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Editorial: Integrating models into practice: the role of modelling in biocontrol and integrated pest management

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Editorial on the Research Topic

Integrating models into practice: the role of modelling in biocontrol and integrated pest management

Motivation

Theoretical models have historically benefitted several applied fields, for example the use of matrix models in conservation management (Benton and Grant, 1999; Ezard et al., 2010; Hunter et al., 2010), the use of individual based models in fisheries (Baskett et al., 2005; Bastardie et al., 2010; van Kooten et al., 2010; Irigoien and de Roos, 2011; Persson et al., 2014), and the use of disease models in management of contagious diseases such as COVID, SARS and HIPV (Yusuf and Benyah, 2012; Rodrigues, 2016; Mokhtari et al., 2021). As such, applications of theoretical models in biocontrol can aid in implementing new control measures and highlight its economic value in Integrated Pest Management (IPM) systems. For example, they can contribute to cost-benefit analyses, highlight long-term efficacy of potential measures and predict areas of climactic compatibility for potential biocontrol agents (Furlong and Zalucki, 2017; Li et al., 2019; Janssen and van Rijn, 2021; Minuti et al., 2022). The formulation of models to describe the dynamics of pests and natural enemies in a biocontrol and IPM setting have a long history (Bernstein, 1985; Nachman, 1987; Bancroft and Margolies, 1999; Barlow et al., 1999; van Rijn et al., 2002; Janssen and van Rijn, 2021; Kotula et al., 2021; Cacho and Hester, 2022). However, IPM models have largely been predator-prey population models (*e.g.*, van Rijn et al., 2002; Janssen and van Rijn, 2021) and so the full potential and benefit of existing models has rarely been realised (but see Li et al., 2019). Moreover, once created, models are often not utilized by researchers in determining effective biocontrol or IPM in a field setting (Barratt et al., 2018) and this gap between theoreticians and researchers has remained largely unchanged. Another challenge to bridging this gap is making mathematical arguments more verbal and explaining counterintuitive results. Attempts have been made to construct simplified models that would avoid some of the concerns raised, with some studies showing simplified models to be successful (Moerkens et al., 2021).

Given this, we identify two challenges. First, improve the collaboration and engagement between theoretical ecologists and applied researchers and stakeholders that actively promote IPM adoption. Second, when these groups are engaged, there is a need to demonstrate the potential contribution of theory to effective application and adoption within the context of an IPM program. As such, this Research Topic contains a set of theoretical and perspective contributions that aim to highlight the use of novel modelling approaches that can contribute to addressing these challenges.

Novel modelling approaches

Being poikilotherms, the behaviour and life-histories of arthropod pests and their natural enemies and their interactions are strongly affected by temperature. Climate change may therefore result in changes in predation of pests and predation among natural enemies (intraguild predation). In their contribution, Laubmeier et al. study this, using a model with allometric scaling and temperature dependence based on body size. They based their model on the aphid *Rhopalosiphum padi* and their predators, consisting of several species of spiders and ground beetles in barley fields in Sweden. Their model includes growth and decline of aphids, but of their much slower population growth rate, the authors only model decreases in predator densities due to lack of food or intraguild predation. The model predicts optimal predator communities for aphid control, which consists primarily of Lycosid spiders but often include ground beetles. This is not only because this combination of predators attack aphids over a larger temperature range, but also because intraguild predation is reduced since the predators are active at different temperature ranges. The authors recommend that farmers should preserve resident spider populations and promote larger species of ground beetles, which are active at lower temperatures. This could be done by releasing them through reduced tilling or the installation of beetle banks.

Adoption of conservation biological control strategies in agriculture has been compromised by the failure of researchers to consider the economic implications of this technology (Johnson et al., 2021). Parry reports the development of a spatially explicit bioeconomic simulation model to demonstrate that conservation of appropriate non-crop vegetation can have better long-term outcomes for reducing yield loss than pesticide-based regimes in intensively cropped landscapes. Currently, most decisions that determine pest management practice are based on cost and ease of adoption, risk aversion and evidence of short-term economic or yield gains (*e.g.*, Lagerkvist et al., 2012; Gong et al., 2016). Although the longer-term detrimental environmental and economic impacts of excessive pesticide use are often considered, farmers face numerous barriers to the behavioural changes required to reduce reliance on these chemicals (Andersson and Isgren, 2021) and legislation can be required to break these down. Consequently, studies such as this are key to achieving wider adoption of conservation biological control in agriculture as they can incentivise abandonment of counterproductive practices such as reliance on pesticides and the destruction of non-crop habitat in agricultural landscapes.

The perspective piece by Wyckhuys et al. highlights how the use of key natural laboratories (*i.e.*, islands and altitudinal ranges of mountains) have yet to be adopted in the field of biological control research (but see Guzmán et al., 2016). The authors utilise existing published datasets to determine how biological control outcomes are impacted by island size and altitudinal range. Several components such as species' functional traits and anthropogenic forces, in addition to island size explain biological control outcomes. So too with altitudinal range, successful biological control is species- and context- dependent with changing altitude. Wyckhuys et al. emphasise that field-level data from these under-utilised natural laboratories are required to parametrise mechanistically based simulation models to highlight the impact of biocontrol under global climate change.

Future considerations

Successful biocontrol requires close collaboration and information sharing with stakeholders (Barratt et al., 2018; van Lenteren et al., 2018). Regardless of the modelling approach, implemented iterative improvements to biological control and integrated pest management (IPM) programs can only be made if follow-up assessments are conducted to identify impacts and model effectiveness (Seastedt, 2015). Importantly, assessments must include quantitative indications of the effectiveness of biocontrol or IPM measures which have been sorely lacking in the field (Clewley et al., 2012). This would not only provide a useful indicator for the end user but also allow researchers to build long term, useable data sets that can be used to improve their models. In turn, additional discussions can be had with stakeholders regarding improved/adjusted models, potentially benefiting the stakeholder in the long term. As for the economic implications of biocontrol, the application of models and ultimately the costs involved will differ when considering greenhouse or open field systems, as the challenges and obstacles faced by growers differ between these systems (Tracy, 2014). Currently there are fewer models for open field systems than for greenhouses, hindering efficient assessment of economic implications of biocontrol in open field systems. The question then arises, how can future economy-based models be utilised to identify the difference, and scale, in economic implications between the two systems? Finally, pest control is the strategic application of interventions to modify the population dynamics of the target pest, and agricultural systems are ideally suited to test basic population-dynamical theory. The rich tradition of mathematical models inspired by pests and natural enemies (*e.g.*, Murdoch et al., 1985; May and Hassell, 1988) shows that biocontrol has found its way into theoretical population biology decades ago. It is high time that the reverse path is shaped into a highway, to do so requires the adoption and effective application of theoretical insights by end users and stakeholders who drive the use of biocontrol measures.

Author contributions

JD and AJ wrote the first draft of the article. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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