatively stable at 900 m or higher. Since individual growth of *Notonecta* is a function of daily food uptake, sensitivity analysis is restricted to the foraging submodel in the Notonecta IBM. Due to its low complexity, sensitivity is assessed by means of the *One Factor At a Time* (OAT) screening technique for the Notonecta IBM. Preliminary evaluation suggested that encounter distance (at low prey densities) and handling time (at high prey densities) are among the sensitive foraging parameters. Sensitivity analyses reveal that measures of foraging distances are sensitive factors affecting the outcome of two independent individual-based models.

Our study shows that regardless of the particular model structure, the output of both models is very sensitive to the distance of prey detection. Other modeling studies available in literature support this finding and reveal that this is a general pattern. Thus any predator-prey systems should carefully considering space between individuals.

2. References

Gergs, A. & Ratte, H.T., 2009: “Predicting functional response and size selectivity of juvenile Notonecta maculata foraging on Daphnia magna”, *Ecological Modelling*, 220, pp 3331-3341.