# The ODD protocol: a standard format for describing individual-based and agent-based models

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# Lack of standards

- The only complete representation of most ABMs is their **implementation**
- Programs are usually not available, **too specific** (language, platform, operation system), and won‘t run on any computer after a few years
- **No standard format** for documenting and communicating ABMs
- **Limited replicability is the major limitation of ABM as scientific tool**

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# Requirements for a standard format

- Support **written formulation**
- **Easy** to use, **simple** structure, **simple** logics
- **Direct benefits** to those using the standard (never count on altruism in science)
- Make writing and reading model descriptions **easier**
- Support **complete** descriptions and replicability
- **Cover simple and complex** models from **different domains**

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# ODD protocol in 2006

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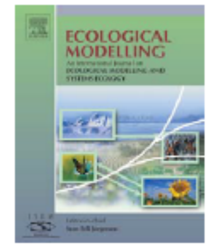


## A standard protocol for describing individual-based and agent-based models

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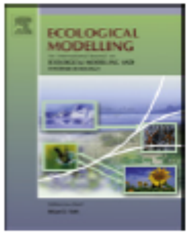


# The ODD protocol: A review and first update

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ABSTRACT

The 'ODD' (Overview, Design concepts, and Details) protocol was published in 2006 to standardize the published descriptions of individual-based and agent-based models (ABMs). The primary objectives of ODD are to make model descriptions more understandable and complete, thereby making ABMs less subject to criticism for being irreproducible. We have systematically evaluated existing uses of the ODD protocol and identified, as expected, parts of ODD needing improvement and clarification. Accordingly, we revise the definition of ODD to clarify aspects of the original version and thereby facilitate future

# The ODD protocol

| | 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<br>• Emergence<br>• Adaptation<br>• Fitness<br><br>• Prediction<br>• Sensing<br>• Interaction<br>• Stochasticity<br>• Collectives<br>• Observation | **4. Design concepts**<br>• Emergence<br>• Adaptation/Adaptive traits?<br>• Objectives<br>• Learning<br>• Prediction<br>• Sensing<br>• Interaction<br>• Stochasticity<br>• Collectives<br>• Observation |
| Details | 5. Initilization | **5. Initialization** |
| | 6. Input | **6. Input data** |
| | 7. Submodels | **7. Submodels** |

# 1. Purpose

*Question*: **What is the purpose of the model?**

# 2. Entities, state variables, and scales

*Questions*:

**What kinds of entities are in the model?**

Agents, collectives, spatial units, global environment

**By what state variables, or behavioural attributes, are these entities characterized?**

Age, sex, wealth, opinion, strategy; soil type, land costs; rainfall, market price, disturbance frequency

**What are the temporal and spatial resolutions and extents of the model?**

# 3. Process overview and scheduling

*Questions*:

**Who (i.e., what entity) does what, and in what order?**

**When are state variables updated?**

**How is time modeled, as discrete steps or as a continuum over which both continuous processes and discrete events can occur?**

Except for very simple schedules, one should use pseudo-code to describe the schedule in every detail, so that the model can be re-implemented from this code. Ideally, the pseudo-code corresponds fully to the actual code used in the program implementing the ABM.

# 4. Design concepts

*Questions*:

There are **10 design concepts**. Most of these were discussed extensively by Railsback (2001), Grimm and Railsback (2005; Ch. 5), and in Railsback and Grimm (2012) and are summarized in the following questions:

**Emergence**

What emerges from the model (rather than being imposed)?

**Adaptation**

How do the agents adapt to improve their fitness? (Directly and indirectly)

**Fitness**

What are the goals of the agents? What determines their survival?

**Prediction**

How do agents predict the consequences of their decisions?

Use of learning, memory, environmental cues, embedded assumptions

**Sensing**

What are agents assumed to know or perceive when making decisions?

Is the sensing process itself explicitly modelled?

**Interaction**

What forms of interaction among agents are there?

**Stochasticity**

Justification for any stochasticity in the model

**Collectives**

Grouping of individuals

**Observation**

How are data collected from the model for analysis?

# 5. Initialization

*Question*:

**What is the initial state of the model world, i.e., at time *t* = 0 of a simulation run?**

In detail, how many entities of what type are there initially, and what are the exact values of their state variables (or how were they set stochastically)?

Is initialization always the same, or is it allowed to vary among simulations? Are the initial values chosen arbitrarily or based on data? References to those data should be provided.

# 6. Input data

*Question*:

**Does the model use input from external sources such as data files or other models to represent processes that change over time?**

# 7. Submodels

*Questions*:

**What, in detail, are the submodels that represent the processes listed in “Process overview and scheduling”?**

What are the model parameters, their dimensions, and reference values?

How were submodels designed or chosen, and how were they parameterized and then tested?

# Example

*2.2.1. Purpose*

The model was designed to predict the probability of small re-introduced populations of wild dogs establishing themselves and persisting in the release area under various scenarios, including regular translocation of disperser groups.

Gusset et al. 2009

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# Example

*2.2.2. State variables and scales*

The three entities included in the model were individuals, packs and disperser groups. Individuals were characterized by their state variables sex, age, social status and pack or disperser group membership. A pack was defined as a reproductive unit (either newly formed or established, see below) that contained a dominant pair, potentially also including pups as well as subordinate yearlings and adults of both sexes. Pups were less than one, yearlings between one and two, and adults more than 2 years of age. A disperser group consisted of one or more same-sexed individuals originating from the same pack. Time proceeded in discrete steps of 1 year. The model was not spatially explicit to make it more generally applicable and because disperser groups are highly mobile; however, space was indirectly included in the model by considering the ecological capacity for wild dogs in HiP (see below).

Gusset et al. 2009

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# Example

*2.2.3. Process overview and scheduling*

The fate of each individual in the population was traced from birth to death. Within each year, the following processes were simulated in the given (biologically meaningful and computationally practical) order for each of the given entities: ageing (individuals), reproduction (packs), dispersal (individuals), pack formation (disperser groups), mortality (individuals), catastrophes (individuals), management interventions (packs and disperser groups) and dominance (packs). Individuals, packs and disperser groups were processed in a randomized sequence every year. The rules defining the above processes are described in Section 2.2.7 below.

*2.2.4. Design concepts*

*2.2.4.1. Emergence.* Wild dog population and pack dynamics emerged from the behaviour of individuals, but individual behaviour was entirely imposed by probabilistic empirical rules. No Allee effects at the pack level were imposed onto the model, as no such effects were observed in the population modelled here (Somers et al., 2008). However, possible Allee effects were allowed to emerge from the model.

*2.2.4.2. Interaction.* Four types of interaction were modelled implicitly: (i) within each pack, dispersing individuals of the same sex formed a disperser group, (ii) formation of a new pack was

# Example

*2.2.5. Initialization*

Simulations started with a specified number of packs and individuals per pack, but no disperser groups. One male and female per pack were randomly selected as dominants. Sex and age of individuals in initial packs was random: the probability of being male was 0.50 and age was uniformly distributed from 1 to 6 years.

*2.2.6. Input*

The model did not include any environmental variables as driving the population, as competitor density, amount of rainfall and prey availability did not significantly influence the population modelled here (Somers et al., 2008). Environmental variation was represented by environmental stochasticity and random catastrophic events.

# Example

*2.2.7. Submodels*

*2.2.7.1. Ageing.* The age of all individuals increased by 1 year. All individuals that reached their observed maximum age of 9 years died (Somers et al., 2008).

*2.2.7.2. Reproduction.* Both males and females could theoretically become dominant and reproduce from 1 to 8 years of age, with only packs that contained a dominant pair potentially reproducing (Somers et al., 2008). The probability of a pack reproducing in a given year was piecewise density-dependent, which best matched the observed linear negative density dependence in population growth rate (Somers et al., 2008). HiP's ecological capacity for wild dogs, based on the availability of the most important prey species, was estimated to be at $N = 62$ (Lindsey et al., 2004), with $N$ being the total number of all adults and yearlings plus half the number of pups. If $N$ was smaller than half of the ecological capacity, a litter was added annually with an observed probability 0.33 to newly formed packs (i.e., in the first breeding season after formation)

# Summary

**ODD is a standard format for describing (and formulating) IBMs/ABMs:**

1. **Overview first, details later**
2. **Design concepts**
3. **Easy to write, easy to read**
4. **Facilitate replication**
5. **Independent from discipline, complexity, operation system, programming language**