Supplementary file S1 to: Grimm, V. et al. (2020) 'The ODD Protocol for Agent-Based and Other Simulation Models: A Second Update to Improve Clarity, Replication, and Structural Realism' *Journal of Artificial Societies and Social Simulation* 23 (2) 7: http://jasss.soc.surrey.ac.uk/23/2/7.html [10.18564/jasss.4259]

S2: Summary ODD

[1]The template below provides guidance for summarizing an existing ODD model description which is too long to be included in the main text of a scientific publication or report, or which is considered too detailed to present the model's underlying story, or narrative, in a comprehensive way. We recommend to always write a full ODD first, ideally read and evaluated by others, before summarizing it.

This template allows for much more flexibility than ODD itself, which has a fixed structure, terminology, and sequence of elements, because it is designed as a standard. However, we suggest to try and keep the same overall sequence here and re-use key words and phrases from the full ODD. Basically, the summary ODD consists of a shortened version of the Overview part of ODD (elements 1 to 3), excluding section titles, plus important Design concepts and those Submodels, which are needed to understand the key processes of the model. Make sure to also describe the underlying rationale for key assumptions and designs of your model, for example whether it (or its parts) was taken from previous models, or related to the patterns the model is addressing. Also aspects of Input Data and Initialization should be included if they are essential for understanding how the model works.

If this condensed ODD still is considered too formal to present the model's narrative, the summary ODD can also start with a summary which is independent of ODD, but then be followed by the elements which are condensed from the full ODD. Please try and use the phrases and words in **bold font** in the template, which will help giving summary ODDs a similar structure. Please keep formatting of ODD's key words in *italics* in the final summary ODD. For clarity, we introduced paragraphs in the template below, but you might link most of them in the final summary ODD.

Example summary ODDs from ecology are provided below.

A complete, detailed model description, following the ODD (Overview, Design concepts, Details) protocol (Grimm et al. 2006, 2010, XXXX) is provided at <Insert link to web repository where you uploaded your ODD>**.**

<Optional: start with a free-form summary: > **The basic idea underlying the model is ...** < …>

The overall *purpose* of our model is … <summarize the corresponding part of the full ODD>.

[1] Lead authors of this supplement: Volker Grimm and Daniel Ayllón

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Specifically, we are addressing the following questions: … <summarize the corresponding part of the full ODD>. **To consider our model realistic enough for its purpose, we use the following *patterns* …** <summarize the corresponding part of the full ODD>.

The model includes the following *entities* … <list entities>**. They are characterized by the following *state variables*/The *state variables* characterizing these entities are listed in Table X: …** <Ideally, present a Table with model entities and their state variables (see Supplement S1 for further guidance). For experienced modellers, such a table provides a good overview of the model's structure and scope>. **The *spatial* and *temporal* resolution and extent are …**

The most important *processes* of the model, which are repeated every *time step*, are ... <Use the sequence of the model's schedule. If possible, use the same self-explaining names, or similar, of the full ODD. Here, in contrast to the full ODD, you would also describe the essentials of these key processes. Exception: for complex submodels, it might be better to present them in some more detail at the end of the summary ODD>.

The most important *design concepts* of the model are ... <List and briefly explain those design concepts, which are essential, most characteristic, and most sophisticated of your model>.

<Optional: list aspects of Initialization and Input data, if they are essential: > **The model is initialized with ...** <Specific initial conditions>. **Model dynamics are driven by *input data* representing ...** <What kind of data, and what processes are they driving? What is the source of the data?>.

<Optional: explain here in more detail submodels that are too complex to be described with one or two sentences in the process overview above: > ***Key processes* in the model are ...** <Refer to each of the processes you want to describe here by the name you used in the overview above, set in italics. Give a verbal summary description, but also include equations if they are essential for understanding.>

Examples

1. Tiger model by Carter al. 2015.

The full ODD is in the main text of Carter, N., Levin, S., Barlow, A., & Grimm, V. (2015). Modeling tiger population and territory dynamics using an agent-based approach. Ecological Modelling, 312, 347-362. This summary ODD was written for this template. Text suggested by the template is underlined to demonstrate the use of the template, but would not be hightlighted in real summary ODDs.

A complete, detailed model description, following the ODD (Overview, Design concepts, Details) protocol (Grimm et al. 2006, 2010, 2019) is provided in Carter et al. (2015). The overall *purpose* of our model is to predict tiger population dynamics to support tiger conservation. Specifically, we are addressing the following question: How does the number, location, and size of tiger territories change in response to habitat quality and tiger density? To consider our model realistic enough for its purpose, we use *patterns* in mortality, age structure, and female territory tenure and overlap of male territories with female territories.

The model includes the following *entities*: tigers, square grid cells of 250x250 m², and territories. The state *variables* characterizing these entities are listed in Table 1. Female territories consist of a set of habitat cells, which the females add to their territory based on prey availability and presence and rank of other females. Male territories consist of a set of up to six female territories, which the males add to their territory based on their spatial proximity and absence or rank of other males. As for the *spatial* and *temporal* resolution and extent: A time step in the model represents one month and simulations are run for 1-20 years. Test simulations were run on landscape of 40x40 and 128x128 cells, while the Chitwan national park required 157x345 cells. Landscape structure in terms of prey availability is assumed to be constant in this model version, but will change in response to human land use in future model applications.

The most important *processes* of the model, which are repeated every *time step*, are the acquisition of territories by dispersing young tigers, and the maintenance of territories by established tigers. Female tigers add grid cells to their territory until they can satisfy their monthly prey requirement. Grid cells can be won from or lost to other females. Male tigers do not strive to add space based on prey availability, but on the availability and location of female territories. They try to overlap up to six female territories, but compete for these with each other, depending on their relative age and rank; the latter depends on the outcome of previous contests. If a female territory is won from another male, infanticide can occur, which can add substantially to juvenile mortality.

The most important *design concept* of the model is the way in which we represented territorial dynamics, in particular the response of females to prey availability, and of males to the distribution of both female and male residents. Thereby we let population structure and dynamics emerge from the prey distribution in the landscape and from overall tiger density.

Table 1. Entities and state variables of the tiger model by Carter et al. (2015).

Entity	Variable	Description	Possible Values	Units
Female	Age	Age in months	1 - 180	Months
	fertile?	Indicates whether female is fertile	True/False	--
	gestating?	Indicates whether female is gestating	True/False	--
	males-in-my-territory	Identities of males overlapping female territory	Set of male identities	--
	my-mom	Identity of mom	Identity of female tiger	--

	my-offspring	Number of offspring in current litter	1 - 5	Individual cubs
	natal-origin	Patch where female was initialized at or the centroid patch of mother's territory	0 - max X, 0 - max Y	Patch units
	num-litters	Total number of litters the female has had up until current time	0 - max number of litters over lifetime	--
	age-class	Indicates development stage of female	Cub, Juvenile, Transient, or Breeder	--
	territory	Set of patches belonging to territory	Set of patch coordinates	--
	terr-orig	Patch that female was initialized at or first patch of territory	0 - max X, 0 - max Y	Patch units
	t-gestation	Indicates how long female has gestated	0 - 3 or 4	Months
	t-parenting	Indicates how long female has been a parent of current litter	0 - 24	Months
Male	Age	Age in months	1 - 180	Months
	dominant-males	Identities of males that have beaten male in challenges	Set of male identities	--
	females-in-my-territory	Identities of females overlapping female territory	Set of female identities	--
	initial-male?	Indicates whether male was created at beginning of simulation	True/False	--
	lost-territory?	Indicates if male lost a territory to a challenger	True/False	--
	male-land-tenure	Total time that male held onto territory	0 - entire breeding phase until death	Months
	my-mom	Identity of mom	Identity of female tiger	--
	natal-origin	Patch where male was initialized at or the centroid patch of mother's territory	0 - max X, 0 - max Y	Patch units
	age-class	Indicates development stage of male	Cub, Juvenile, Transient, or Breeder	--
	territory	Set of patches belonging to territory	Set of patch coordinates	--
Cell	owner-fem	Identity of female with patch in her territory	Identity of female tiger	--
	owner-male	Identity of male with patch in his territory	Identity of male tiger	--
	Prey	Prey produced at patch	0 - max prey production	kg/month
	is-churia?	Indicates whether patch falls within churia hill boundary (Chitwan landscape only)	True/false	--
	is-park?	Indicates whether patch falls within national park boundary (Chitwan landscape only)	True/false	--

2. Trout model by Ayllón al. 2016.

The full ODD is in the supplementary material of [2]Ayllón, D., Railsback, S.F., Vincenzi, S., Groeneveld, J., Almodóvar, A., & Grimm, V. (2016). InSTREAM-Gen: Modelling eco-

[2] The full ODD of this model is included in its TRACE document in Suppplement S6.

evolutionary dynamics of trout populations under anthropogenic environmental change. Ecological Modelling, 326: 36-53. This summary ODD was written for this template.

A complete, detailed model description, following the ODD (Overview, Design concepts, Details) protocol (Grimm et al. 2006, 2010, 2019) is provided in the supplementary material of Ayllón et al. (2016). The overall *purpose* of our model is to understand how environmental conditions and anthropogenic disturbances drive the evolution of demographics and life-history strategies of stream-dwelling trout populations. Specifically, we are addressing the following question: How do trout population demographic and evolutionary dynamics change in response to changes in environmental drivers caused by climate and land use change? To consider our model realistic enough for its purpose, we use *patterns* of habitat selection and population dynamics, including quantitative patterns of age-specific population changes over time and qualitative population-level phenomena (e.g., self-thinning, density-dependent growth). The model's ability to reproduce a variety of patterns in adaptive habitat selection behavior was demonstrated by Railsback & Harvey (2002) and its ability to reproduce observed patterns in population dynamics was demonstrated by Railsback et al. (2002).

The model includes the following *entities*: cells, trout, and redds. The state *variables and attributes* characterizing these entities are listed in Table 2. The global environment (a stream reach) is characterized by water temperature and flow. Cells represent patches of relatively uniform habitat within the reach, and are characterized by both their physical habitat (mean depth and water velocity that are flow-dependent, area of velocity shelter for drift feeding, spawning gravel area, and mean distance to hiding cover), and their production rate of drift and benthic food. Cells are rectangles in the horizontal plane (habitat variability in the vertical dimension is ignored) of nonuniform size and shape. Trout have unique values of body length, weight and condition, and both phenotypic and genotypic values for the heritable traits. Redds are spawning nests made by trout, which have variables for the number and development status of the eggs they contain. Redds also carry the genetic information of the female spawner who created the redd and of the male spawners who fertilized the eggs. As for the *spatial* and *temporal* resolution and extent: A time step in the model represents one day and simulations are run for a length set by the input environmental time series. The model is spatially explicit and describes one reach of a stream, typically a few hundred meters in length. Both spatial extent and resolution are set by the user. The length of the reach simulated in this study is 305 meters, having 220 cells at an average flow, with a total area of 2390 m^2.

The most important *processes* of the model, which are repeated every *time step*, are the update of environmental conditions in the reach and cells' flow-dependent variables, and the following trout actions: (1) All trout select habitat following a size-based dominance hierarchy that gives larger trout first access to food and preferred habitat. In order from largest to smallest, each trout moves to the available cell–within a radius that increases with trout lengththat–maximizes short-term fitness, which is a function of the cell's mortality risk and growth potential; (2) Trout feed and grow according to their food intake and energy costs experienced in their cell, which are calculated through a bioenergetics model; (3) All trout are subject to six natural sources of mortality (high temperatures, high flow velocity, stranding, starvation, predation by terrestrial animals, and predation by piscivorous trout). Only during the spawning (i.e., reproductive) season, mature females spawn if both environmental and internal conditions are met. If so, female trout create a redd and its eggs are fertilized by the largest available male spawner plus a random number of smaller mature males. The number of eggs increases exponentially with female length and also varies inversely with egg size. Egg size increases with the genotypic value of the female's trait for size at emergence. Each redd stores the genetic information of the mother and all contributing males. Redds are subject to egg mortality and surviving eggs develop at a rate that increases with temperature. When eggs are fully developed, they hatch into new trout (emerge) that inherit the redd's traits.

The most important *design concepts* of the model are adaptation, objectives and prediction. Habitat selection is the key adaptive behavior, which is modeled according to the "state- and prediction-based" foraging theory (Railsback and Harvey 2013), an approach that combines existing tradeoff methods with routine updating: when choosing their habitat, trout make a prediction of the future growth and risk conditions offered by each cell over an entire time horizon under different alternative behaviors (e.g., feeding strategy), but each time they update their decision by considering how their internal state and external conditions have changed, so that they can select the alternative optimizing an objective measure called "Expected Maturity" (EM; Railsback et al. 1999). EM represents the expected probability of surviving both predation and starvation over the time horizon, multiplied by a term representing how growth affects fitness. Thus, habitat and feeding-strategy selection strongly drive growth and survival of individuals. Trout are also able to adapt some of their reproductive behaviors to environmental conditions and their own state. Dynamics of population demography and trajectory of life-history and genetic traits thus emerge from the growth, survival, and reproduction of individuals, individual-level processes that are driven by environmental conditions and adaptive decisions.

Model dynamics are driven by input data representing daily time series of water temperature and flow.

A key process in the model is also the transmission of heritable traits. Each new trout inherits its genetic traits from the mother and one father randomly selected from the males that fertilized the redd, with equal probability of fertilization across males. We model the phenotype of an individual as the sum of an inherited additive genetic effect (genotypic value) and a non-heritable environmental effect, being the inheritance rules based on the infinitesimal model of quantitative genetics (Lynch and Walsh 1998).

Table 1. Entities and state variables of the trout model by Ayllón et al. (2016).

Agent	Variable	Description	Unit
Cells	cellArea*	Area of the cell	cm^2

	CellAreaCover*	Area of the cell with cover	cm^2
	cellAreaShelter*	Area of the cell with velocity shelters	cm^2
	cellDepth	Value of depth at specific time	cm
	cellDistanceToHide	Average distance from hiding cover from the cell's center	cm
	cellFracCover*	Fraction of the cell with cover	Unitless (0-1)
	cellFracGravel*	Fraction of the cell with spawning gravel	Unitless (0-1)
	cellFracShelter*	Fraction of the cell with velocity shelters	Unitless (0-1)
	cellFracSpawn*	Fraction of the cell with spawning gravel	Unitless (0-1)
	cellNumber*	Number of the cell	number
	cellVelocity	Value of velocity at specific time	$cm\ s^{-1}$
	driftHourlyCellTotal	Production rate of drift food items	$g\ h^{-1}$
	my-adjacentCells*	Adjacent cells	agents
	my-patches*	Patches composing the cell	agents
	searchHourlyCellTotal	Production rate of search food items	$g\ h^{-1}$
	Transect*	Transect where the cell is located	number
Redds	creationDate*	Date when the redd is created	date
	days-after-hatch	Number of days since emergence starts in the redd	days
	eggsLostToDewateringTot	Total number of eggs lost due to scouring	eggs
	eggsLostToHighTempTot	Total number of eggs lost due to high water temperatures	eggs
	eggsLostToLowTempTot	Total number of eggs lost due to low water temperatures	eggs
	eggsLostToScourTot	Total number of eggs lost due to dewatering	eggs
	eggsLostToSuperimpTot	Total number of eggs lost due to superimposition of redds	eggs
	fracDeveloped	Developmental status of a redd's eggs	Unitless (0-1)
	my-cell*	Cell where the redd is located	cell-id
	numberOfEggs	Number of eggs in the redd	eggs
	numberOfHatchedEggs	Number of eggs hatched (creating a new trout)	eggs
	reddFathersgenNeutralTrait*	Genotypic values of neutral trait of fathers	User-specific
	reddFathersgenNewlength*	Genotypic length at emergence of fathers	cm
	reddFathersgenSpawnMinLength*	Genotypic minimum length to spawn of fathers	cm
	ReddID *	Identity number of the redd	id
	reddMothergenNeutralTrait*	Genotypic value of neutral trait of the mother	User-specific
	reddMothergenNewlength*	Genotypic length at emergence of the mother	cm
	reddMothergenSpawnMinLength*	Genotypic minimum length to spawn of the mother	cm
Trout	age	Number of days since the fish was born	days
	age-class	Age class	Age0-Age5
	CauseOfDeath*	Mortality source by which the fish is dead	8 sources
	cMax	Physiological maximum daily intake	$g\ d^{-1}$
	energyAvailableforGrowth	Net energy gain in my-cell during the time step	$J\ d^{-1}$
	fishCondition	Condition factor	Unitless (0-1)

fishLength	Body length	cm
fishMaxSwimSpeed	Maximum sustainable swimming speed	cm s^{-1}
fishNeutralTrait*	Phenotypic value of the neutral trait	User-specific
fishNewLength*	Phenotypic length at emergence	cm
fishSpawnMinLength*	Minimum length to spawn	cm
fishWeight	Body weight	g
genNeutralTrait*	Genotypic value of the neutral trait	User-specific
genNewLength*	Genotypic length at emergence	cm
genSpawnMinLength*	Genotypic minimum length to spawn	cm
is-sheltered?	Access to a velocity shelter	True/False
maturityStatus	Maturity status	mature/non-mature
my-cell	Cell where the fish is located	cell-id
sex*	Sex	M/F
spawnedThisSeason?	Spawned this spawning season	true/false
status	Status	alive/dead