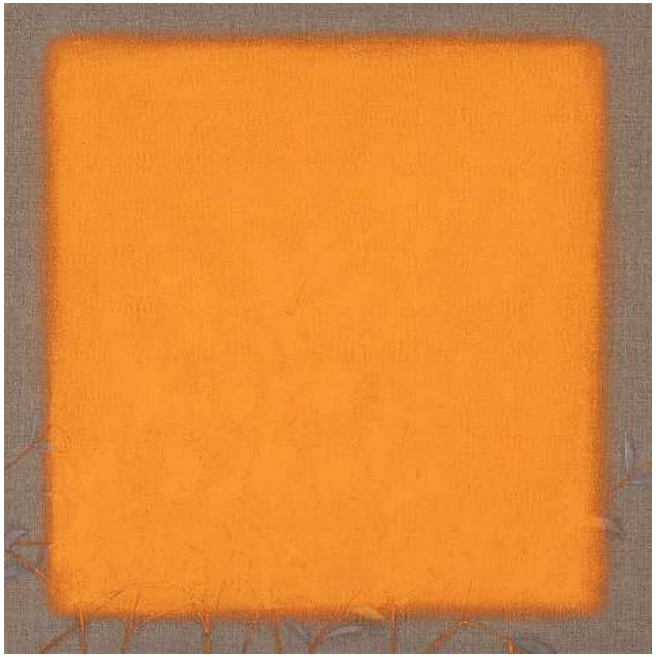
Agent-based modeling: From manifestos to manifestations



Volker Grimm

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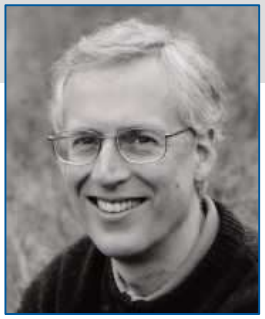
Acknowledgements

- **Steve Railsback**
  Humboldt State University



- **Uta Berger**
  Technische Universität Dresden

- **Department of Ecological Modelling at Helmholtz Center for Environmental Research–UFZ, Leipzig**

Can we get beyond manifestos?

"I was one of the people who got all excited about the possibility of getting somewhere with very detailed agent-based models — but that was 20 years ago. And after all this time, it's all still manifestos and promises of great things one of these days."

Paul Krugman, Nov. 30, 2010, in response to an article about INET housing project in Wall Street Journal.

State of the art 1999

Review by angry (relatively) young man:

Ten years of individual-based modelling in ecology: what have we learned and what could we learn in the future?

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Abstract

Each modeller who builds and analyses an individual-based model learns of course a great deal, but what has ecology as a whole learned from the individual-based models published during the last decade? Answering this question proves extremely difficult as there is no common motivation behind individual-based models. The distinction is introduced between 'pragmatic' motivation, which uses the individual-based approach as a tool without any reference to the theoretical issues which have emerged from the classical state variable approach and 'paradigmatic'

State of the art 1999

- Most IBMs driven by pragmatic considerations, not by theory
- Model design usually ad hoc, no general design concepts
- No specific methods used to cope with model complexity
- Model analysis very limited
- No testable predictions
- No culture of verification and validation

State of the art 2016

We are getting there …

Ecological Modelling 326 (2016) 177–187

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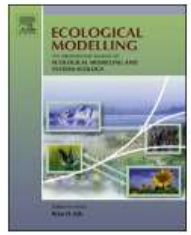

Structural realism, emergence, and predictions in next-generation ecological modelling: Synthesis from a special issue

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Emergence

ABSTRACT

The two main challenges of ecological modelling are to yield more general understanding and theory and to provide testable and robust predictions. To achieve this, emergence, structural realism, and prediction have to become key elements of designing models. In the special issue "Next-generation ecological modelling", which is dedicated to Donald DeAngelis on the occasion of his 70th birthday, 16 contrib-

Dream of a new systems science

Science of
Agent-based Complex Systems (ACS)

Complements and develops *Complex Adaptive Systems* science:

- **ABMs as a central tool**
- **Focus on adaptive behaviour of agents, not of systems**
- **Resilience emerges from adaptive behaviour of agents and their interactions**

ABMs and IBMs used everywhere!

Why a new science of ACS?

- Adaptive agents everywhere
- Their behavior emerges from adaptive decision making
- Their decisions are based on their model of the world, which has evolved or been learned
- General principles of selforganization and resilience emerge from agents‘ behaviours
- Observe patterns at multiple scales and levels of organisation

The first thing we need is a common language

The next thing we need is a plan for how to learn more from our models

The ultimate thing we need is theory

The first thing we need is a common language

Lessons from bibliometric analysis

Emergence of ACS science across disciplines is fostered by/requires:

- **Describing our models in a common language (currently: ODD protocol)**
- **Avoiding ad hoc design of models but use generic design principles instead (currently: POM and ODD)**
- **Reviews across disciplines to identify general questions and principles (Young folks: write more reviews!)**

The common language of ODD

ECOLOGICAL MODELLING 198 (2006) 115–126

available at www.sciencedirect.com

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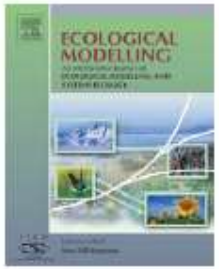
journal homepage: www.elsevier.com/locate/ecolmodel



A standard protocol for describing individual-based and agent-based models

Volker Grimm[a,*], Ut
Jarl Giske[c], John Gos
Andreas Huth[a], Jan
Guy Pe'er[i], Cyril Pio
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The ODD protocol: A review and first update

Volker Grimm[a,*], Uta Berger[b], Donald L. DeAngelis[c], J. Gary Polhill[d], Jarl Giske[e], Steven F. F

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ODD 2006/2010

	Elements of the original ODD protocol (Grimm et al. 2006)	Elements of the updated ODD protocol
Overview	1. Purpose	**1. Purpose**
	2. State variables and scales	**2. Entities, state variables, and scales**
	3. Process overview and scheduling	**3. Process overview and scheduling**
Design concepts	4. Design concepts • Emergence • Adaptation • Fitness • Prediction • Sensing • Interaction • Stochasticity • Collectives • Observation	**4. Design concepts** • Emergence • Adaptation/Adaptive traits? • Objectives • Learning • Prediction • Sensing • Interaction • Stochasticity • Collectives • Observation
Details	5. Initilization	**5. Initialization**
	6. Input	**6. Input data**
	7. Submodels	**7. Submodels**

Current usage of ODD

60% (or so) of ABM papers in ecology are using ODD

JASSS, OpenABM recommend ODD …

Current usage of ODD

- **Way too sloppy**
- **A standard is standard is a standard, damn it!**

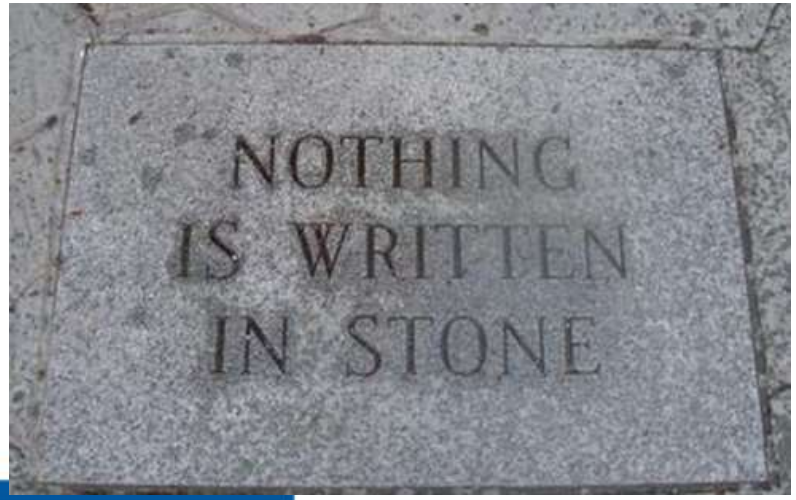
- (Should we offer training/certifications of ODDs?)
- **Describe what the program is doing, not what you think it does!**
- **Take Design Concepts S-E-R-I-O-U-S, they determine the quality and usefulness of your work**

ODD Limitations – ways forward

- **Words are ambiguous**
  - ODD alone not sufficient
  - Programs alone not sufficient
  - Need to link ODD to snippets of code
    - a la DoxyGen?
    - Hyperlinks
  - Need permanent repositories for programs (e.g., OpenABM, github, etc.)
- **ODD cannot be run on computers**
  - ODD is for people, not for computers
  - Translate ODD into code stubs and vice versa?

Future of ODD

- ODD was expected to **change and develop** once enough people used it and provided feedback
- This is exactly what happened (See ODD update, Grimm et al. 2010, **Birgit Müller** et al. 2013, **It-Could-Be-You** et al. 20XX).
- Next update planned this years



The next thing we need is a plan for how to learn more from our models

It’s about modelling, not models

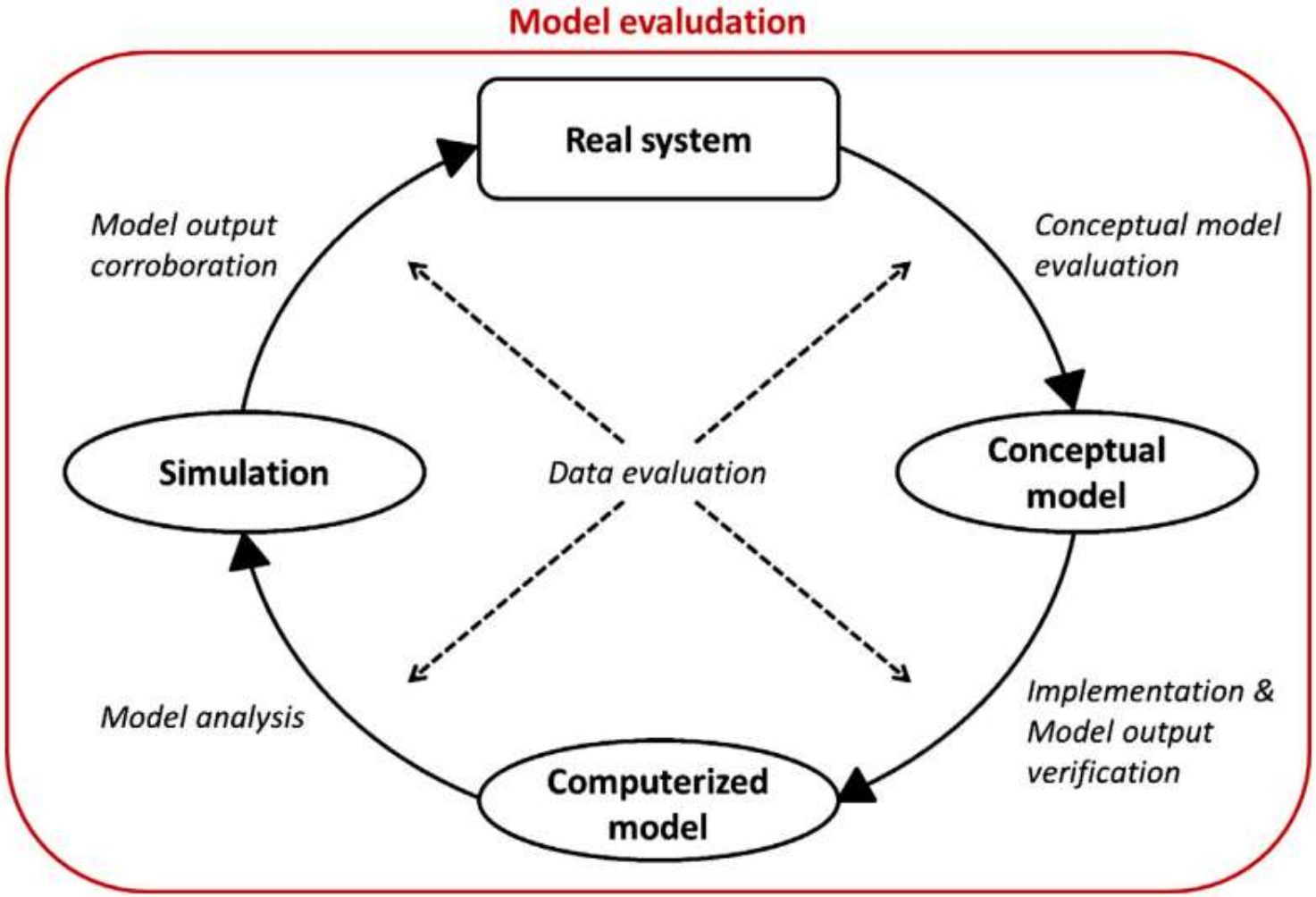
David O‘Sullivan (input to ABM 17 position paper):

“any modeling method is **most useful to the model-builder because of what is learned in the process of building and refining the model**,

but the ways in which models are **communicated scientifically** (often dominated by pre/postdiction and goodness of fit of some ‘final’ model) **do not unlock what was learned in the process of developing and exploring the model**.”

What modellers do ..

J. Augusiak et al. / Ecological Modelling 280 (2014) 117–128



… and what they often finally report

<Take any results section that just shows a time series or a few maps representing scenarios, which is not bad per se, but insufficient to learn from the model.>

TRACE AND EVALUDATION

EVALUDATION (=Evaluation + Validation):

'The entire **process** of establishing model quality and credibility throughout all stages of model development and application' (Augusiak et al. 2014)

TRACE:

- A standard format for organizing and documenting the elements of model evaludation
- Documenting to what degree and how well modelling practice was followed
- A checklist for modellers
- Provides a common terminology

TRAnsparent and **C**omprehensive model **E**valudation

Review

Cell PRESS

Ecological models supporting environmental decision making: a strategy for the future

Amelie Schmolke[1], Pernille Thorbek[2], Donald L. DeAngelis[3] and Volker Grimm[1]

[1] UFZ, Helmholtz Centre for Er
Germany
[2] Syngenta, Environmental Sa
[3] USGS/Biological Resources D
USA

Ecological models are in
decision support because t
of alternative policies and
explored. However, curren
tisfactory. A literature revie
good modeling practice ha

Ecological Modelling 280 (2014) 129–139

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ELSEVIER

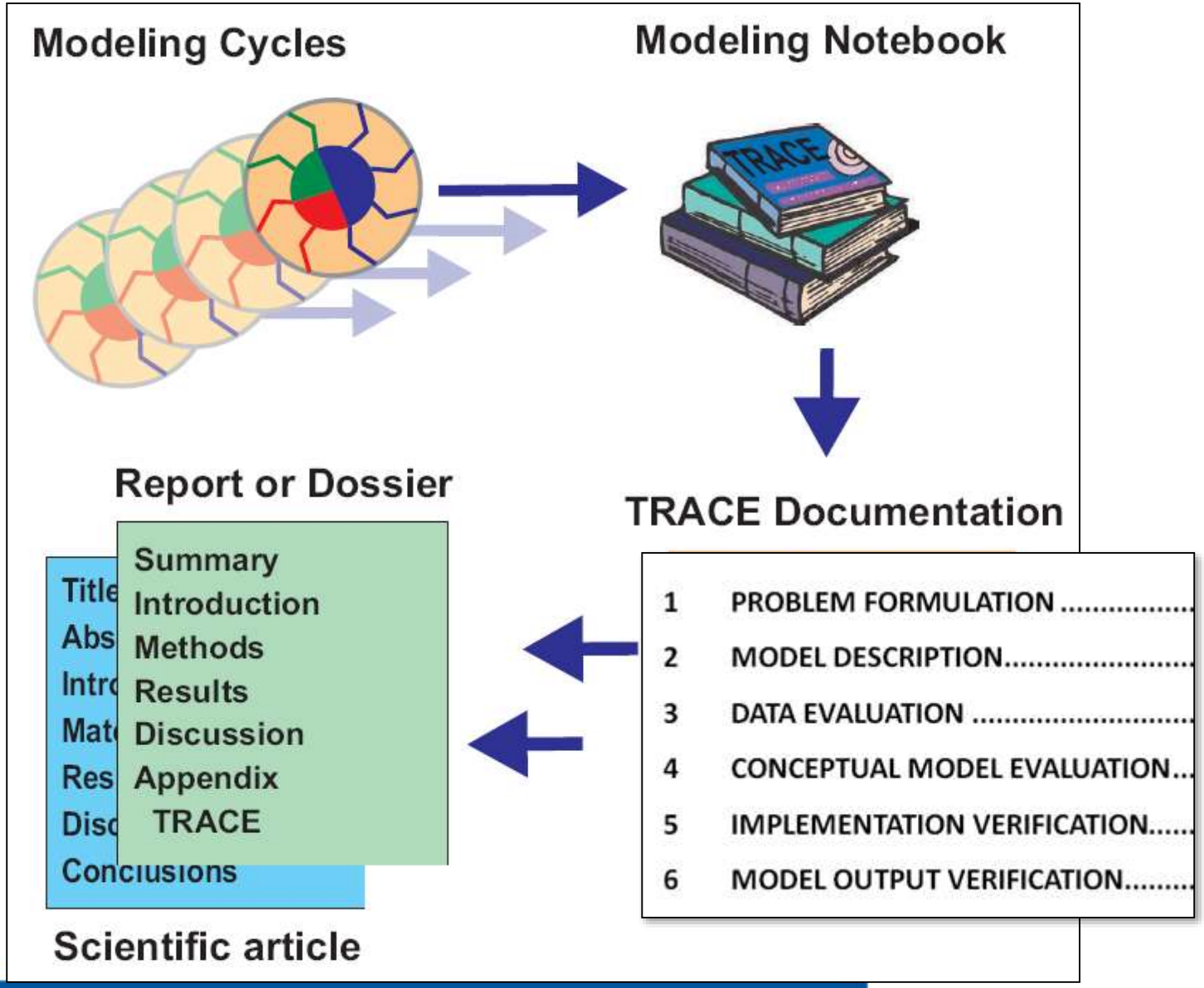
Towards better modelling and decision support: Documenting model development, testing, and analysis using TRACE

Volker Grimm[a,b,c,*], Jacqueline Augusiak[d], Andreas Focks[d], Béatrice M. Frank[e], Faten Gabsi[f], Alice S.A. Johnston[g], Chun Liu[g,h], Benjamin T. Martin[a,i], Mattia Meli[j], Viktoriia Radchuk[c,e], Pernille Thorbek[h], Steven F. Railsback[k]

TRACE TEMPLATE

Contents

BENEFITS FOR INDIVIDUAL MODELLER



TRACE use

In your paper you refer to the TRACE document:

“In the Supplementary Material, we provide a TRACE document (“TRAnsparent and Comprehensive model Evaludation”; Schmolke et al. 2010; Grimm et al. 2014; Augusiak et al. 2014) containing evidence that our model was thoughtfully designed, correctly implemented, thoroughly tested, well understood, and appropriately used for its intended purpose. A summary of the TRACE document is given in Table <..>.”

TRACE use

- **ODD used a lot**
  - You have to write a model description anyway
  - No extra effort
- **TRACE used by a few only**
  - Extra effort (not that much!)
  - Community benefits will require a certain standard or culture (chicken-egg situation)
  - Direct benefits for modeler still exist!
  - **Do it, try it!**

TRACE element: MODEL ANALYSIS

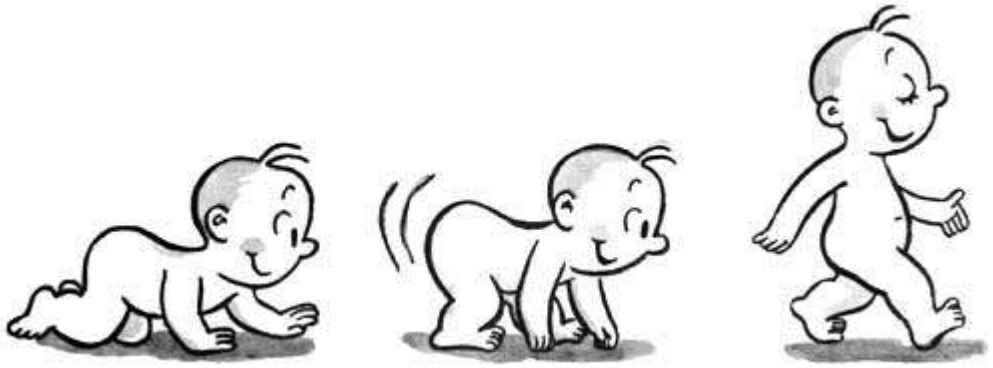
“model performance is potentially sensitive to level of detail as well as stochastic elements, alternative decision models, and representation of spatial structure” (from Li’s draft summary article of ABM 17)

Yes, that’s our job!

Yes, that’s how we learn from modelling!

Do it, communicate it!

The ultimate thing we need is theory



What do I mean by “theory”?

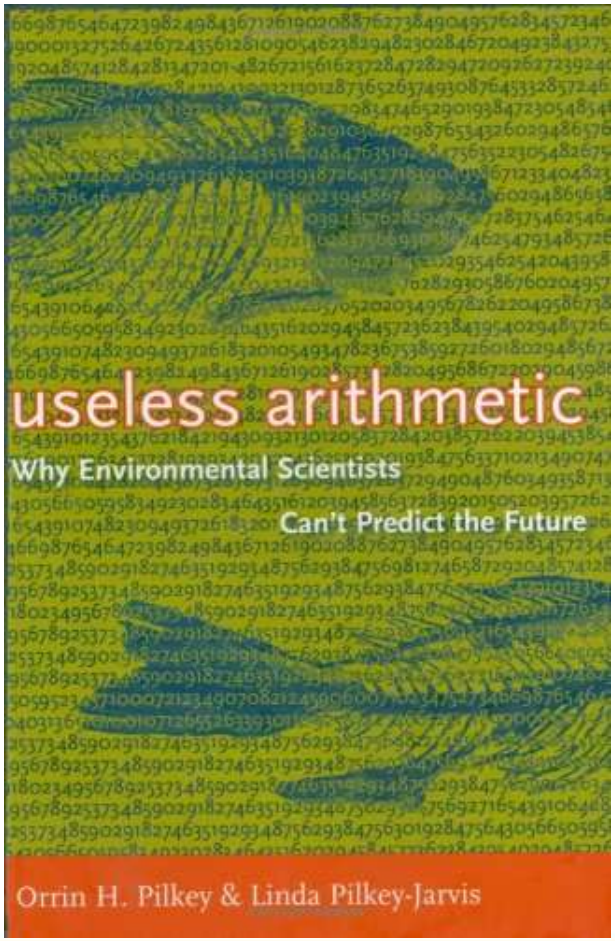
“A scientific theory is a well-substantiated explanation of some aspect of the natural world that is acquired through the scientific method and repeatedly tested and confirmed through observation and experimentation.

… Agent-based modelling?

As used in everyday non-scientific speech, "theory" implies that something is an unsubstantiated and speculative guess, conjecture, or hypothesis; such a usage is the opposite of a scientific theory.” Wikipedia 11.5.2016

Why should modelling aim for theory?

- **To strive for testable predictions**
  - **Not nessarily about the future (rarely possible)**



Why should modelling aim for theory?

- **To strive for testable predictions**
  - **Not nessarily about the future (rarely possible)**
  - **But about patterns in systems‘ organisation and behavior**
- **To identify general principles underlying the organization of ecological systems (resilience, biodiversity)**
- **To find robust practical solutions without needing a new model for each case and question**

'There is nothing more practical than a good theory'.

*Phrase attributed to Kurt Lewin, German-American psychologist, known as one of the modern pioneers of social, organizational, and applied psychology.

Two kinds of theory in ABMs

I. **Theories of individual behavior=submodels that have been shown to predict emerging responses to new conditions**

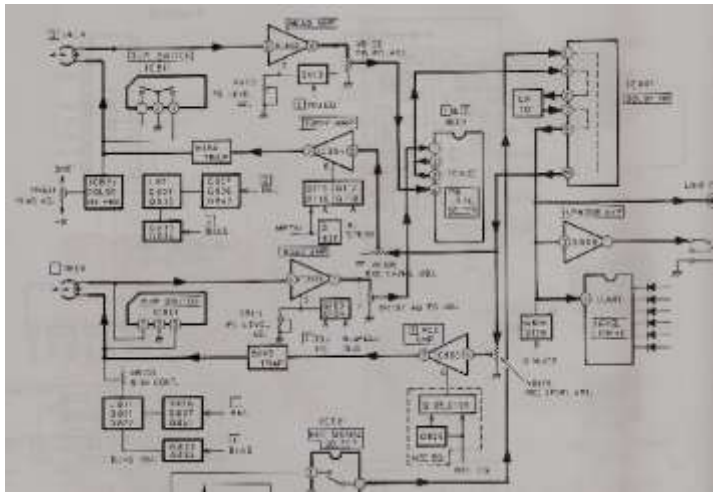
   - **Energy budgets, territorial behavior, habitat selection (trait-based predictive theory: Railsback and Harvey 2002, 2012)**

II. **Theory of Agent-based Complex Systems: emergence, resilience, ontologies**

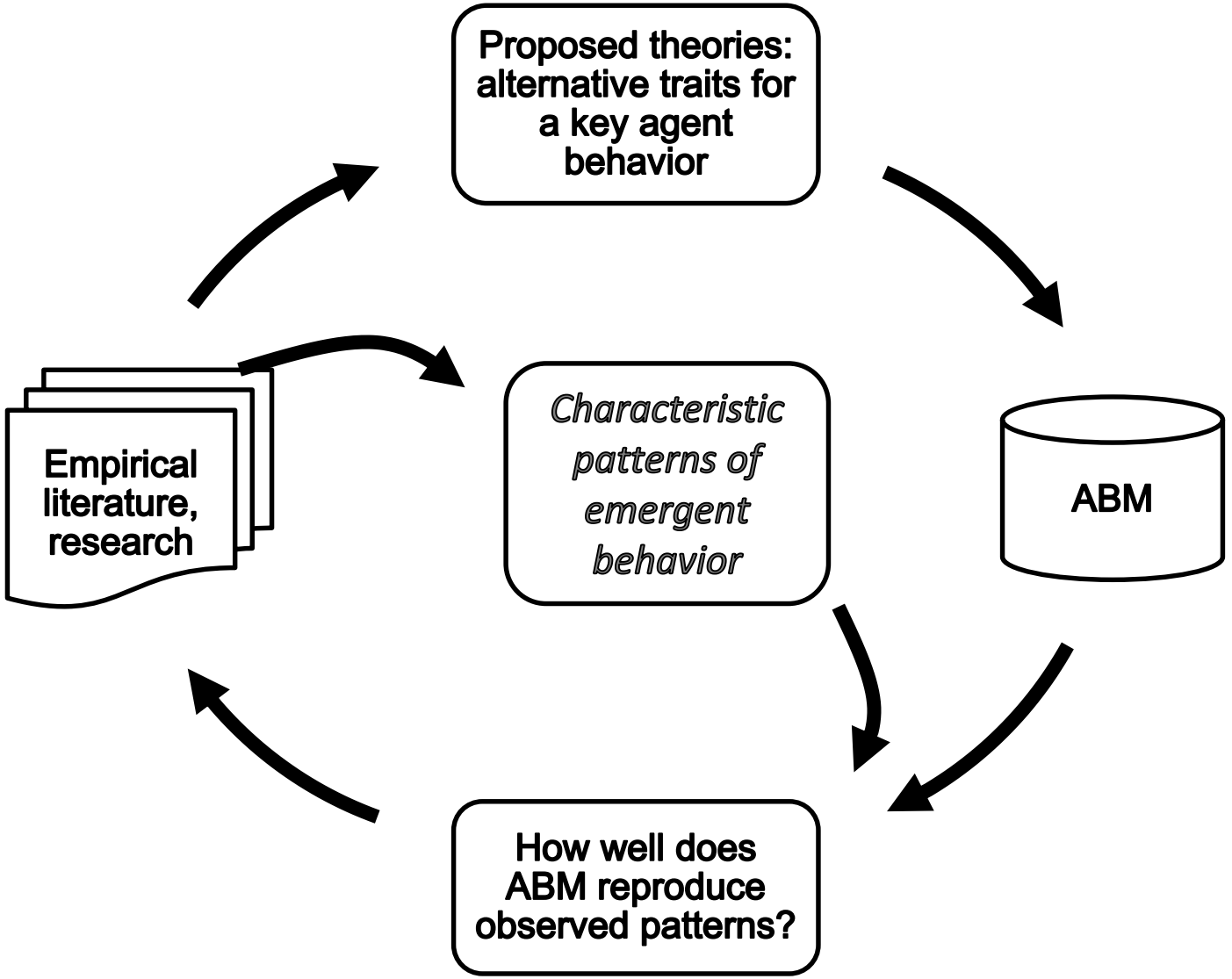
Pattern-oriented theory development

Theory in ACS science is *across-levels*

Theory=models of what *individuals* do that explain *system* dynamics (Capture *enough essence* of individual behavior to model the system)



THEORY DEVELOPMENT CYCLE



EXAMPLE: VULTURES AND CARCASSES

Pattern: # of feeders at a carcass

'non-socia *tures'*

Searcher

Finder

Feeder

Feeder

Feeder

$D_{foll/find\text{-}sear} < D_{foll}$

lower

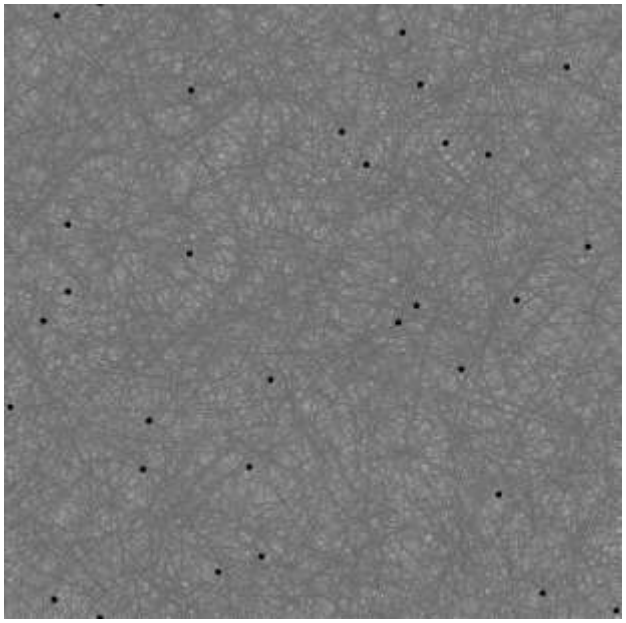
car < D_{occ}

Jackson et al. 2008. Biology Letters 4

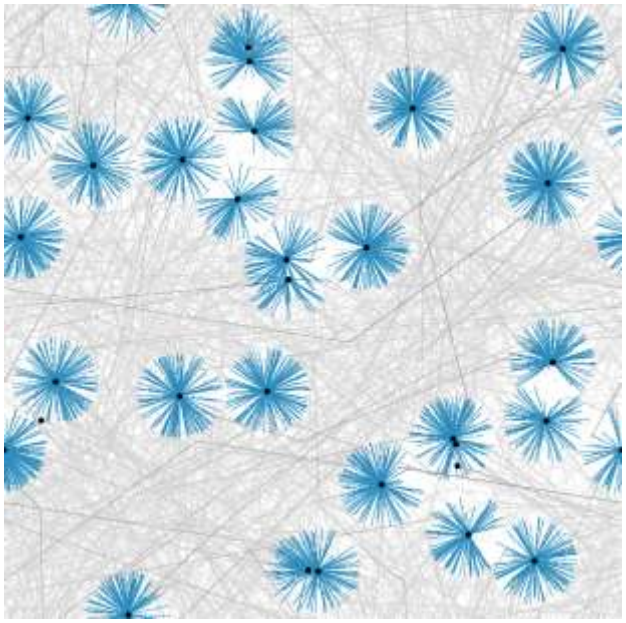
Cortes-Avizanda A, Jovani R, Donázar JA, Grimm V. Ecology (2014)

EXAMPLE: VULTURES AND CARCASSES

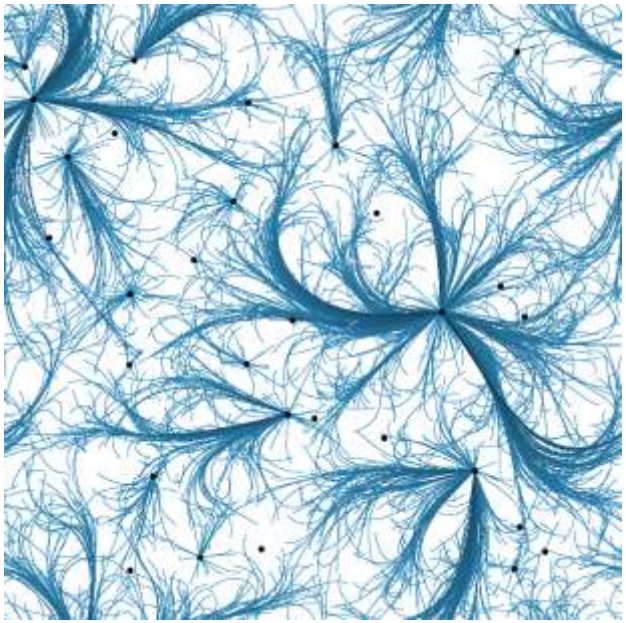
‘non-social



‘local enhancement’



‘chains of vultures’



Cortes-Avizanda, Jovani, Donázar & Grimm. 2014. Ecology.

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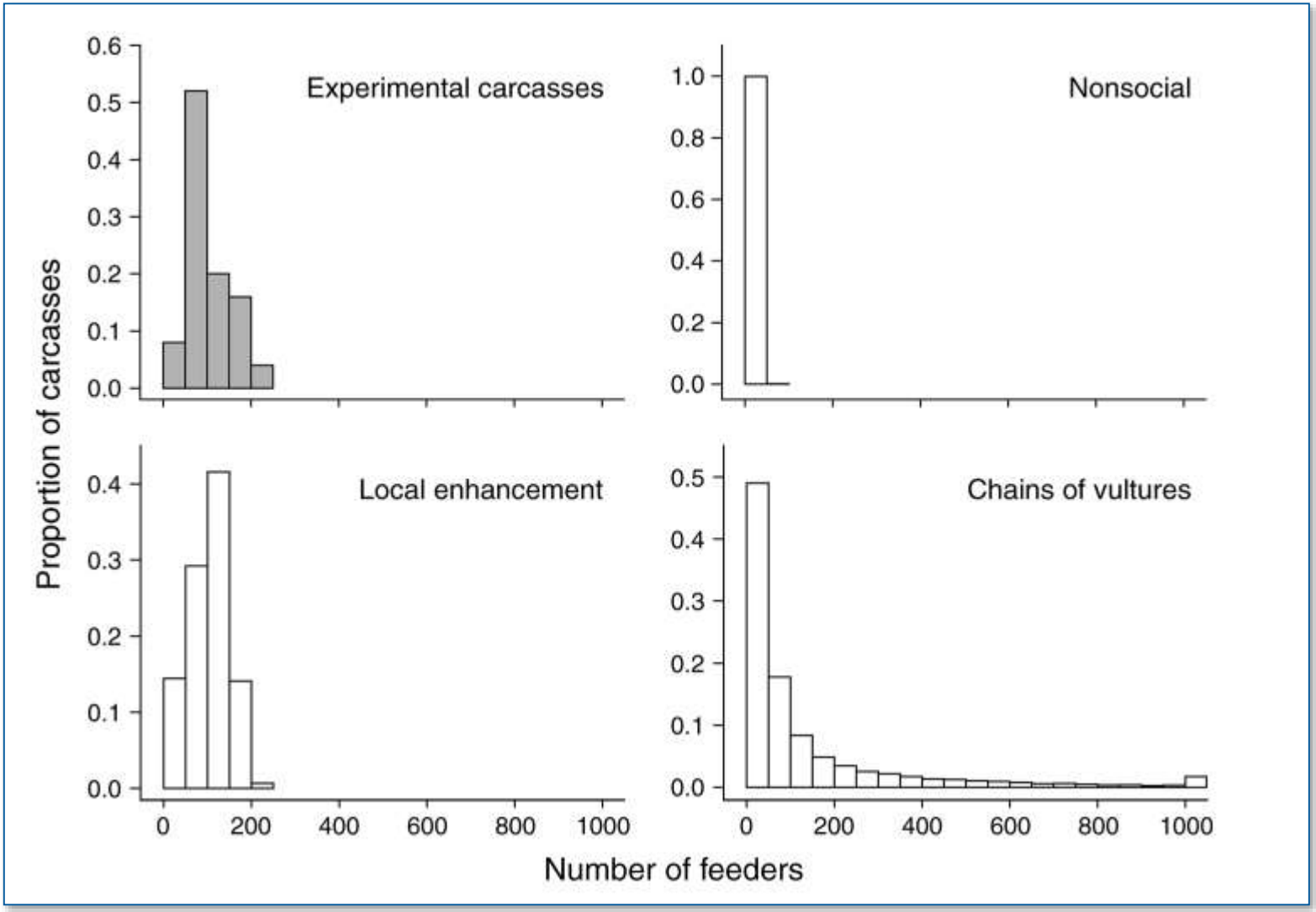

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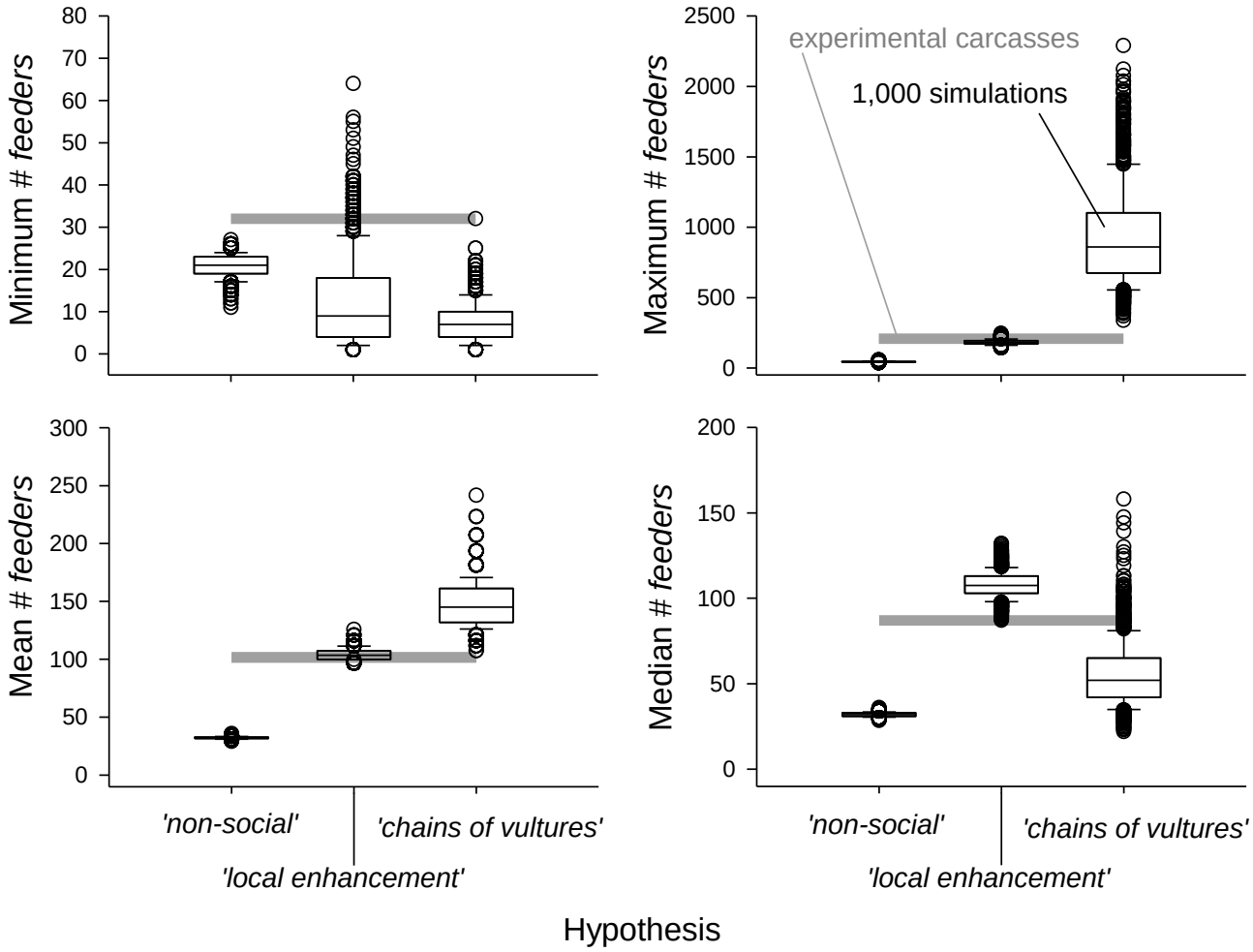

Cortes-Avizanda, Jovani, Donázar & Grimm. 2014. Ecology.

Generic submodels for theory

- Save time
- Tested submodels, known properties
- No need to "defend" everything anew
- Easier to communicate
- Easier to systematically compare models of different systems
- Nothing like this so far in models of human behavior

Complex Adaptive Systems

A complex adaptive system is a "complex macroscopic collection" of relatively "similar and partially connected micro-structures" formed in order to adapt to the changing environment and increase its survivability as a macro-structure. Wikipedia 20.9.2016

Resilience!!

Examples:

Gobal macroeconomic network, stock market, social insect colonies, immune system, brain, ecosystem, biosphere, cells, political parties, internet, …

There must be a general systems theory beyond equilibrium and negative feedbacks

Research program for ACS science

- Detect patterns at all levels and scales (big data, machine learning, whatever is there and cool)
- Use ABMs to reproduce these patterns and constrast alternative theories of behaviors, in particular decision making
- Explore resilience (recovery and resistance) for different
  - Levels of organization
  - State variables
  - Temporal and spatial scales
  - Types of disturbances and changes in drivers
  - Reference states or dynamics
- Integrate findings into lessons about persistence and resilience (which defines „the system“)

Agent-based modeling: From manifestos to manifestations

The first thing we need is a common language

The next thing we need is a plan for how to learn more from our models

The ultimate thing we need is theory

ABMs in 2030: my vision

Established ABMs are used to:

- Assess and manage the resilience of Agent-based Complex Systems (ACS)
- Avoid unwanted regime shifts
- Restore degraded systems
- Support sustainable use of natural resources
- Develop policies and institutions that make this world a better place