

Supplementary material part 1

This model description follows the ODD (Overview, Design concepts, Details) protocol for describing individual- and agent-based models (Grimm *et al.*, 2006, 2010).

1. Purpose

Our goal is to study the effect of habitat configuration of a resource on the body size distribution of a herbivore and its predator. We here took an arthropod-centered approach and parameterized allometric rules for a haploid, parthenogenetic herbivore and predator with a semelparous lifecycle.

By applying an individual-based approach, we were able to include intra-specific size variation and stochasticity within our model. This approach in conjunction with the assumption of asexual reproduction and equivalent ontogenetic and interspecific scaling exponents (West, Brown and Enquist, 2001; Moses *et al.*, 2008), implies that our results can be interpreted both at the metapopulation and metacommunity level for both the herbivore and the predator.

2. Entities, state variables, and scales

An individual

The herbivore(s) and predator(s) are individually modeled and have the following state variables:

- W_{td} (kg): current mass of an individual.
- W_0 (kg): egg mass of an individual
- W_{max} (kg): an individual's maximum adult mass.
- t_d (days): developmental age of an individual.
- E_r (Joule): Each individual has an energy reservoir in which assimilated energy is stored, which can be invested in growth, reproduction, movement or the cost of basal metabolic rate.
- Developmental stage: A distinction is made between juvenile and adult herbivores and predators. Juveniles invest their assimilated energy in growth, whereas, adults invest their assimilated energy in reproduction.
- x and y coordinate
- trophic level: an individual is either a herbivore or a predator. Within the analyses, both trophic levels are analyzed separately.
- p : probability of moving is calculated per time step per individual

The landscape

The configuration of the landscape is defined by two state variables:

- P : The amount of suitable cells within the landscape
- H : The level of spatial autocorrelation

The landscape is cellular consisting of several grid cells.

A grid cell

The resource species is not individually modeled. Instead, resource amounts are defined per cell.

Per cell, the following state variables are defined:

- Suitability: whether or not a cell is suitable for the resource to grow.
- $R_{x,y}$ (Joule): per cell a resource amount is defined in Joule.
- K (Joule): carrying capacity of the resource (Joule).
- r : growth speed of the resource (Joule).
- Enc (Joule): amount of resource present per cell that is non consumable by the herbivore.
- A list of individuals present in a particular cell
- x and y coordinate
- N_H : the number of herbivores present in a cell

A predator - herbivore interaction

- s_a : successful attack rate
- i_{PH} : predator-herbivore interaction rate
- O_{BSR} : optimality of predator-herbivore body size ratio

Scales

The landscape is a cellular grid of 200 by 200 cells and is generated using the Python package NLMpy (Etherington, Holland and O'Sullivan, 2015). Each cell has a dimension of 0.25×0.25 m. One time step corresponds to one day. Total runtime is 3000 time steps (days).

3. Process overview and scheduling

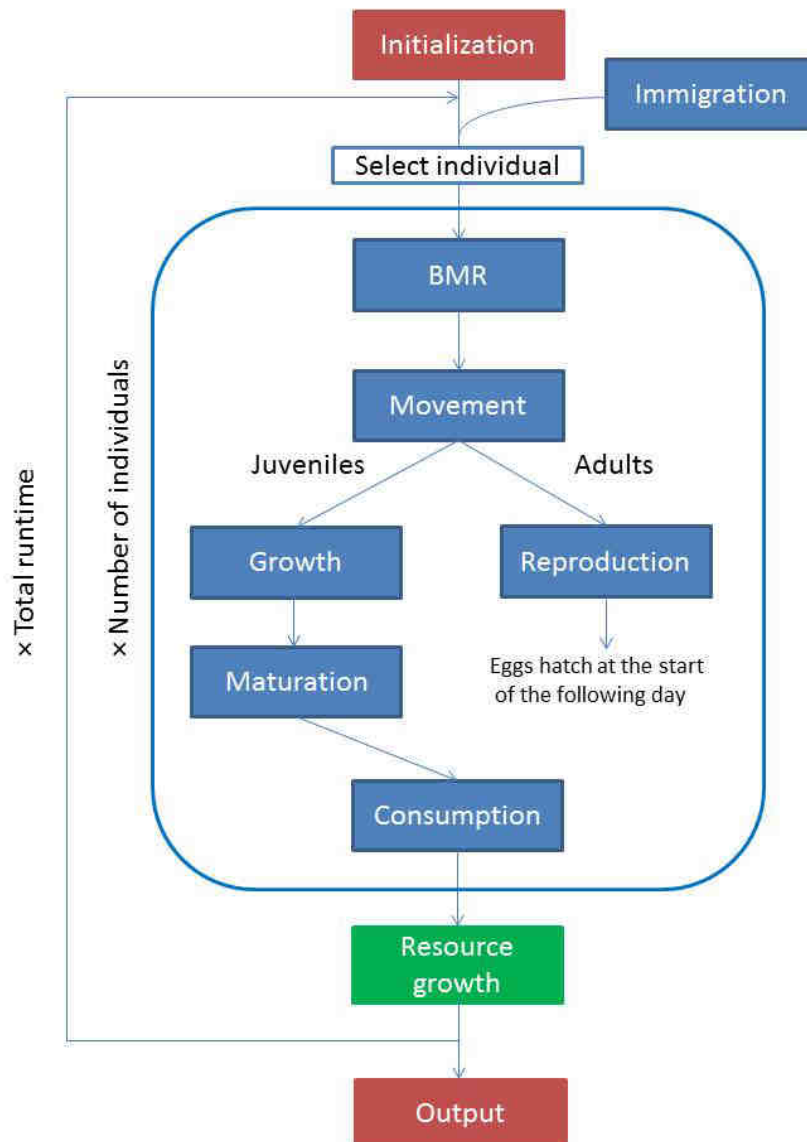


Figure 1: This figure depicts an overview of all events within the model. BMR stands for the basal metabolic rate costs. Initialization and output generation are regulated at the level of the model. Blue boxes represent events of the herbivore and predator. The green box represents the event regulating resource growth.

The applied model is a spatially explicit, discrete-time model with overlapping generations. One time step corresponds to one day within the lifetime of the herbivore(s) or predator(s).

In case immigration is allowed (according to immigration rate q), one immigrant herbivore and one immigrant predator are initialized within the landscape at the start of a day. During a day, all herbivore and predator individuals are selected in a random order. A selected individual executes several events during one day in the following order: basal metabolic rate, movement, growth and maturation (both restricted to juveniles) or reproduction (restricted to adults) and consumption.

During the first event, the energy invested in basal metabolic rate is subtracted from an individual's energy reserve. Only if the remaining energy is not negative, an individual survives. Next, an individual has the opportunity to move. When moving, an individual moves to the cell with the highest amount of resources (in case of a herbivore individual) or the cell with the highest number of herbivores (in case of a predator individual) within its foraging area. During movement, the energy reserve is depleted by the cost of movement. Third, juveniles may further deplete the energy reserve by growth, eventually resulting in maturation if they approximate their adult mass (W_{max}). Finally, individuals replenish their energy reserve by consumption. Competition for resources is contest. Consumed energy that is not expended during the following day remains in the energy reserve. As such, individuals may collect energy within their energy reserve over several days, which is invested in the production of one clutch during the lifetime of an individual. The energetic threshold for reproduction increases with body size. As the herbivore species is semelparous, adults die after reproduction.

During growth, an individual's mass is updated. When moving, an individual's x and y coordinate change. If maturation is allowed, a juvenile becomes an adult (updating an individual's developmental stage). Resource quantities per cell decrease during consumption but replenish during resource growth.

During a simulation, summarizing output variables are collected, which are written out at the end of a simulation.

4. Design concepts

Basic principles:

An organism's body size is one of its most comprehensive characteristics. As described by the metabolic theory of ecology, body size is strongly correlated with an array of functional traits (Peters, 1983; Brown *et al.*, 2004). Based on this theory, we linked many individual traits to body size (e.g. basal metabolic rate, movement speed, ingestion rate, clutch size and developmental time). It is crucial to include these allometric rules, as body size represents the outcome of several selective pressures acting on different life history traits, setting boundaries to the ecology, physiology and functioning of an individual (Peters, 1983).

As habitat fragmentation and destruction progress, the spatial distribution of resources is altered. The importance of resource distribution for body size distributions is advocated by the 'textural discontinuity hypothesis' of Holling (Nash, 2014). We test this hypothesis by investigating the effect of habitat configuration and destruction on body size distributions. Earlier, the effect of habitat fragmentation and destruction on the body size distribution of a herbivore had been investigated. However, this study is now extended by adding an extra trophic level (predator) to the model. Our model

investigates whether or not a predator affects the body size distribution of a herbivore and how the body size distribution of a predator is influenced by habitat fragmentation and destruction. Moreover, the effect on resource distribution and amount is investigated.

Emergence:

As habitat fragmentation and destruction progress, the spatial distribution of resources is altered, yet the consequences for (future) body size distributions of different trophic levels are unclear. On the one hand, large-bodied individuals may be selected as they have high starvation resistance and are able to cover large distances (Peters, 1983; Davies, Margules and Lawrence, 2000; Tschardtke and Brandl, 2004). On the other hand, small-sized individuals may have the benefit of short developmental times and low energy requirements (Peters, 1983). Therefore, the most important results of the model are the observed differences in body mass distributions between simulation types (defined by habitat configuration) according to trophic level.

Body size distributions will cause a feedback on the overall food web dynamics (overall instability, resource distributions and observed predator-herbivore body size ratios). These feedbacks are also investigated by collecting data on resource distribution and fluctuations in resource amount, herbivore numbers and predator numbers.

Adaptation:

Body size is linked to many features of an individual. In this model, larger individuals move faster, have longer development times, have larger clutch sizes, have larger basal metabolic rates, and have higher ingestion rates. These traits also change during the developmental phase of an individual, corresponding to its body mass.

Furthermore, the energy invested in growth and movement depends on the energy available within an individual's energy reserve. As such, an individual will never die due to exhaustion by moving too far. Also, the available energy is invested in the events in the following order: (1) basal metabolic rate, (2) movement and (3) growth or reproduction. As such, an individual's priority is investing energy in basal metabolic rate cost. Secondly, it will try to guarantee access to resources by moving. Thirdly, it will invest energy in growth or reproduction if some energy is left. Energy for reproduction is collected during several days as only one clutch is produced during the lifetime of an individual.

Probability of moving (p) decreases with resource availability in a cell (in case of a herbivore) or successful chance of attack (in case of a predator). When moving, an individual moves to the cell with the highest amount of resources (in case of a herbivore individual) or the cell with the highest number of herbivores (in case of a predator individual) within its foraging area.

Objectives:

The short-term objective of an individual is to consume resources or herbivores. The long-term objective, however, is to produce a clutch of individuals. Those individuals that have the most optimal body size, are selected and hence become the most abundant within the community or population.

Sensing:

A herbivore may sense the amount of resources present within a cell. Based on this information, it decides whether it will start moving and in which cell it will spend the following day. A predator may estimate its chance of successful attack within its current cell and use this information to decide whether or not to start moving. Its habitat choice is based on the number of herbivores present within a cell. A predator always selects the cell with the highest number of herbivores.

Interaction:

During consumption, competition for resources or herbivores is contest. Individuals always move to the cell with the highest abundance of resources (in case of herbivores) or herbivores (in case of predators). A predator can consume any herbivore which is located in its cell. A predator's probability of moving is based on the successful attack rate, which increases with local herbivore abundance.

Stochasticity:

Stochasticity is included when defining which individuals will move from a particular cell. Also, stochasticity regulates the mutation events of the allele describing the maximum mass of an individual. A herbivore's chance of being successfully attacked by a predator increases with local herbivore density and depends on the successful attack rate.

Collectives:

A distinction is made between herbivores and predators. Both trophic levels consist of juveniles and adults. Juveniles invest their energy in growth, whereas adults invest their energy in reproduction.

Observation:

Only simulations in which the predator persists during the final 500 days of a simulation are included within the analysis. An overview of the number of included simulations per landscape type is given in Table S2.1. During each simulation, we traced changes in the mean amount of resources per cell, total number of adults and juveniles and average adult mass (W_{max}) of both the herbivore and the predator over time. Throughout the final 1500 days of a simulation, 1000 eggs were randomly selected to be followed during their lifetime. The movements and reproductive success of the resulting herbivore individuals were recorded. During the final 100 days of a simulation, the $\log_{10}(\text{predator-herbivore body size ratio})$ was recorded per successful predation event. As such, the average $\log_{10}(\text{predator-herbivore body size ratio})$ could be determined per scenario, as well as the deviation from this average to the optimum $\log_{10}(\text{body size ratio})$.

At the end of a simulation, the body masses of maximally 50 000 predators and maximally 50 000 herbivores were randomly sampled. Also, the abundance of predators and herbivores as well as the resource amount per cell was written out. This allows to study the spatial distribution of the predator(s), the herbivore(s) and the resource.

In order to determine the effect of the predator(s) on herbivore body mass distributions, the herbivore-resource model was run with the exact default settings of the predator-herbivore-resource model (see Table S1.1). The runtime of this model was 1000 time steps in case of $P = 0.50$ and $P = 0.90$. Otherwise, this model ran for 10 000 time steps.

5. Initialization

Per parameter combination, 50 simulations were run. At the start of a simulation, adult individuals were introduced with an average density of one herbivore per two suitable cells. After 20 timesteps, 1000 predators are randomly introduced in suitable patches within the landscape. This time lag allows the herbivore to reach a stable population number before the predators are introduced, increasing predator survival chances. The adult mass of each individual (W_{max}) (for both herbivores and predators) was defined as ten raised to the power of a value drawn from the uniform interval $[-5, -2.522878745]$. In other words, we sample a value between 0.00001 kg (minimum adult mass) and 0.003 kg (maximum adult mass). As such, individuals with masses of different orders of magnitude have an equal chance of being initialized in the landscape. Moreover, initialized distributions are

skewed to small individuals. Also, each initialized individual carried enough energy within its energy reserve to survive the first day. This amount of energy is calculated based on an individual's mass and accounts for the cost of basal metabolic rate and movement during one day. Initial resource availability per cell was 100 J. Total runtime was 3000 time steps.

6. Submodels

The landscape

The landscape is a cellular grid of 200 by 200 cells and is generated using the Python package NLMpy (Etherington, Holland and O'Sullivan, 2015). Each cell within the landscape has a side length (SL) of 0.25 m and therefore a total surface of 0.0625 m². Within the landscape, a distinction is made between suitable and unsuitable habitat. Only within suitable habitat, the resource is able to grow. When testing the effect of landscape configuration, the proportion of suitable habitat (P) and habitat autocorrelation (H) were varied between landscapes. Habitat availability increases with P , whereas habitat fragmentation decreases with H . The following values were assigned to P : 0.05, 0.20, 0.50 or 0.90. H equaled either 1 (in all four cases), 0.5 (when P equaled 0.05 or 0.20) or 0 (when P equaled 0.05). As such, highly fragmented landscapes with a high amount of suitable habitat were not included in the analysis as these rarely occur in nature (Neel, McGarigal and Cushman, 2004).

The resource

Resources are not individually modeled but by a logistic growth model for each habitat cell. Local resource biomass is represented as the total energetic content of resource tissue within that cell ($R_{x,y}$ in Joule). This resource availability grows logistically in time depending on the resource's carrying capacity (K) and intrinsic growth rate (r). In any cell, a fixed amount of resource tissue (E_{nc} , in Joules, fixed at 2 J) is non-consumable by the herbivore species, representing below-ground plant parts. As such, E_{nc} is the minimum amount of resource tissue present within a suitable cell, even following local depletion by the herbivore species.

Herbivore- predator

All herbivores and predators are individually modelled within the landscape. The herbivore and predator have two life stages: a juvenile and adult life stage. Within a day, both stages have the chance to execute different events (see Figure 1). Daily, an individual executes all these events in line. The order in which individuals are selected is daily randomized. Importantly, during the consumption event, the herbivore feeds on the resource whereas the predator feeds on the herbivore.

First, an individual nourishes its energy reserve by consumption. Second, the energy reserve is depleted by the cost of daily maintenance (i.e. basal metabolic rate) and the cost of movement. Third, juveniles may further deplete the energy reserve by growth, eventually resulting in maturation if they approximate their adult size (W_{max}). Energy that was not utilized is stored within the energy reserve. Adults can only reproduce if their internally stored energy (E_r) exceeds a predefined amount. As the herbivore species and the predator species are semelparous, adults die after reproduction.

In both the herbivore and the predator, an individual's body size at maturity (W_{max} , in kg) is coded by a single gene. Adult size is heritable and may mutate with a probability of 0.001 during reproduction. A new mutation is drawn from the uniform distribution $[W_{max} - (W_{max}/2), W_{max} + (W_{max}/2)]$ with W_{max} referring to the adult size of the parent. New mutations may not exceed the predefined boundaries $[0.01g, 3g]$ that represent absolute physiological limits. Both minimum and maximum weight are similar for the predator and the herbivore. New variants of this trait may also originate by immigration (see further). Mutation enables fine-tuning of the optimal body size, whereas immigration facilitates fitness peak shifts.

Immigration

The frequency with which immigrants arrive in the landscape is described by q . This variable is fixed at one per 100 days. The process of determining an immigrant's adult mass is similar as during initialization (see above). An immigrant is always introduced within a suitable cell and its energy reserve contains just enough energy to cover the cost of basal metabolic rate and movement during the first day.

The implementation of body size within each of the daily events (see Figure S1.1)

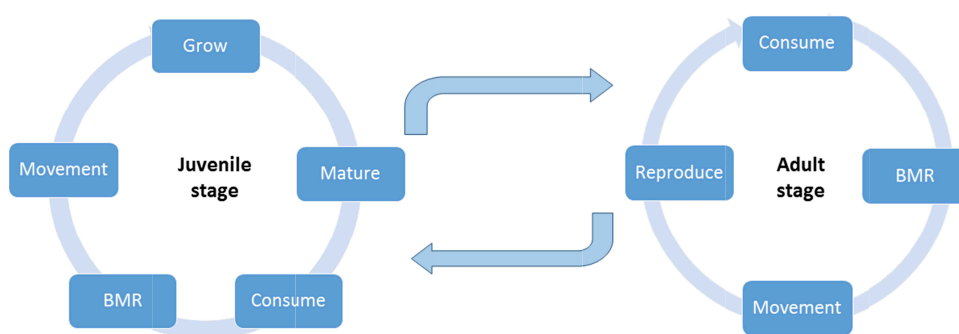


Figure S1.1: A comparison of daily events for the juvenile and adult stage of the herbivore and the predator. BMR stands for the basal metabolic rate costs.

The assumptions describing the daily events of the herbivore are described in the herbivore model. Some events do not significantly differ between trophic levels and are therefore assumed to be the same for the herbivore and the predator (this is the case for basal metabolic rate, growth, maturation and reproduction).

Consumption

Individual ingestion rate (IR , in Watts) of an individual increases with its size (W , in kg) by the following equation for both the herbivore and the predator:

$$IR = 2 * W^{0.80} \text{ (eq. 1)}$$

Following log transformation, the slope (0.80) was found by Peters (1983) to be the mean of several studies focusing on ingestion rates of poikilotherms. The intercept of this equation lays within the observed range of elevations [0.12 to 2] of these studies (Peters, 1983).

Based on eq. 1, the amount of energy ingested per day for an individual (i_{max} in Joules) is determined as:

$$i_{max} = 2 * W^{0.80} * t_f \text{ (eq. 2)}$$

with t_f referring to the time devoted per day to consumption (in seconds), which is fixed at 15 hours.

The herbivore

The amount of resources consumed by a herbivore (E_c) only equals i_{max} if this amount is available. Otherwise, E_c equals the amount present within a cell. As such, competition for resources is contest.

When we consider that the herbivore feeds on young terrestrial foliage, it may only assimilate 65 percent of its daily ingested energy (Ricklefs, 1974; Peters, 1983). Moreover, we assume that the herbivore loses 10 percent of its ingested energy to processing costs (i.e. specific dynamic action; Ricklefs 1974). As such, only 55 percent of the ingested energy remains available to the organism. Therefore, the energy that is being assimilated by a herbivore individual (E_a in Joules) is described by

$$E_a = 0.55 * E_c \text{ (eq. 3)}$$

The predator

For each predator, the herbivore individuals located within its cell are selected in a random order. Per selected herbivore, the chance of successful attack (s_a) is calculated. This chance is defined by multiplying the chance of interaction (i_{PH}) with the measure for optimality of the predator-herbivore body size ratio (O_{BSR}):

$$s_a = i_{PH} \cdot O_{BSR} \text{ (eq. 4).}$$

The chance of interaction increases with herbivore abundance in a cell, according to:

$$i_{PH} = \frac{1}{1 + e^{-\frac{1}{4}(N_H - 11)}} \text{ when } N_H > 0 \text{ (eq. 5).}$$

with N_H representing the number of herbivores present within a cell. This function has a sigmoid shape and therefore implies a functional type III response (see Figure S1.2), stabilizing food web dynamics as highlighted by the sensitivity analysis (see supplementary material part 2). During a day, the number of herbivores present in a cell (N_H) is constantly updated.

Contrary to a preferred predator- prey body mass ratio which depends on predator body mass, we included a fixed ratio which is in line with (Tsai, Hsieh and Nakazawa, 2016). Per selected predator- herbivore pair, the corresponding $\log_{10}(\text{predator-herbivore body mass ratio})$ is calculated. This ratio is then compared with the observed distribution of $\log_{10}(\text{predator-prey body mass ratios})$ in terrestrial systems with invertebrate predators (normal distribution with average 0.6 and SD 1.066) (Brose *et al.*, 2006). We refer to this observed distribution as the preferred predator-herbivore body mass ratio (Tsai *et al.*, 2016). If the ratio of the selected pair is rarely observed in nature, the value for O_{BSR} is close to zero. In case the ratio is often observed, the value for O_{BSR} lays close to 1. In order to obtain values for O_{BSR} between 0 and 1, the observed normal distribution in nature is scaled by an extra factor. As such, the formula for the calculation of O_{BSR} is the following (see Figure S1.3):

$$O_{BSR} = \frac{\frac{1}{1.066 \cdot \sqrt{2\pi}} e^{-\frac{1}{2} \left(\frac{\log_{10}\left(\frac{W_{predator}}{W_{herbivore}}\right) - 0.6}{1.066} \right)^2}}{\frac{1}{1.066 \cdot \sqrt{2\pi}}} \text{ (eq. 6).}$$

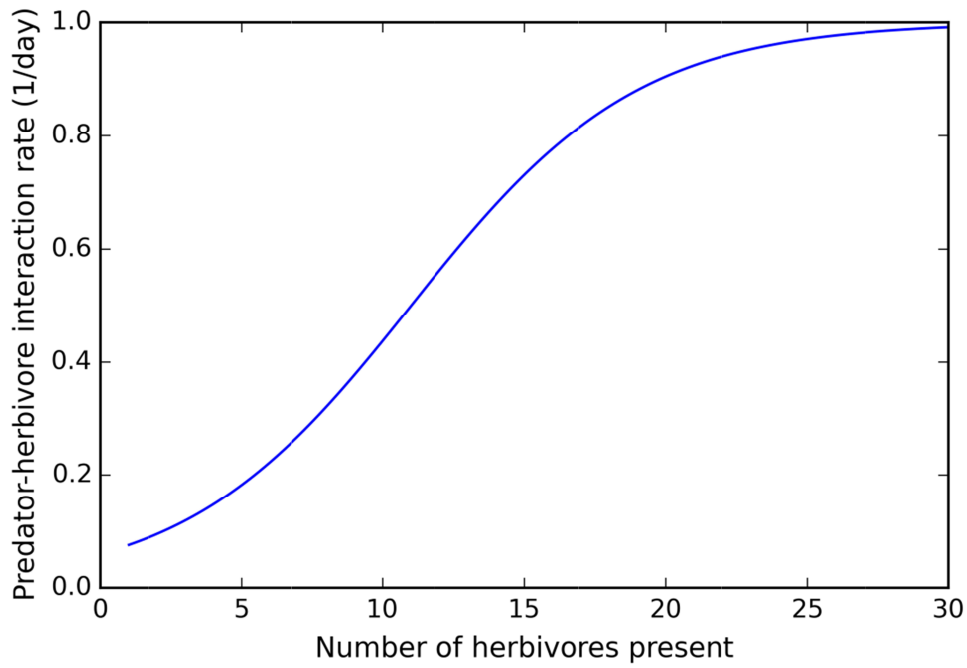


Figure S1.2: Relationship between predator-herbivore interaction rate and number of herbivores present within a cell. During a day, the number of herbivores present in a cell is constantly updated.

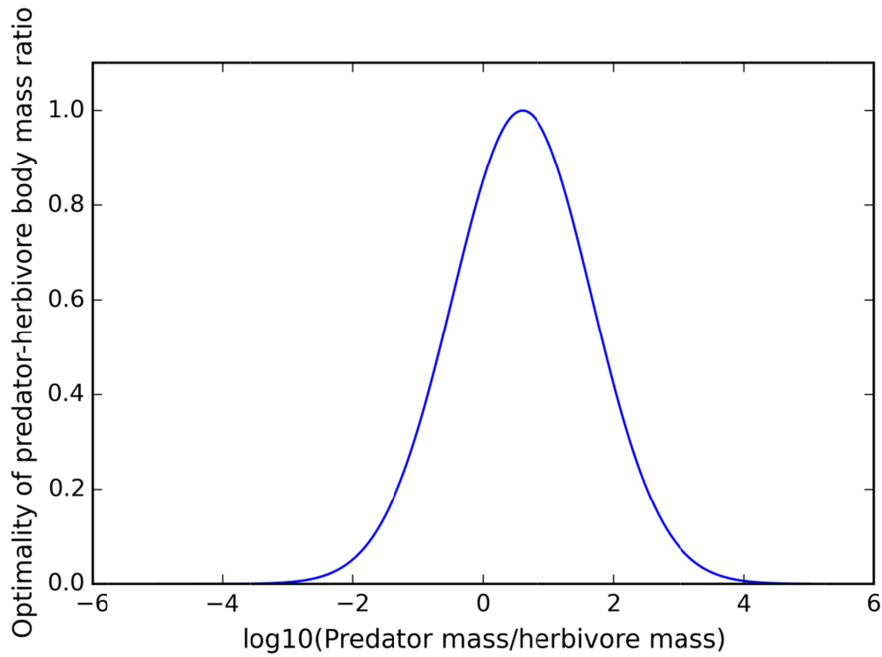


Figure S1.3: The optimal predator-herbivore body size ratio. This distribution follows Brose (2006) for terrestrial invertebrate predators.

As i_{PH} and O_{BSR} are both floats within the interval $[0,1]$, the same is true for s_a . In case a randomly sampled number from the interval $[0,1]$ is smaller than s_a the attack of the predator on the herbivore is successful. Then, E_c of the predator is increased with $W_{t,herbivore} * 7000000 + E_{r,herbivore}$. This for-

mula assumes that the energetic content of wet tissue corresponds to 7000000 Joule per kg (Peters, 1983) and that the body mass of a herbivore ($W_{t,herbivore}$) does not include the energy stored within its energy reserve (E_r). As long as E_c is smaller than i_{max} of the predator, another herbivore within the same cell may be attacked by the predator. However, E_c does never exceed i_{max} .

Considering that the predator feeds on insects, it may assimilate 80 percent of its daily ingested energy (Ricklefs, 1974; Peters, 1983). However, we assume that the predator loses 25 percent of its ingested energy to processing costs (i.e. specific dynamic action) (Ricklefs 1974, Peters 1983). As such, only 55 percent of the ingested energy remains available to the organism. Therefore, the energy that is being assimilated by a predator individual (E_a in Joules) is described by the same formula as for the herbivore (see eq. 3).

Basal metabolic rate

The standard metabolic rate of poikilotherms (M , in watts) is described by:

$$M = 0.14W^{0.751} \text{ (eq. 7)}$$

Here, W is the body mass (in kg) (Hemmingsen, 1960 cited in Peters, 1983). As such, the total standard metabolic rate costs per day (M_{day}) are calculated according to:

$$M_{day} = 0.14W^{0.751} * (3600 * 24 - t_m) \text{ (eq. 8)}$$

If an individual has stored less energy within its reserve (E_r) than M_{day} , it dies at the beginning of the day. The standard metabolic rate exhibited during movement is already included within the cost of movement (Peters, 1983). Therefore, the cost of daily existence is only calculated based on the time that an individual is not moving per day. The time an individual moves per day (t_m , in seconds) varies between individuals and over time (see below).

The movement phase

Probability of moving (p)

Whether an individual moves depends on the ratio of the amount of energy present within a cell relative to the amount of energy it can obtain via consumption during a day (i_{max}).

The probability of moving (p) for a herbivore is thereby calculated as:

$$p_{herbivore} = 1 - \frac{R_{x,y}}{i_{max}} \quad \text{if } \frac{R_{x,y}}{i_{max}} < 1 \text{ (eq. 9)}$$

$$p_{herbivore} = 0 \quad \text{if } \frac{R_{x,y}}{i_{max}} \geq 1.$$

A predator's probability of moving is based on s_a : the chance of moving decreases with the chance of successful attack by:

$$p_{predator} = 1 - s_a \text{ (eq. 10).}$$

In the formula of s_a , the average herbivore mass within the cell is applied (see eq. 4 and 6).

Defining searching area

As one time step in our model corresponds to one day, we do not model the movement behavior of an individual explicitly but instead, estimate the total area an individual can search for resources during a day. This area is called an individual's searching area is calculated once per time step, for each moving individual. As all cells within a particular distance from the origin are equally intensively searched, the searching area is circular with a radius (rad) and a center corresponding to the current location of an individual (Delgado *et al.*, 2014). An individual's searching area increases with an individual's optimal speed (v_{opt}), movement time (t_m) and perceptual range (d_{per}). Both optimal speed and perceptual range depend on body mass, resulting in larger searching areas for larger individuals. The cost of movement includes the energy invested by an individual in prospecting its total searching area. Therefore, it is dependent on the size of the total searching area instead of the shortest distance between the cell of origin and cell of destination.

An individual's optimal speed of movement (v_{opt} , in meters per second) depends on body size and is calculated for herbivores according to the following equation, derived for walking insects (Buddenbrock, 1934 cited in Peters, 1983):

$$v_{opt, herbivore} = 0.3 \cdot W^{0.29} \text{ (eq. 11)}$$

Optimal speed of movement (v_{opt} , in meters per second) of the predator is defined by the following equation (Hirt *et al.*, 2017):

$$v_{opt, predator} = 1.0045 \cdot W^{0.42} \text{ (eq. 12).}$$

The time an individual invests in movement per day (t_m , in seconds) is maximally 1 hour. In case too little internally stored energy is present to support movement for one hour, t_m is calculated by:

$$t_m = \frac{E_r}{c_m} \text{ (eq. 13).}$$

c_m refers to the energetic cost of movement (in joules per second) and is calculated for herbivores by the following formula, which is based on running poikilotherms (Buddenbrock, 1934 cited in Peters, 1983):

$$c_{m, herbivore} = (0.17W^{0.75} + 3.4W) \text{ (eq. 14).}$$

We adapt the formula of c_m for the predator by implementing the formula for $v_{opt, predator}$ in the formula of c_m (see supplementary material part 3 for derivation):

$$c_{m, predator} = (0.17W^{0.75} + 11.35W^{1.14}) \text{ (eq. 15).}$$

The cost of moving during the time t_m ($c_m \cdot t_m$) is subtracted from an individual's energy reserve. Based on t_m and v_{opt} , the total distance an individual covers at day t (d_{max}) is determined as:

$$d_{max} = v_{opt} \cdot t_m \text{ (eq. 16).}$$

Next, the perceptual range of an individual is determined by means of the following relationship:

$$d_{per} = 301W + 0.097 \text{ (eq. 17).}$$

For simplicity, this relationship is linear and based on the assumption that the smallest individual (0.01g) has a perceptual range of 0.10 m and the largest individual (3g) a perceptual range of 1 m. The effect of this relationship has been tested (see supplementary material part 2). Moreover, the positive relationship between body size and perceptual range or reaction distance has been illustrated over a wide range of taxa, including arthropods (supplementary information of Pawar et al. 2012).

The foraging area of an individual is circular and its radius (rad , in m) is calculated by taking into account the total distance the individual has covered during the day and the individual's perceptual range (see supplementary material part 3 for explanation of this formula):

$$rad = \sqrt{\frac{2 \cdot d_{max} \cdot d_{per} + \pi \cdot d_{per}^2}{\pi}} \text{ (eq. 18).}$$

In order to avoid side-effects of applying the variable rad for a continuous landscape within a cellular landscape, a value drawn from the following distribution, $[-0.5 \cdot SL, 0.5 \cdot SL]$, is added to rad .

Habitat choice

Here, movement is informed as an individual always moves to the cell with the highest amount of resources (the herbivore) or the cell with the highest rate of successful attack (based on average herbivore weight per cell in case of the predator) within its foraging area.

Growth

The applied growth model is the one described by West et al. (2001) (West, Brown and Enquist, 2001) for deterministic growth:

$$W = W_{max} \times \left\{ 1 - \left[1 - \left(\frac{W_0}{W_{max}} \right)^{1/4} \right] e^{-at_d/4W_{max}^{1/4}} \right\}^4 \text{ (eq. 19).}$$

Within this formula, W refers to an individual's actual mass (in kg) at developmental age t_d (in days), W_{max} to an individual's genetically inherited adult mass (in kg), W_0 to an individual's egg mass (in kg) and a to a species-specific constant. Here, a was fixed at 0.2 which is a realistic value for species with deterministic growth (West, Brown and Enquist, 2001). When applying the formula, W , W_{max} and W_0

are converted to gram. According to West et al. (2001) (West, Brown and Enquist, 2001) the proportion of available energy that is devoted to growth (A) is described by:

$$A = 1 - \left(\frac{W}{W_{max}}\right)^{0.25} \text{ (eq. 20).}$$

In ideal conditions, an individual's total amount of assimilated energy during one day (E_a) should correspond to $0.55 \cdot i_{max}$. Here, we assume that an individual will only increase its developmental age by one day if $A \cdot 0.55 \cdot i_{max}$ Joules is still available within its energy reserve. Otherwise, its developmental age is not increased by one but by $E_r / (A \cdot 0.55 \cdot i_{max})$ with E_r being the energetic content of an individual's energy reserve. This value is larger than or equal to 0 and smaller than 1. This implies that individuals experiencing a shortage in energy will grow at a slower rate than individuals developing under ideal conditions.

Maturation

Juveniles reaching 99 percent of their adult mass (W_{max}) mature.

Reproduction

During reproduction, the relationship between total clutch size (CS , in kg) and mass (W , in kg) is determined by the following equation which is based on aquatic poikilotherms (Blueweiss *et al.*, 1978):

$$CS = 0.158W^{0.92} \text{ (eq. 21).}$$

However, an adult is only allowed to produce a clutch of this size if it has collected enough energy within its energy reserve and if it is located within a suitable patch. The entire clutch is deposited within that single patch, simultaneously. The required energy to produce such a clutch is calculated by:

$$E_{CS} = CS \cdot 7 \cdot 10^6 \frac{J}{kg} + N \cdot E_i \text{ (eq. 22).}$$

Here, 1 kg of wet tissue is considered to have an energetic content of $7 \cdot 10^6$ Joules (Peters, 1983). For simplicity, the number of eggs per clutch (N) is assumed to be fixed at 15. Further, each newly laid egg is provisioned with the necessary energy to survive its first day (E_i , in Joules). The mass of a newly laid egg (W_0 , in kg) is calculated as follows:

$$W_0 = \frac{CS}{N} \text{ (eq. 23).}$$

Also, we guarantee that the adult size of an individual is never smaller than the size it obtained during the egg stage (i.e. $W_0 \leq W$). Such contradictions might occur as the egg size of an individual depends on the adult size of its parent, not on its own adult size.

Table S1.1: Overview and definition of all parameters. In case a parameter is fixed, its value is given. In case a parameter depends on an individual's size, the corresponding allometric rule is given.

Parameter	Unit	Definition	Fixed value or equation
P	-	Proportion of suitable habitat within the landscape	0.90, 0.50, 0.20, 0.05
H	-	Spatial autocorrelation	1, 0.5, 0
t	day	Time since the start of the simulation	
$R_{x,y}$	Joule	Total energetic content of resource tissue present within cell _{x,y}	
K	Joule	Carrying capacity of resource per cell	2000 Joules
r		Growth speed of the resource	0.9
E_{nc}	Joule	Fixed amount of non-consumable resource energy per cell	2 Joule
W_{max}	kilogram	Adult size of an individual	
W	kilogram	Mass of an individual at developmental age t_d	eq. 19
W_0	kilogram	Egg mass of an individual	eq. 23
IR	Joule per second	Ingestion rate of an individual with mass W	eq. 1
i_{max}	Joule	An individual's maximum ingestible amount of energy at time t	eq. 2
t_f	seconds	Time devoted per day to consumption	15 hours
E_c	Joule	Energy being consumed by an individual at time t	
E_a	Joule	Energy being assimilated by an individual at time t	eq. 3
N_H		Number of herbivores present within a cell	
s_a	1/day	Successful attack rate on a herbivore	eq.4
i_{PH}	1/day	Predator-herbivore interaction rate	eq. 5
O_{BSR}		Optimality of predator-herbivore body size ratio	eq. 6
M	J/s	The standard metabolic rate of an individual with size	eq. 7

		W	
M_{day}	Joule	Total standard metabolic rate costs for an individual at time t	eq. 8
t_m	seconds	Time devoted to movement at time t	eq. 13
p	-	Probability of moving at time t	Herbivore: eq. 9 Predator: eq. 10
v_{opt}	Meter per second	Average speed of movement for individual with size W	Herbivore: eq. 11 Predator: eq. 12
d_{max}	meter	Maximum distance an individual can cover at time t	eq. 16
d_{per}	meter	Perceptual range of an individual	eq. 17
rad	meter	Radius of searching area at time t	eq. 18
c_m	Joule	Cost of movement at time t	Herbivore: eq. 14 Predator: eq. 15
q	1 per day	Immigration rate	1 per 10 days
a	-	Species-specific constant within formula of West et al. (2001)(West, Brown and Enquist, 2001)	0.2
t_d	day	An individual's developmental age	
A	-	Proportion of available energy devoted to growth at time t	eq. 20
E_r	Joule	Energy available within energy reservoir at time t	
CS	kilogram	Total clutch size of an individual with size W	eq. 21
E_{CS}	Joule	Required energy to produce a clutch of size CS	eq. 22
N	-	Number of eggs within one clutch	15

7. References

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