Supplementary material for the paper Baggio et al. (2010): Landscape Connectivity and predator-prey population dynamics.

ODD protocol of the model presented

Purpose:

An agent (individual) based model has been developed to assess how connectivity of patches on a landscape influences predator-prey dynamics and to assess the dependence of population levels on nodes and/or network connectivity measured in node degree and network density.

State Variables and Scales:

The model contains predator, prey and habitat patches (the latter is also referred to as nodes). Variables differ for the three main groups as follows.

Individual predator-prey variables

- Prey:
  - Location (which node they feed on)
  - Density (of prey) on a node
  - Reproduction rate

- Predators:
  - Location (which node they search for prey)
  - Density (of predators) on a node
  - Reproduction rate
  - Predation (probability of attacking and killing a prey that is located on the same node)

- Handling (time in which the predator does not attack but can reproduce)

Landscape variables:

- Nodes (or habitat-patches):
  - Number of nodes
  - Size of nodes (based on maximum number of prey it can support)
  - Connectivity of the network (number of edges in the network and the configuration)

Process Overview and Scheduling:

The initial network of patches will not vary, as we are mainly interested in how the landscape (viewed as a network) affects the dynamics and the population sizes of predators and prey.

The landscape is initialized first, the number of nodes is fixed, and distances between nodes are not taken into account (thus the existence (or absence) of an edge connecting two nodes is the only point of relevance). Moreover, the size of the nodes is assumed constant and equal for every node. The number of edges present in the network varies but not during the simulation (only in the initial settings). Nodes are randomly set on a two-dimensional grid; edges are added based on the proximity of the nodes, starting with the nodes that are closest to each other.

Prey and Predators are assigned randomly to each node; though, their initial population is fixed.

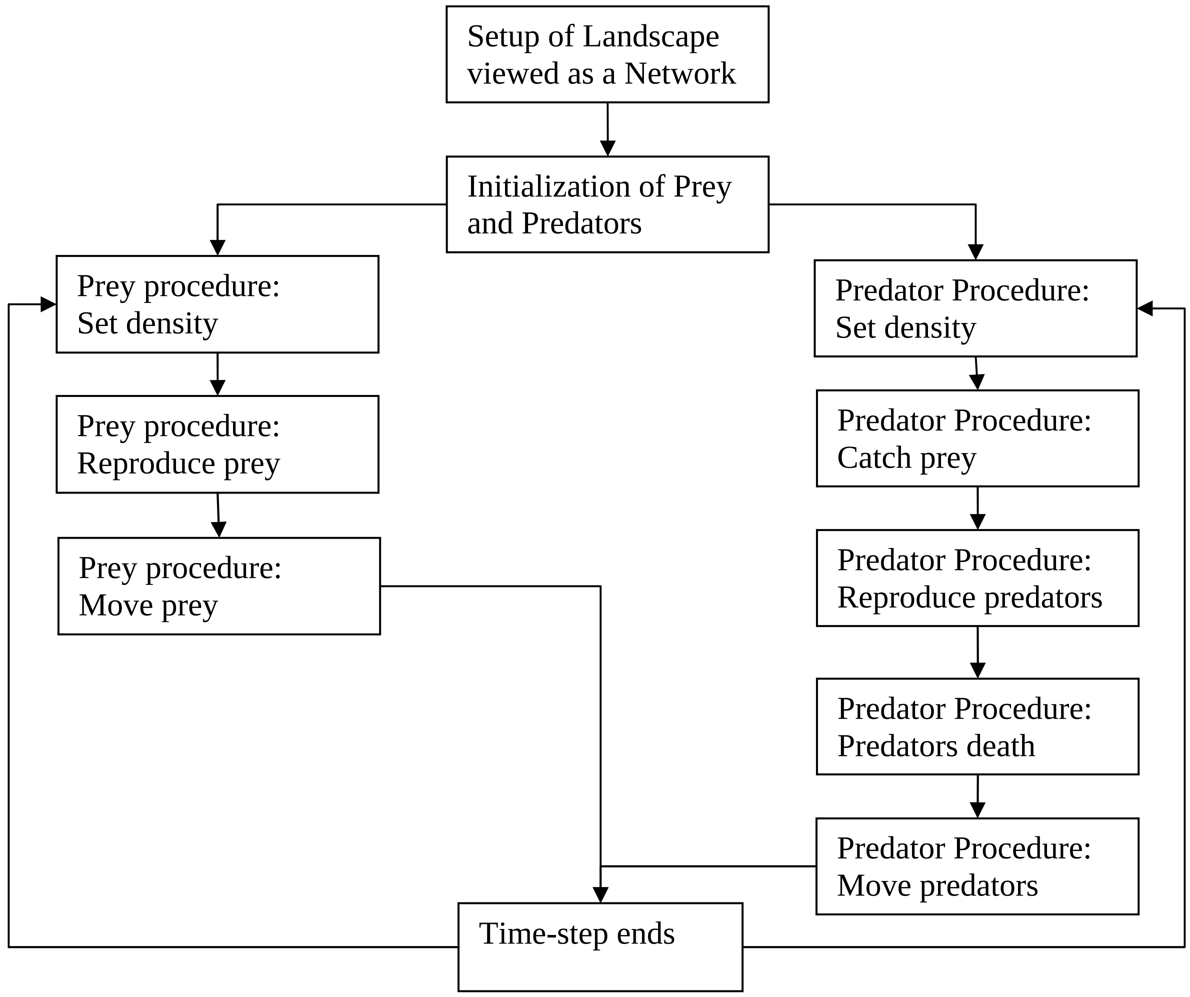
The following is a precise outline of model procedures during one time step. The procedures are sequential (i.e. one prey performs the whole procedure, followed by another prey etc.). However, the order in which agent are selected is random (prey1 may perform the procedure before prey2 in a given time-step, but prey2 may perform the procedures described before prey1 in a later time-step). Each agent (predator or prey) will complete the first procedure before moving on to the next:

1) Each prey sets node density (Dn_{1i}), so they know how many predators and prey reside on their current patch.
2) Each predator also sets node density (Dn_{2i})
3) Each prey has the ability to reproduce with probability $P_{r,1}$.
4) Each prey then has the ability to move to another node based on current density thresholds. That is, if the current node is connected and possesses high predator or prey density, each

prey moves to a randomly chosen connected node and recalculates current node density, else the prey dies. More precisely, prey move if $Dn_{1i} = \frac{n_{1i}}{C} > D_{U,1}$ or $Dn_{2i} = \frac{n_{2i}}{C} > D_{U,2}$. If the chosen node for migration already has a high prey density, the migratory prey dies instantly. This is the final prey procedure in one time step

5) In the same time step, each predator can successfully catch and kill a single prey with probability $P_{k,2}$; given both prey and predator reside on the same patch.
6) Successful capture of prey means the predator is now in the handling period, where it may give birth to a single offspring with probability $P_{r,2}$. Note, predators may be in the handling period for several time steps, during this time, they cannot hunt prey.
7) Then, with probability $P_{m,2}$, each predator may die 'naturally'.
8) Lastly, predators may move between nodes according to a prey density threshold. If the current node is connected and possesses low prey density, predators move to a randomly chosen connected node and recalculate current node density, else the predator immediately dies. If the prey density of the chosen node is low, the migratory predator dies immediately. More precisely, predators move if $Dn_{1i} = \frac{n_{1i}}{C} < D_{L,1}$ and die if $Dn_{1i} < D_{L,1}$ on the chosen node. This is the final predator procedure in one time step, and the final procedure of any agent.

The following diagram gives a graphical representation of what has been explained in this section:



Design Concepts:

Emergence

- Population cycles and size depending on the landscape (network) configuration

Interaction

- Prey and predator interact through predation and density-dependent migration.

Stochasticity

- The model assumes probabilistic events (predation, reproduction, death, movement to other nodes, connection between nodes, initial placement of predators and prey).

Observation

- The focus is on the size of predators and prey for every node and node degree.

Initialization:

The total number of nodes are fixed and each of them are placed randomly on a two dimensional grid. Edges are formed based on Euclidean distances between nodes, connecting the nearest nodes first. Predators and prey are randomly assigned to a node. Their numbers are proportional to the number of nodes. Reproduction rates are fixed within a given species (thus every prey/predator has the same probability of reproducing). Rates of mortality and predation are also fixed for all predators.

Upper and Lower density thresholds are assigned to prey, while just an upper density threshold is assigned to predators. Density thresholds do not vary across nodes.

Variables are initialized as shown in the table below. In order to correct for the high stochasticity of the model, repeated runs are performed. Moreover, during the simulations the number of edges will vary from 0 to 45 with a 5 edge increment, while internal species parameters such as reproduction, death, predation rates and movement decision are initialized according to Table 1 and fixed. The biological parameters are not varied during the simulation because the purpose of the model is to assess the effect of network connectivity on predator-prey population dynamics.

Input:

Symbol	Variable Name	Values drawn from distribution used for Monte Carlo simulations
N	Number of nodes	10
E	Number of edges	Varies from 0 to 45
C	Size of a node	100
n_1	Initial number of prey	Poisson with mean 25 * 10
$P_{r,1}$	Prey reproduction rate	Poisson with mean 0.25 (25%)
$D_{U,1}$	Prey density upper limit	Random uniform distribution [0.5, 0.9]
$D_{L,1}$	Prey density lower limit	Random uniform distribution [0.2, 0.4]
n_2	Initial number of predators	Poisson with mean 10 * 10
$P_{r,2}$	Predator reproduction rate	Poisson with mean 0.2 (20%)
$P_{k,2}$	Predation probability	Poisson with mean 0.2 (20%)
$P_{m,2}$	Predator death rate	Poisson with mean 0.06 (6%)
$D_{U,2}$	Predator density upper limit	Random uniform distribution [0.3, 0.6]
T_h	Predator handling time	3

Submodels:

<u>Model Setup:</u>

- Network
    - Landscape is represented by an undirected network
    - Multiple edges and loops are not allowed
    - Edges are placed between nodes based on Euclidean distances
    - N number of nodes are generated
    - The network will contain E edges where: $0 \le E \le N(N-1)/2$
    - Size C is assigned to every node

- Prey and Predators
    - Initial number of prey, n_1, calculated from a poisson distribution with mean 25 (before every run, a value is chosen according to a poisson distribution with mean 25).
    - Initial number of predators, n_2, calculated from a poisson distribution with mean 10 (before every run, a value is chosen according to a poisson distribution with mean 10.)
    - Random assignment of predators and prey to a node *i*
    - The density of prey on node *i*, $Dn_{1i} = \frac{n_{1i}}{C}$
    - The density of predators on node *i*, $Dn_{2i} = \frac{n_{2i}}{C}$

<u>Model Development:</u>

- Prey
    - Prey reproduce with probability $P_{r,1}$ derived from a poisson distribution with mean 0.25 (for every run, a value is chosen according to a poisson distribution with mean 0.25. The value is fixed for the whole simulation run).
    - Intraspecific competition for space/food
        - If the current node is isolated (its degree = 0), then the migratory prey dies.
        - If $Dn_{1i} > D_{U,1}$ then prey move to a randomly chosen connected node *j* and recalculate current node density
        - If $Dn_{1i} > D_{U,1}$ then the prey dies.
    - Anti-predator behaviour
        - If the node is isolated (its degree = 0), then a migratory prey dies.
        - If $Dn_{2i} > D_{U,2}$ then prey move to a randomly chosen connected node *j* and recalculate current node density
        - If $Dn_{2i} > D_{U,2}$ then the prey dies.

- Predators
    - Predators search and attack prey. If predators and prey are on the same node *i*, and handling time, T_h, equals zero, Predators kill prey with probability $P_{k,2}$ derived from a poisson distribution with mean 0.2 (for every run, a value is chosen according to a poisson distribution with mean 0.2. The value is fixed for the whole simulation run)
        - If predator is successful then it sets T_h to *3*

            - T_h decreases by 1 at every timestep
    - If predator is successful then it reproduces with probability $P_{r,2}$ derived from a poisson distribution with mean 0.2 (for every run a value is chosen according to a poisson distribution with mean 0.2. The value is fixed for the whole simulation run)
    - Predator search behaviour
        - If the current node is isolated (its degree = 0), the migratory predator dies.
        - If $Dn_{1i} < D_{L,1}$ then predators move to a randomly chosen connected node j in order to look for prey.
        - Recalculate density of the prey on the new node j
        - If $Dn_{1i} < D_{L,1}$ then the predator dies.
    - Predators die of natural death with probability $P_{m,2}$ derived from a poisson distribution with mean 0.06 (for every run, a value is chosen according to a poisson distribution with mean 0.06. The value is fixed for the whole simulation run).

Implementation.

The model is implemented in NetLogo 4.1

Definitions of node-centrality and network metrics used

- *closeness centrality (clos)*: it is used to calculate the geodesic distance between different nodes. A node is globally central if it is the neighbour of many other nodes. In other words the shorter the path between node *i* and other nodes, the more 'central' the node *i* is. Formally: $Cc(i) = \frac{1}{\sum_{j=1}^{n} P_{i,j}}$, where $P_{i,j}$ is the path from node *i* to node *j*. Since closeness centrality depends on the size of the network, it is normally standardized in order to allow comparisons; it is divided by $N-1$
- *average closeness centrality (avgclos):* The average, taken over the closeness centralities of all the nodes.

- *global efficiency (avgeg):* the efficiency in communication between a pair of nodes i, j can be defined as being inversely proportional with respect to the shortest path; hence, $\varepsilon_{ij} = \frac{1}{d_{ij}}$ for every pair of nodes i, j. If there is no path that connects nodes i, j, $d_{ij} = +\infty$ then $\varepsilon_{ij} = 0$. Given the definition of efficient communication it is possible to define the global efficiency as the average efficiency of the network. So, $E(G) = \frac{\sum_{i \neq j \in G} \varepsilon_{ij}}{N(N-1)} = \frac{1}{N(n-1)} \sum_{i \neq j \in G} \frac{1}{d_{ij}}$. In order to allow for comparison between the efficiency $E(G)$ of different networks, we need to normalize it by considering the case in which a network with the same number of nodes is fully connected (it has $\frac{N(N-1)}{2}$ edges in which case the communication is most efficient. Thus $0 \leq E(G) \leq 1$ being $E(G) = 1$ only if the network is fully connected.
- *local efficiency (el):* Local efficiency is thought of as the efficiency of sub-graphs. Formally $E_{loc} = \frac{1}{N} \sum_{i \in G} E(G_i)$, where G_i is the sub-network of the neighbours of node i.
- *average local efficiency (avgel):* The average, taken from the local efficiencies of all the nodes.

- *degree centrality (deg)*: The number of edges that are connected to a node is known as the node degree (the degree *k* of node *i* can be written as, k_i). The degree of a node is normalized.
- *average network degree (avgdeg):* The average, taken from the degrees of all nodes

- *cde:* (*clos* + *el* + *deg*)/ 3
- *average cde (avgcde): avgcde* = (*avgclos* + *avgel* + *avgdeg*) / 3

- *density (dens):* Is a measure used to calculate the "density" of the edges. Namely it is the ratio between the existent number of edges and the maximum number of possible edges of a network: $d = m \big/ [n(n-1)]/2$ where $m =$the number of edges that exist in the web and $n(n-1)/2 =$the number of possible edges (hence for big enough n, $d \cong m \big/ n^2/2$).

- *giant connected component(gcc):* it can be defined as the largest part of the network whose nodes are connected to each other. More precisely it is measured by comparing the number of nodes belonging to the giant connected component with the number of nodes that exist in a network. So, $gcc = \frac{Nc}{N}$ where N_c = number of nodes belonging to the largest connect part of the network, and *N* is the total number of nodes.

- *average cluster coefficient (avgcc):* The clustering coefficient can be thought of as a way to determine how many nearest neighbours of node *i* are also nearest neighbours to each other. More precisely, if we select a node *i* with degree k_i, then the maximum number of edges between the nodes connected to node *i* will be equal to $k_i(k_i - 1)/2$, and the actual number of edges between the k_i nodes will be equal to E_i; thus the clustering coefficient of node *i*, C_i can be defined as the ration between the maximum number of edges and the actual number of edges: $C_i = 2E_i \big/ k_i(k_i - 1)$. The average clustering coefficient is defined as the average value, taken from the sum of the clustering coefficients of all nodes over the possible *N* nodes: $C = \sum_i C_i \big/ N$.

Spearman correlations

Spearman correlations are reported in the following tables. As tables 1 and 2 show, average population levels on the whole network and on the nodes can not be directly associated with model parameters. The only internal parameter that seem to have a direct effect on population levels is the upper-prey density threshold ($D_{L,1}$) that influences average prey levels on nodes and on the network. From the correlation tables we can infer that general population levels, although they may be dependent by $D_{L,1}$, are actually dependent on a combination of the parameters and the connectivity of the network (tables 3 and 4).

More precisely, connectivity seems to be more related with averaged population levels than most of the internal parameters (when taken singularly). Thus, the main argument of the paper is reinforced. Connectivity matters and enhances coexistence probability independently of the internal parameters used.

Table 1 Spearman correlation table of prey and predators on nodes vs internal parameters.

	nodeprey	nodepred
n_1	0.0079*	-0.0051
$P_{r,1}$	0.1509*	0.2349*
n_2	-0.0013	0.0167*
$P_{r,2}$	-0.2011*	0.1925*
$P_{m,2}$	0.2392*	-0.2904*
$P_{k,2}$	-0.1269*	0.0969*
$D_{U,1}$	0.6010*	0.1900*
$D_{L,1}$	0.2077*	-0.1313*
$D_{U,2}$	-0.0071*	0.0261*

Note: * denote significance at 5% level

Table 2 Spearman correlation table of prey and predators on the whole network vs internal paramenters.

	netprey	netpred
n_1	0.0070*	-0.0055
$P_{r,1}$	0.1641*	0.2785*
n_2	-0.0037	0.0201*
$P_{r,2}$	-0.2163*	0.2063*
$P_{m,2}$	0.2591*	-0.3060*
$P_{k,2}$	-0.1393*	0.0851*
$D_{U,1}$	0.6394*	0.2267*
$D_{L,1}$	0.2249*	-0.1444*
$D_{U,2}$	-0.0050	0.0203*

Note: * denote significance at 5% level

Table 3 Spearman correlation table of average prey and predators on nodes vs node centralities.

	nodeprey	nodepred
clos	0.3002*	0.4738*
cde	0.3004*	0.4622*

Note: * denote significance at 5% level

Table 4 Spearman correlation table of average prey and predators on network vs network metrics.

	netprey	netpred
avgeg	0.2648*	0.4146*
avgel	0.2628*	0.4057*
gcc	0.2645*	0.4395*

Note: * denote significance at 5% level

Logit Regression Results for the metrics explained above

Table 5 and 6 report logit regression results for the metrics used. As it is possible to notice, results are very similar due to the fact that all the measures used have the same ecological meaning, that is, they are all responsible for the diffusion of a predator or a prey at the local level. Moreover, all measures are highly correlated as reported in table 7 and 8.

Table 5 Logistic regression results of local survival probabilities for predator populations given node centrality measures

dep var	indep var	β par est	β par est	β par est	β par est
locdpred	clos	3.505 (0.023)***			
	deg		2.787 (0.021)***		
	el			2.572 (0.195)***	
	cde				3.436 (0.023)***
	Pseudo R	0.179	0.142	0.151	0.178
	Class	67.90%	66.57%	66.73%	68.79%
	AIC	1.130	1.181	1.169	1.129

Note: Standard errors in parenthesis, *** = significant at 1% level. 100000 observations, McFadden adjusted R^2 is reported as well as the probability of correctly classifying the dependent variable given the parameter estimates (Class). Akaike Information Criterion is reported (AIC).

Table 6 Logistic regression results of global survival probabilities for predator populations given network metrics

Indep var	**dep var**	**β par est**	**β par est**	**β par est**	**β par est**	**β par est**	**β par est**	**β par est**	**β par est**
globdpred	avgclos	3.162 (0.023)***							
	avgdeg		0.311 (0.003)***						
	avgel			3.204 (0.023)***					
	avgcde				3.163 (0.023)***				
	dens					2.799 (0.225)***			
	avgeg						3.140 (0.022)***		
	gcc							3.910 (0.029)***	
	avgcc								3.264 (0.233)***
	Pseudo R	0.142	0.122	0.157	0.146	0.122	0.152	0.167	0.150
	Class	66.69%	66.72%	67.08%	66.81%	66.72%	67.49%	67.51	66.77%
	AIC	1.187	1.213	1.166	1.182	1.213	1.172	1.149	1.176

Note: Standard errors in parenthesis, *** = significant at 1% level. 100000 observations, McFadden adjusted R^2 is reported as well as the probability of correctly classifying the dependent variable given the parameter estimates (Class). Akaike Information Criterion is reported (AIC).

Table 7 Correlation between node-centrality used in the logit models presented in table 1

	clos	**deg**	**el**	**cde**
clos	1			
deg	0.9764	1		
el	0.7938	0.7461	1	
cde	0.9708	0.9520	0.9100	1

Table 8 Correlation between the network metrics used in the logit models presented in table 2

	avgclos	**avgdeg**	**avgel**	**avgcde**	**dens**	**avgeg**	**gcc**	**avgcc**
avgclos	1							
avgdeg	0.9872	1						
avgel	0.9407	0.9071	1					
avgcde	0.9937	0.9816	0.9816	1				
dens	0.9872	1	0.9071	0.9816	1			
avgeg	0.9908	0.9638	0.9476	0.9854	0.9638	1		
gcc	0.8774	0.8012	0.8870	0.8725	0.8011	0.9198	1	
avgcc	0.9478	0.9253	0.9941	0.9753	0.9252	0.9455	0.8670	1

Dynamics of the model: parameters used and graphs of the dynamics

Table 9 reports the internal species parameters, network metrics and node centralities for all the 10 nodes of the 8 runs selected and representative of the different dynamic regimes arisen from the model. Data are repeated as internal species parameters and network metrics do not change from node to node, while, obviously, node-centralities do change. As it is possible to notice from the figures (figure 1 and 2) presented following the table, different dynamics emerge, although the main qualitative differences lie in the predator extinction, thus non-coexistence between species. Extinction can be global, local (if the node in which the extinction occur is isolated or if the component on which the local extinction occurs is isolated), or temporary; that is, predators go extinct locally for a certain period of time, due to predatory strategies.

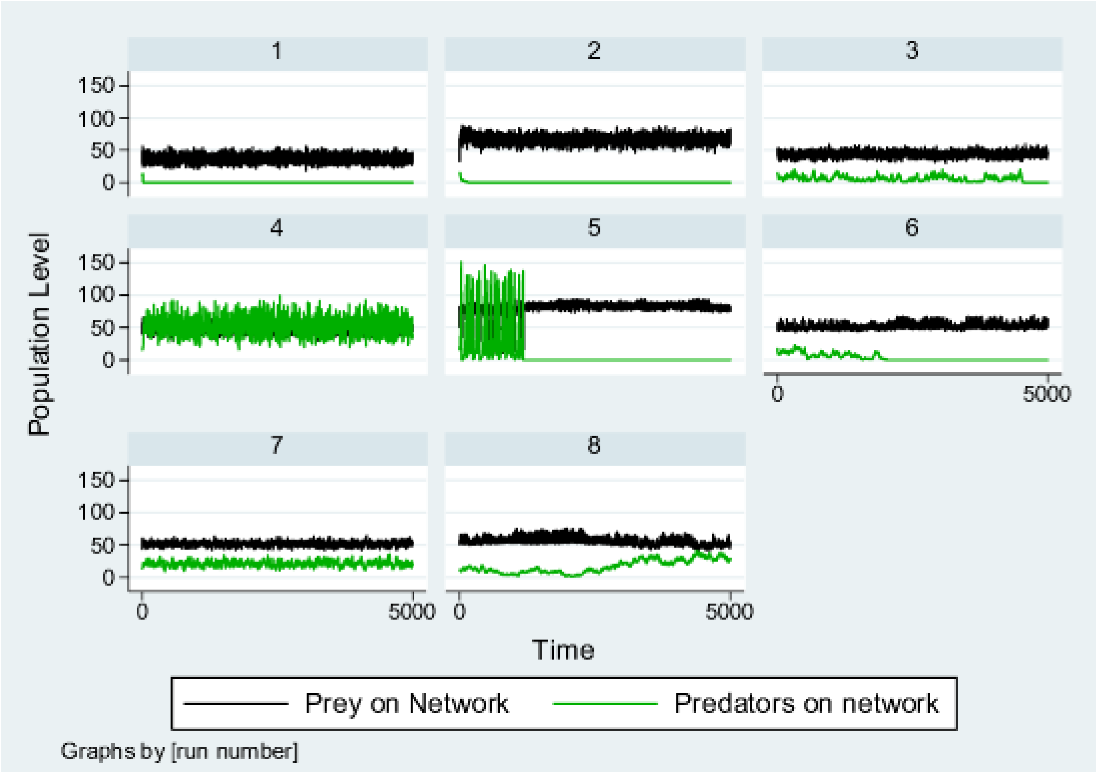
Table 9 Parameter values for selected Runs representing all different dynamic regimes; reproduction, death and predation rate in percentages

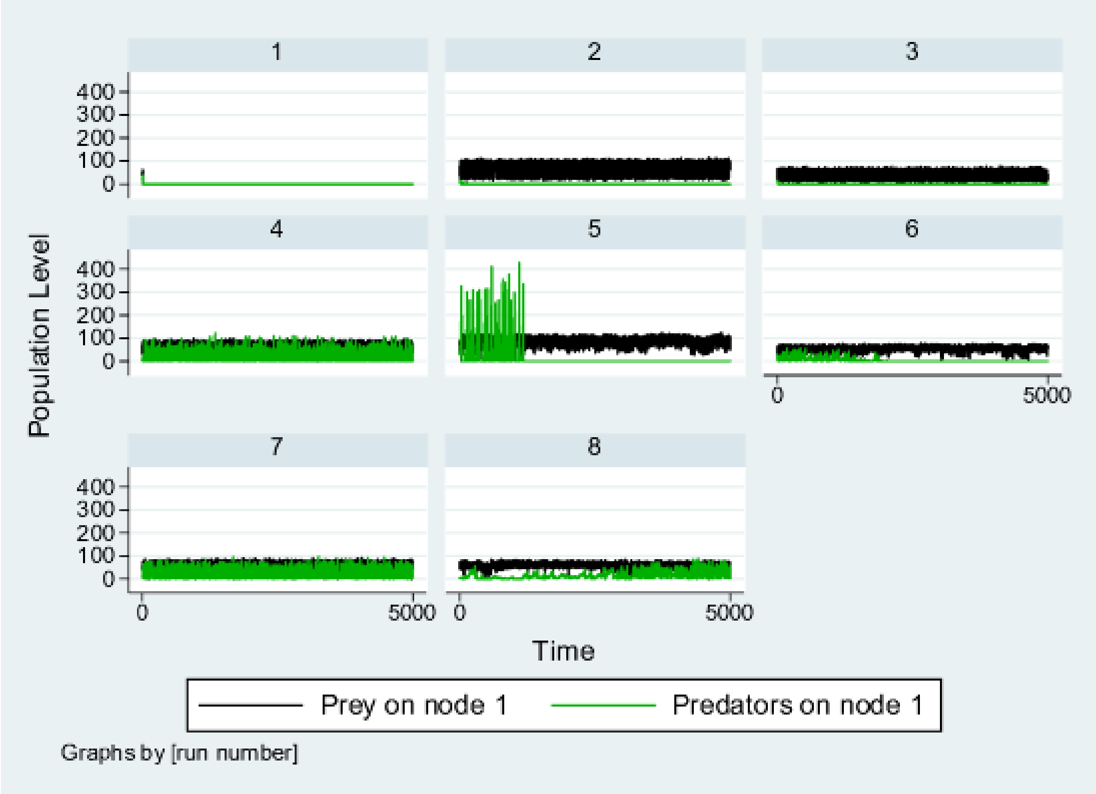
run	n_1	n_2	$P_{r,1}$	$P_{r,2}$	$P_{m,2}$	$P_{k,2}$	$D_{U,1}$	$D_{L,1}$	$D_{U,2}$	*E*	N_i	*el*	*clos*	*deg*	*cde*	*avgel*	*avgclos*	*avgdeg*	*avgcde*	*avgeg*	*gcc*	*avgcc*	*dens*
1	27	15	28	25	9	21	0.626	0.238	0.359	0	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	27	15	28	25	9	21	0.626	0.238	0.359	0	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	28	16	30	21	10	19	0.793	0.252	0.400	5	1	0.000	0.200	0.111	0.104	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	2	0.000	0.200	0.111	0.104	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	3	0.000	0.200	0.111	0.104	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	4	0.000	0.200	0.111	0.104	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	5	0.000	0.000	0.000	0.000	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	6	0.000	0.200	0.111	0.104	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	7	0.000	0.300	0.222	0.174	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	8	0.000	0.000	0.000	0.000	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	9	0.000	0.200	0.111	0.104	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
2	28	16	30	21	10	19	0.793	0.252	0.400	5	10	0.000	0.300	0.222	0.174	0.000	0.180	0.111	0.097	0.133	0.300	0.000	0.111
3	45	14	24	21	4	20	0.578	0.258	0.598	10	1	0.000	0.000	0.000	0.000	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
3	45	14	24	21	4	20	0.578	0.258	0.598	10	2	0.000	0.329	0.222	0.184	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
3	45	14	24	21	4	20	0.578	0.258	0.598	10	3	1.000	0.373	0.222	0.532	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222

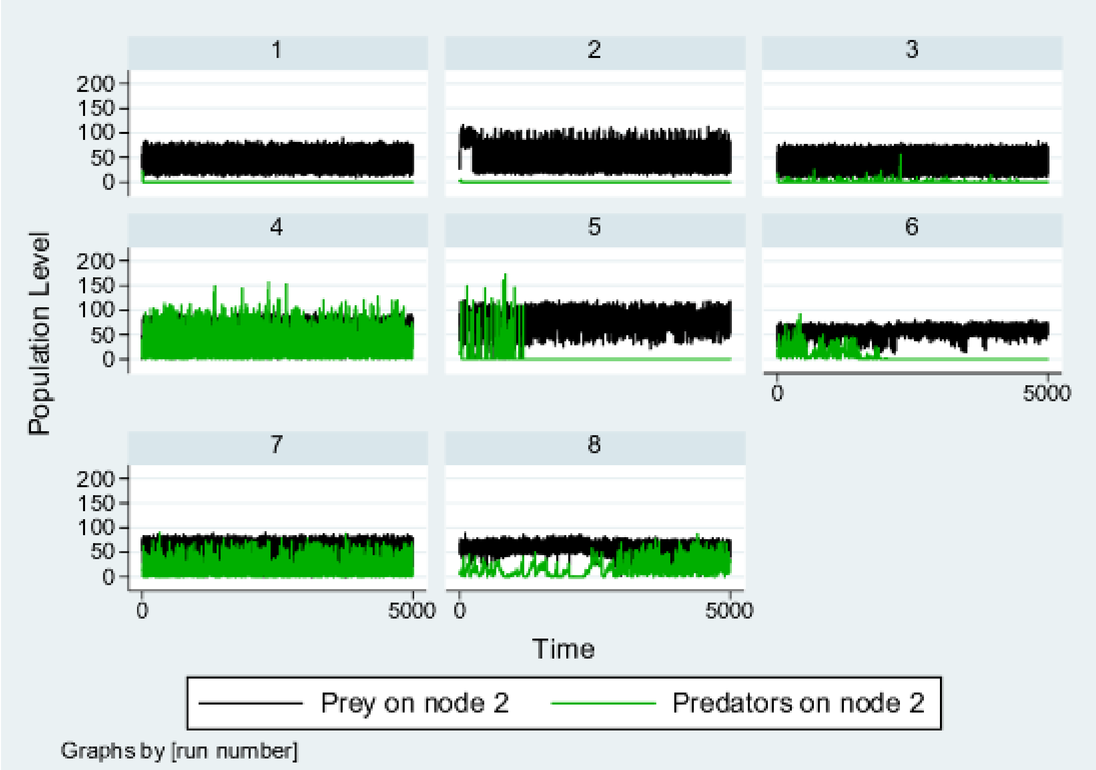
run	n_1	n_2	$P_{r,1}$	$P_{r,2}$	$P_{m,2}$	$P_{k,2}$	$D_{U,1}$	$D_{L,1}$	$D_{U,2}$	*E*	N_i	*el*	*clos*	*deg*	*cde*	*avgel*	*avgclos*	*avgdeg*	*avgcde*	*avgeg*	*gcc*	*avgcc*	*dens*
3	45	14	24	21	4	20	0.578	0.258	0.598	10	4	0.000	0.431	0.222	0.218	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
3	45	14	24	21	4	20	0.578	0.258	0.598	10	5	0.417	0.509	0.444	0.457	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
3	45	14	24	21	4	20	0.578	0.258	0.598	10	6	0.000	0.243	0.111	0.118	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
3	45	14	24	21	4	20	0.578	0.258	0.598	10	7	1.000	0.311	0.222	0.511	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
3	45	14	24	21	4	20	0.578	0.258	0.598	10	8	0.722	0.431	0.444	0.532	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
3	45	14	24	21	4	20	0.578	0.258	0.598	10	9	0.000	0.000	0.000	0.000	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
3	45	14	24	21	4	20	0.578	0.258	0.598	10	10	0.833	0.400	0.333	0.522	0.397	0.303	0.222	0.307	0.375	0.800	0.350	0.222
4	33	18	28	25	6	20	0.701	0.346	0.300	30	1	0.917	0.643	0.444	0.668	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	2	0.900	0.692	0.556	0.716	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	3	1.000	0.643	0.444	0.696	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	4	1.000	0.692	0.556	0.749	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	5	0.821	0.900	0.889	0.870	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	6	0.792	1.000	1.000	0.931	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	7	0.833	0.750	0.667	0.750	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	8	0.857	0.818	0.778	0.818	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	9	0.900	0.750	0.667	0.772	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
4	33	18	28	25	6	20	0.701	0.346	0.300	30	10	0.900	0.750	0.667	0.772	0.892	0.764	0.667	0.774	0.833	1.000	0.784	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	1	0.839	0.900	0.889	0.876	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	2	1.000	0.600	0.444	0.681	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	3	0.900	0.750	0.667	0.772	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	4	0.857	0.818	0.778	0.818	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	5	0.839	0.900	0.889	0.876	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	6	0.857	0.818	0.778	0.818	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	7	0.867	0.750	0.667	0.761	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	8	1.000	0.529	0.333	0.621	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	9	0.867	0.750	0.667	0.761	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
5	42	16	31	20	3	24	0.856	0.217	0.392	30	10	0.950	0.643	0.556	0.716	0.898	0.746	0.667	0.770	0.826	1.000	0.795	0.667
6	46	18	28	31	9	12	0.545	0.349	0.346	35	1	0.893	0.900	0.889	0.894	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	2	0.861	1.000	1.000	0.954	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	3	0.911	0.900	0.889	0.900	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	4	0.861	1.000	1.000	0.954	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	5	1.000	0.750	0.667	0.806	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	6	0.905	0.818	0.778	0.834	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	7	1.000	0.692	0.556	0.749	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	8	0.911	0.900	0.889	0.900	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	9	1.000	0.643	0.444	0.696	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
6	46	18	28	31	9	12	0.545	0.349	0.346	35	10	1.000	0.750	0.667	0.806	0.934	0.835	0.778	0.849	0.889	1.000	0.868	0.778
7	39	13	23	12	1	27	0.664	0.330	0.484	40	1	0.931	1.000	1.000	0.977	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889

run	n_1	n_2	$P_{r,1}$	$P_{r,2}$	$P_{m,2}$	$P_{k,2}$	$D_{U,1}$	$D_{L,1}$	$D_{U,2}$	*E*	N_i	*el*	*clos*	*deg*	*cde*	*avgel*	*avgclos*	*avgdeg*	*avgcde*	*avgeg*	*gcc*	*avgcc*	*dens*
7	39	13	23	12	1	27	0.664	0.330	0.484	40	2	0.964	0.900	0.889	0.918	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
7	39	13	23	12	1	27	0.664	0.330	0.484	40	3	0.931	1.000	1.000	0.977	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
7	39	13	23	12	1	27	0.664	0.330	0.484	40	4	0.931	1.000	1.000	0.977	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
7	39	13	23	12	1	27	0.664	0.330	0.484	40	5	0.931	1.000	1.000	0.977	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
7	39	13	23	12	1	27	0.664	0.330	0.484	40	6	0.976	0.818	0.778	0.857	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
7	39	13	23	12	1	27	0.664	0.330	0.484	40	7	1.000	0.818	0.778	0.865	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
7	39	13	23	12	1	27	0.664	0.330	0.484	45	8	1.000	0.750	0.667	0.806	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
7	39	13	23	12	1	27	0.664	0.330	0.484	40	9	1.000	0.818	0.778	0.865	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
7	39	13	23	12	1	27	0.664	0.330	0.484	40	10	0.931	1.000	1.000	0.977	0.959	0.910	0.889	0.919	0.944	1.000	0.919	0.889
8	40	13	34	16	8	24	0.580	0.248	0.475	45	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	40	13	34	16	8	24	0.580	0.248	0.475	45	10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

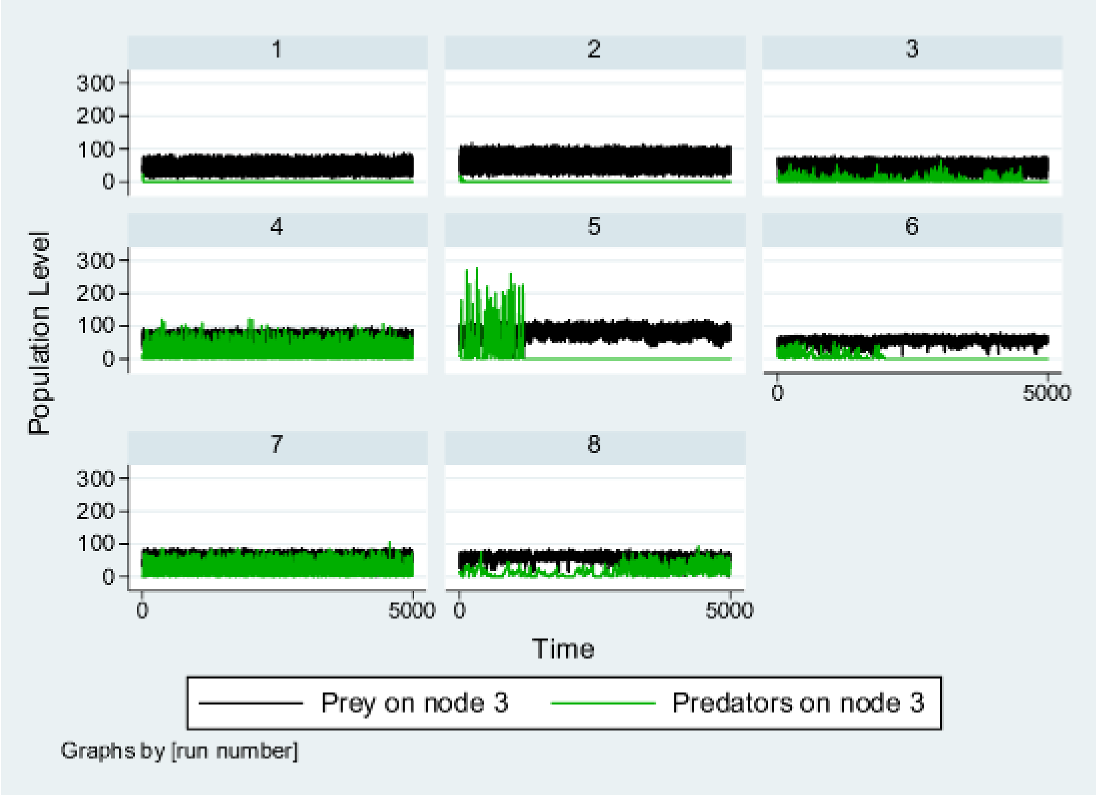
Fig. 1 Comparing the dynamics of the model for the 8 selected runs. Parameter values for the runs are reported in table 5. Figures are divided by node, commencing with the global scale (the whole network, where populations are divided by 10).



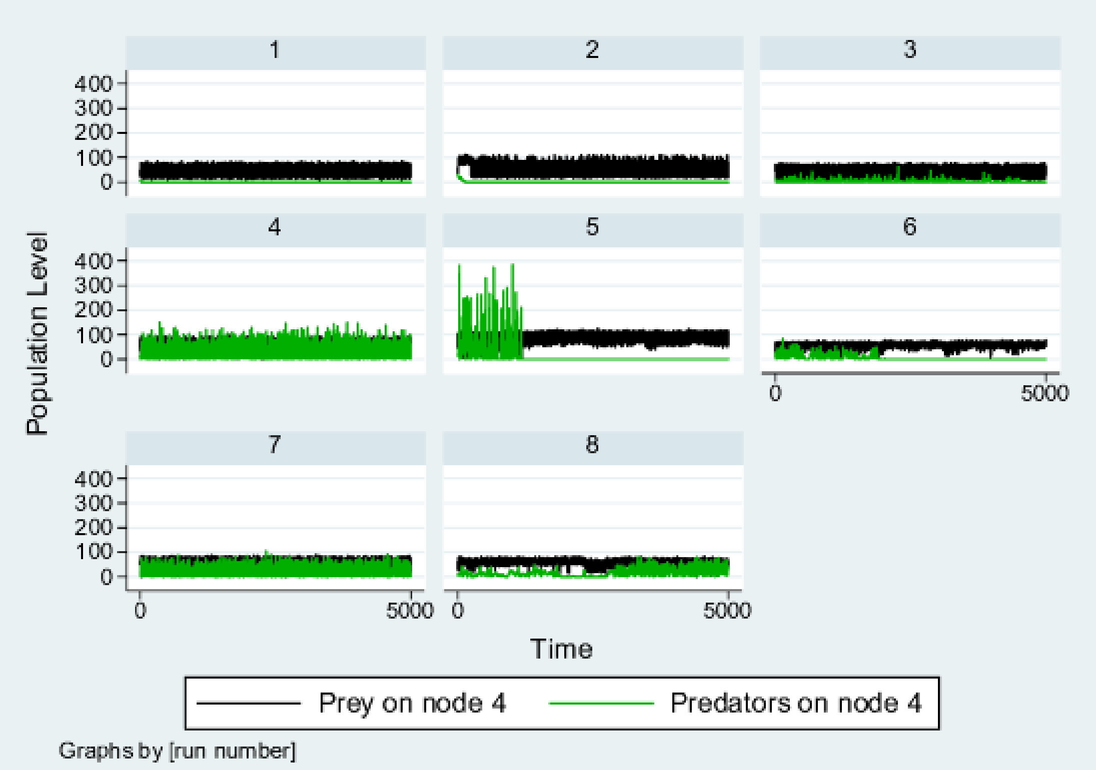



1
2
3
4
5
6
7
8
200
150
100
50
0
Population Level
Time
0
5000
Prey on node 2
Predators on node 2
Graphs by [run number]

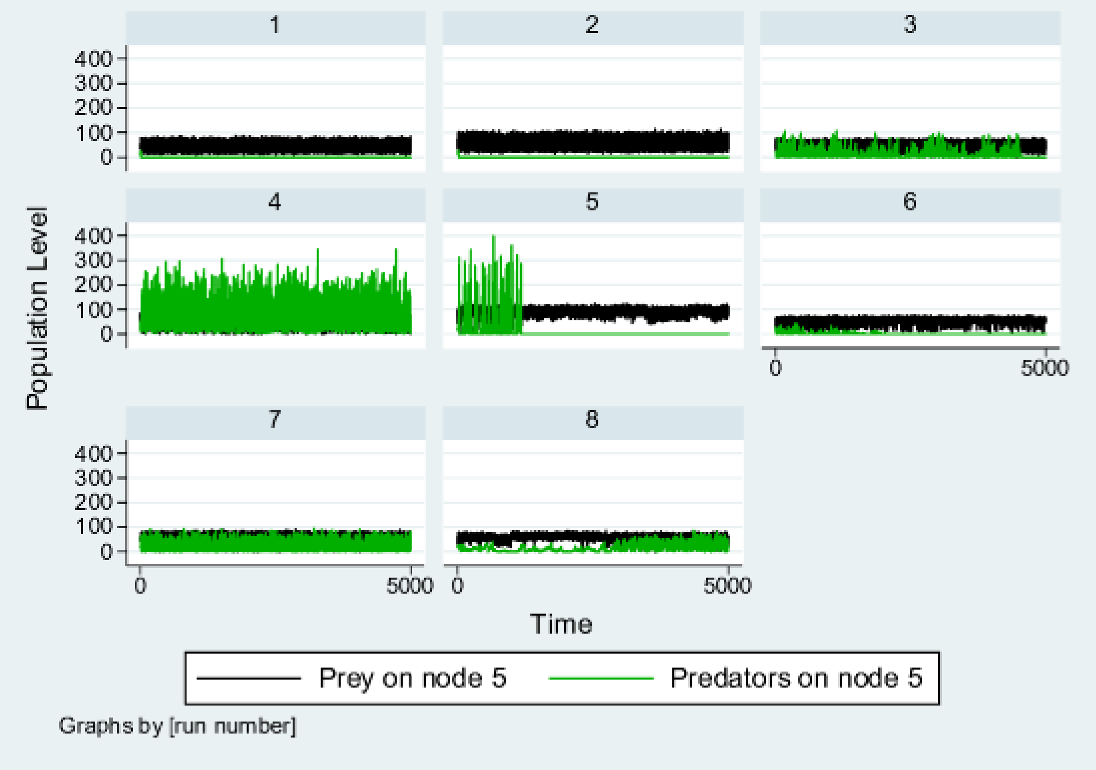
1


1
2
3
4
5
6
7
8
300
200
100
0
Population Level
Time
0
5000
Prey on node 3
Predators on node 3
Graphs by [run number]

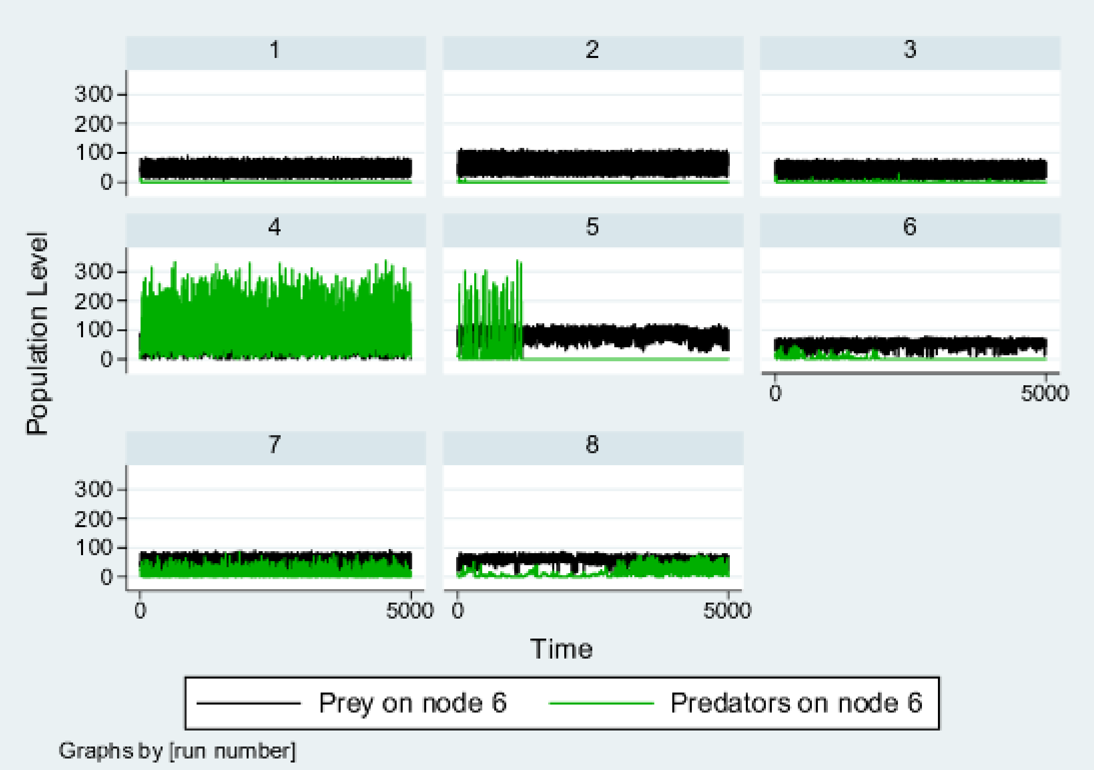
2


1
2
3
4
5
6
7
8
400
300
200
100
0
0
5000
Population Level
Time
Prey on node 4
Predators on node 4
Graphs by [run number]

1

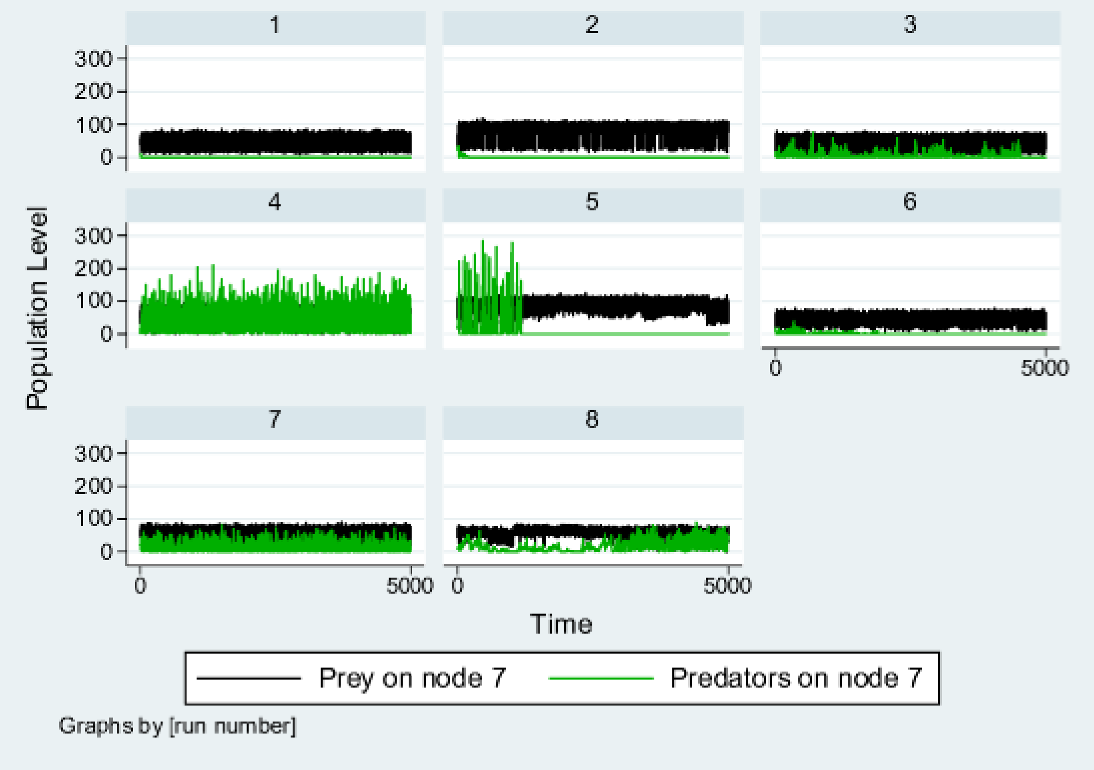

1
2
3
4
5
6
7
8
400
300
200
100
0
0
5000
Population Level
Time
Prey on node 5
Predators on node 5
Graphs by [run number]

2



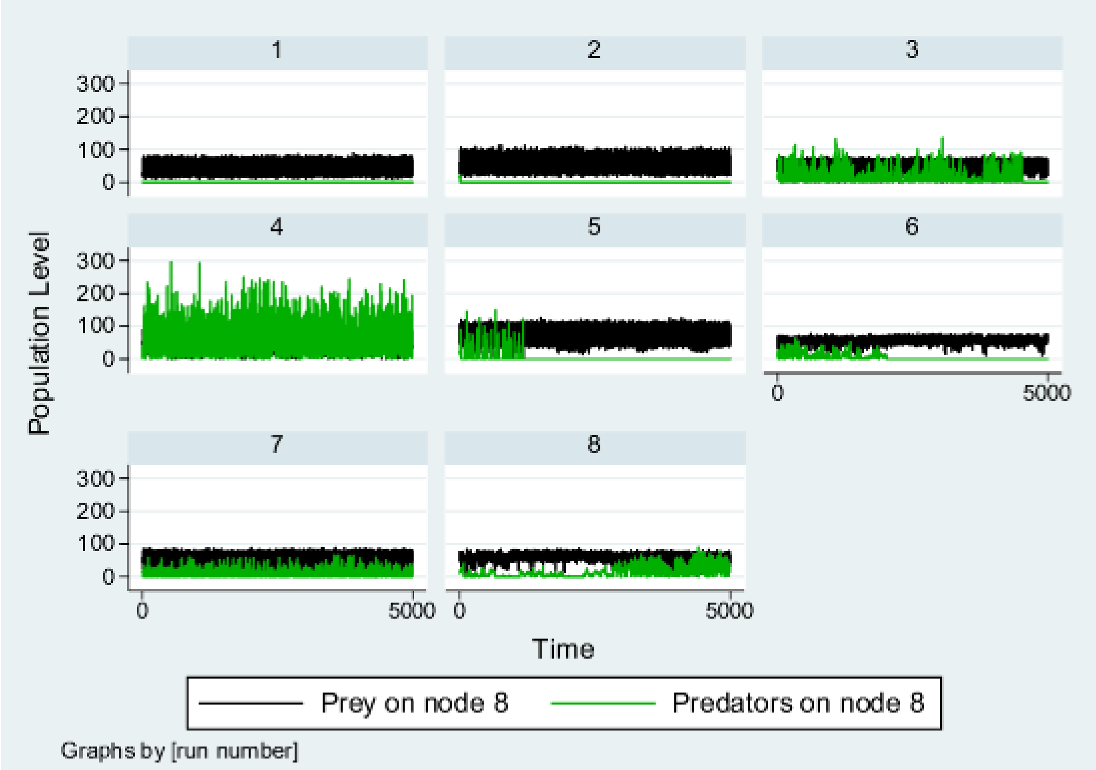
1
2
3
4
5
6
7
8
300
200
100
0
Population Level
0
5000
Time
Prey on node 6
Predators on node 6
Graphs by [run number]

1



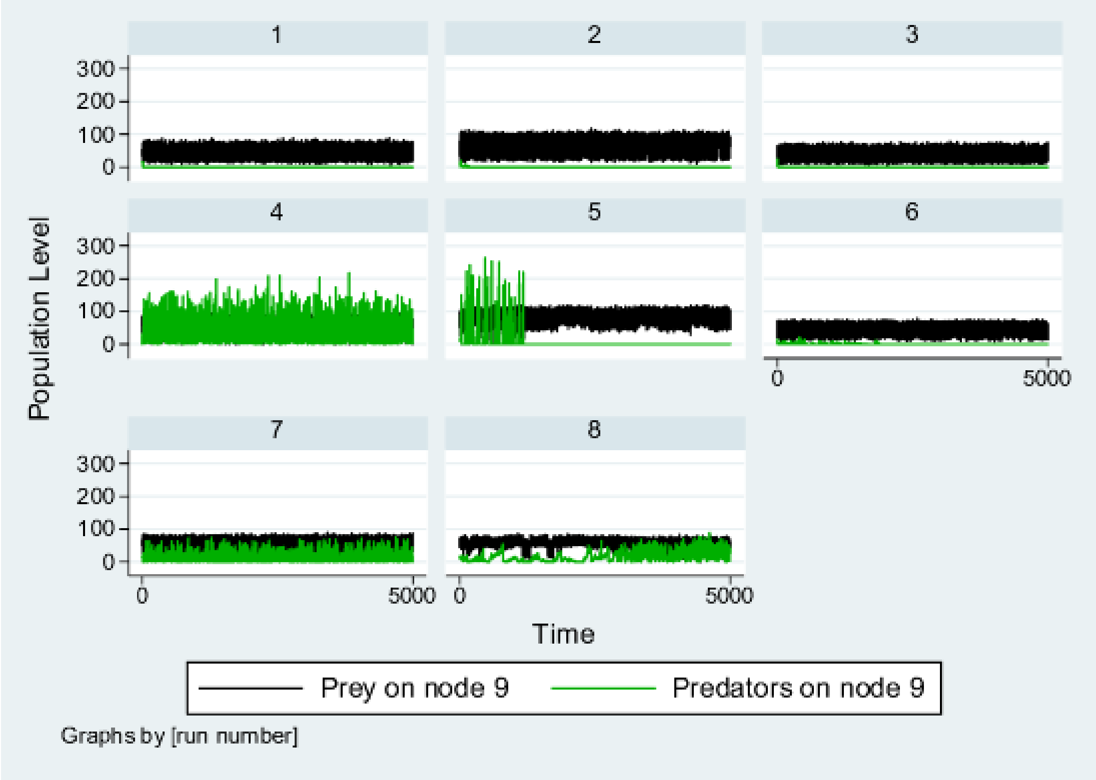
1
2
3
4
5
6
7
8
300
200
100
0
Population Level
0
5000
Time
Prey on node 7
Predators on node 7
Graphs by [run number]

2



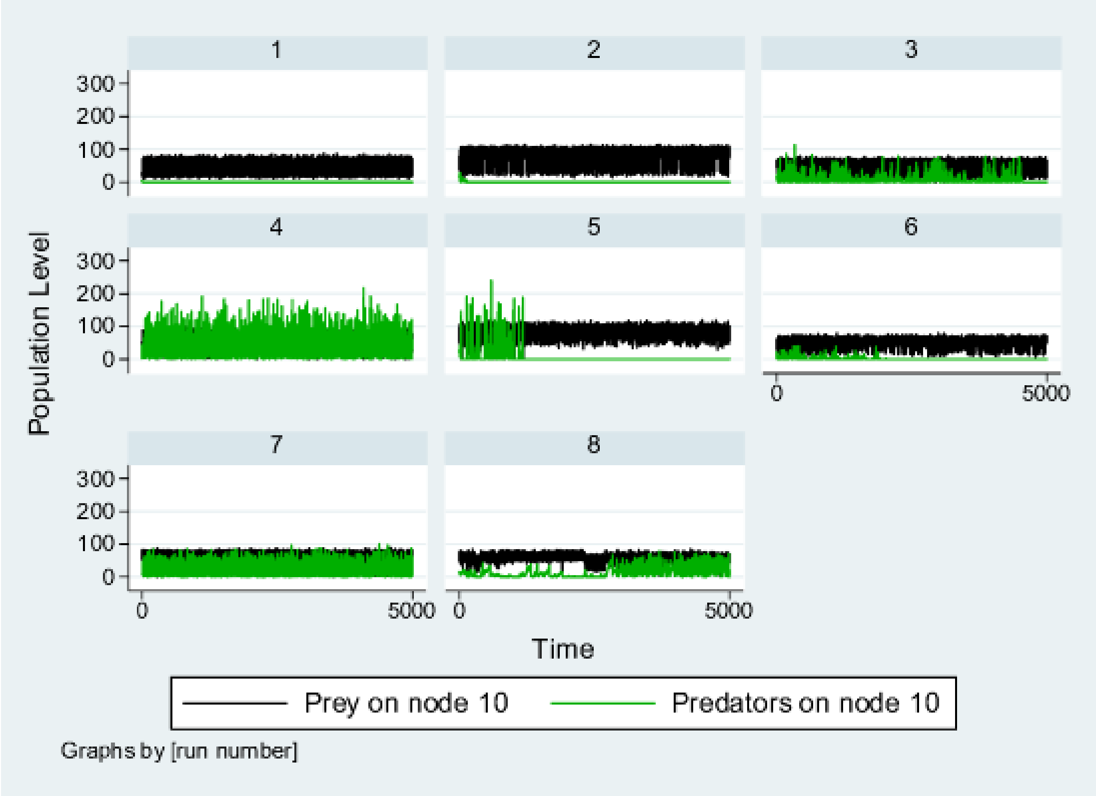
1
2
3
4
5
6
7
8
300
200
100
0
0
5000
Population Level
Time
Prey on node 8
Predators on node 8
Graphs by [run number]

1



1
2
3
4
5
6
7
8
300
200
100
0
0
5000
Population Level
Time
Prey on node 9
Predators on node 9
Graphs by [run number]

2

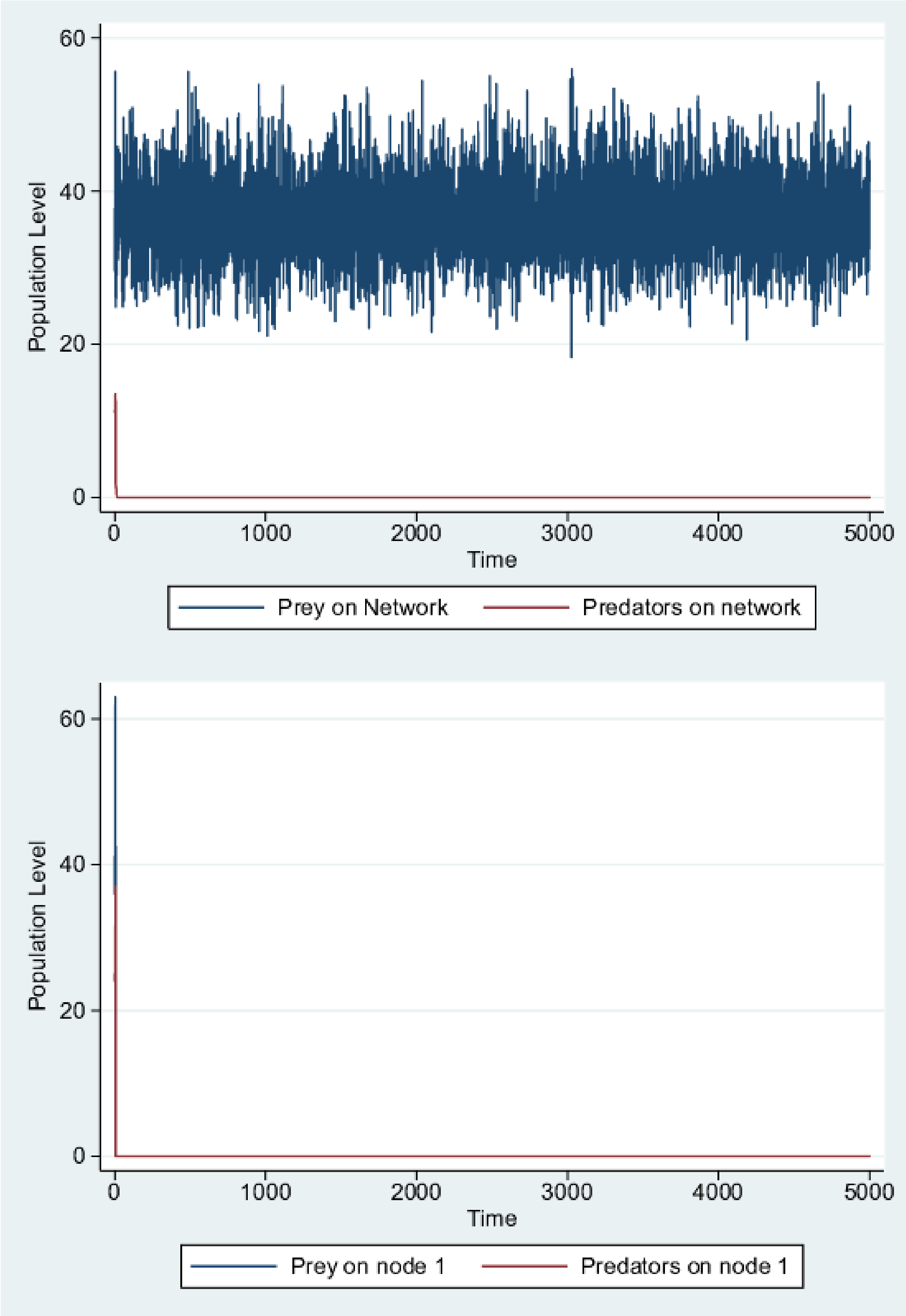

1
2
3
4
5
6
7
8
300
200
100
0
Population Level
0
5000
Time
Prey on node 10
Predators on node 10
Graphs by [run number]

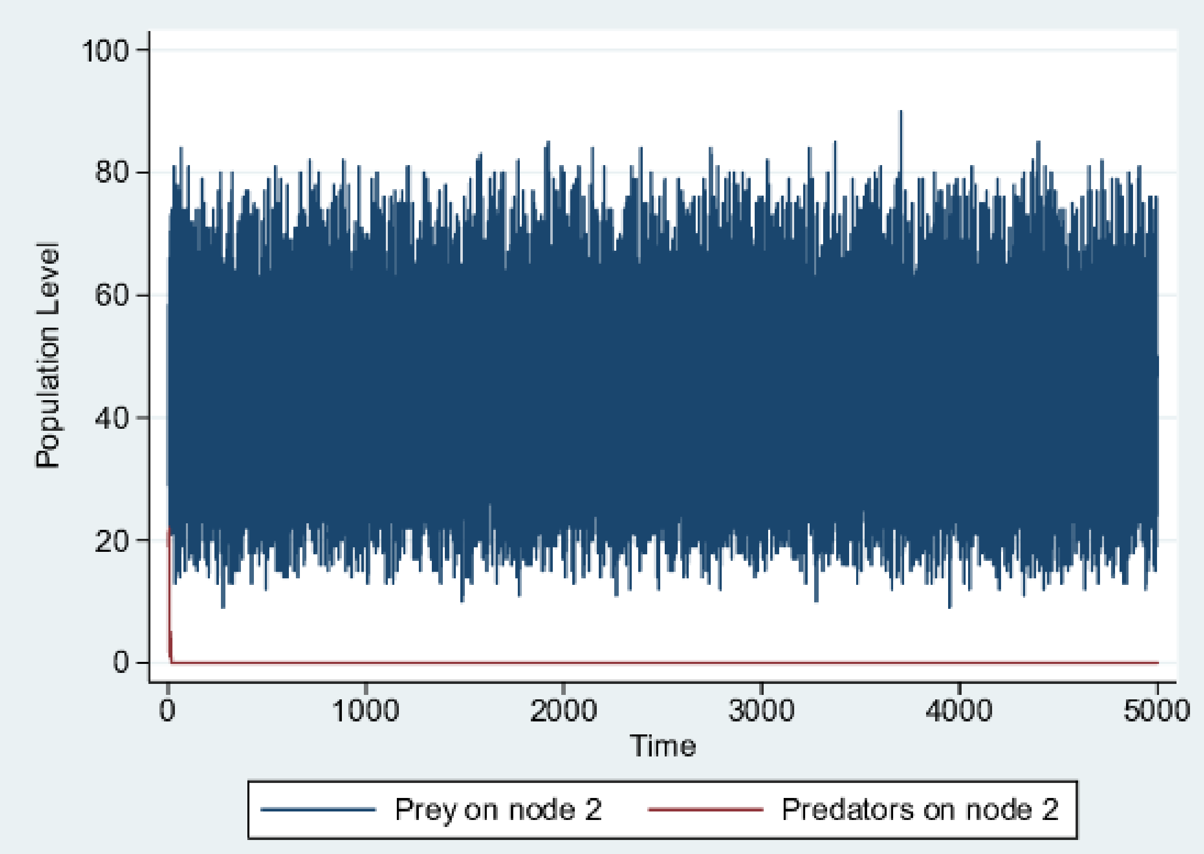
1

Fig. 2 Dynamics of the model for the 8 selected runs. Parameter values for the runs are reported in table 5.

Figure 2 is divided by RUN and for each dynamics happening on the network and all nodes are shown.

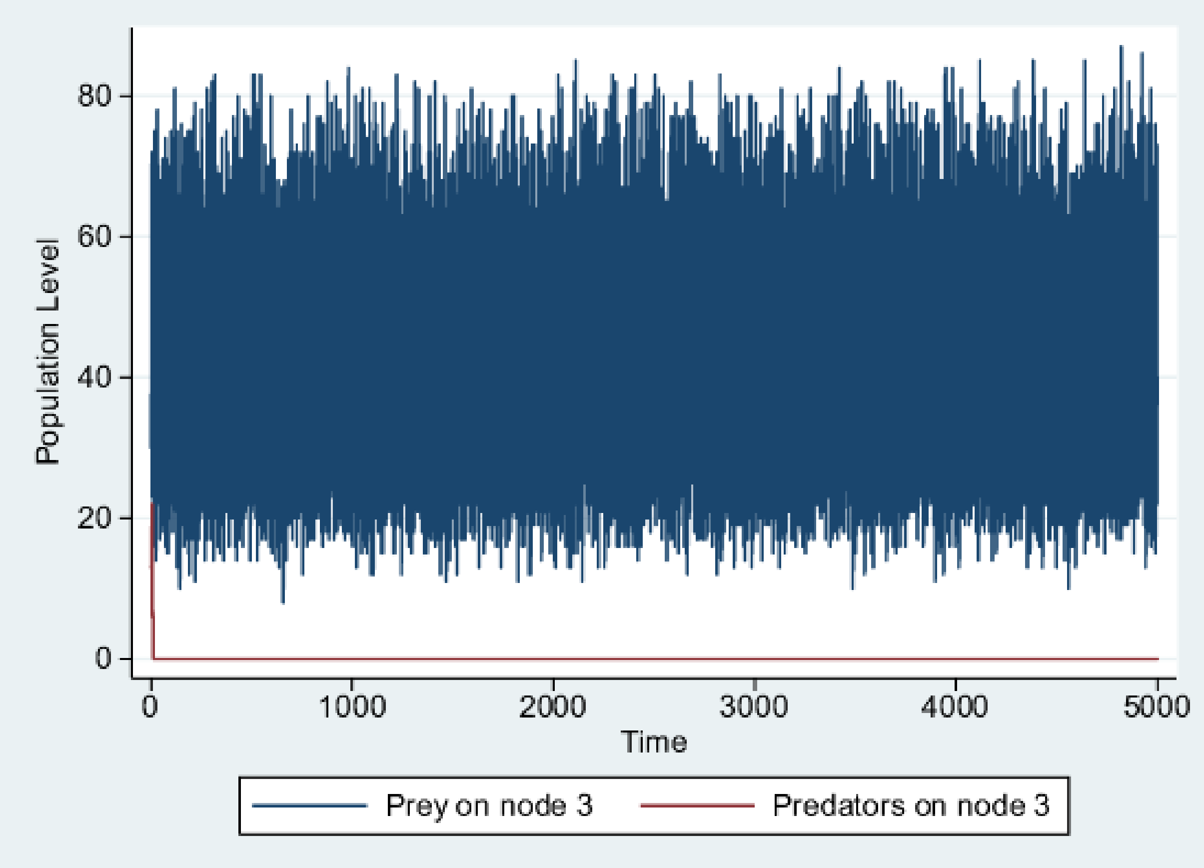
RUN 1





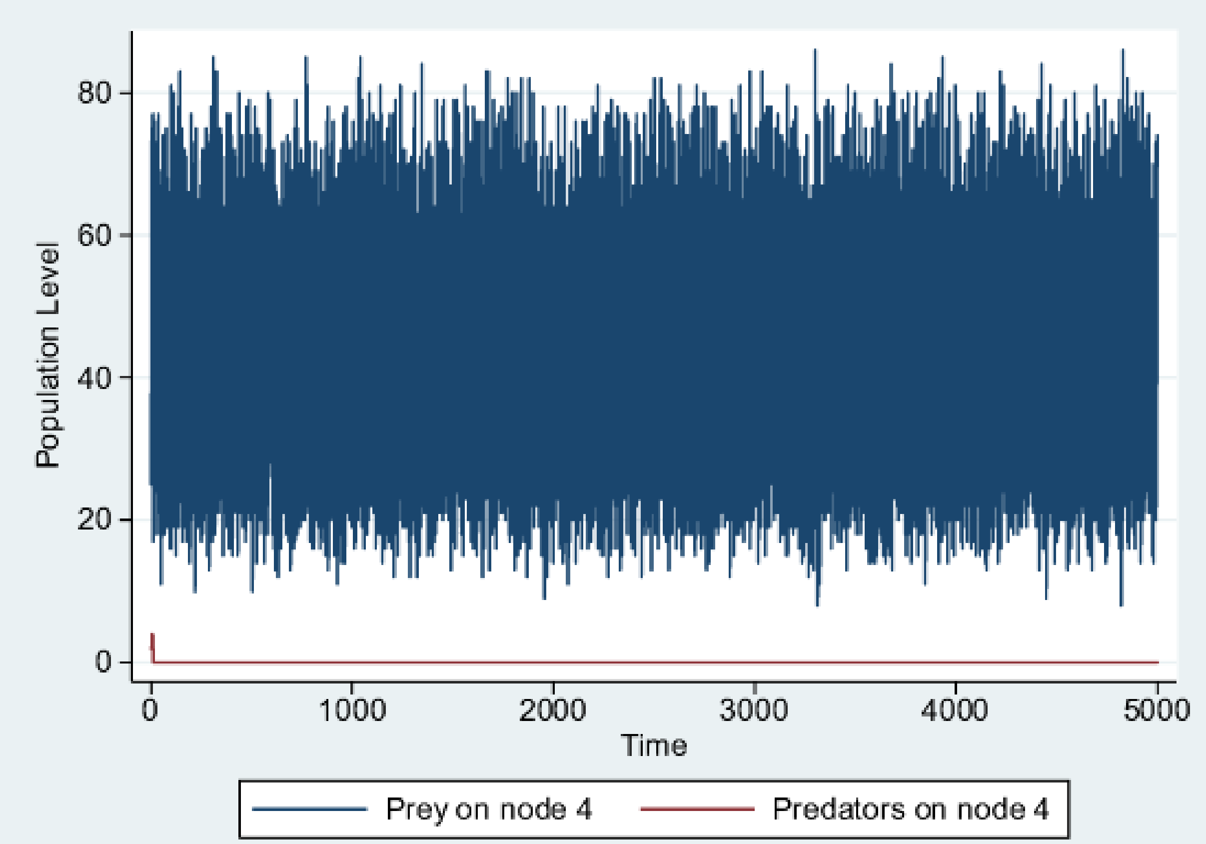
100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 2
Predators on node 2

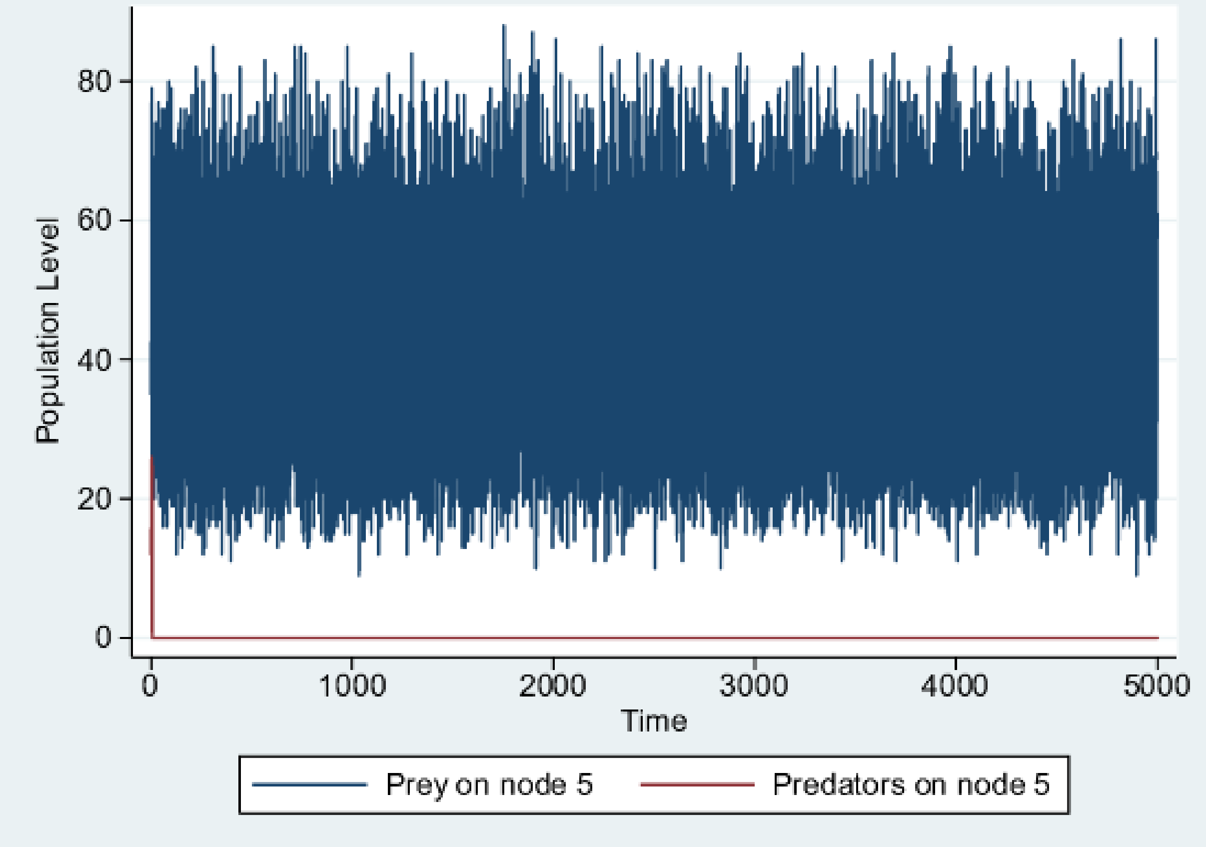
1

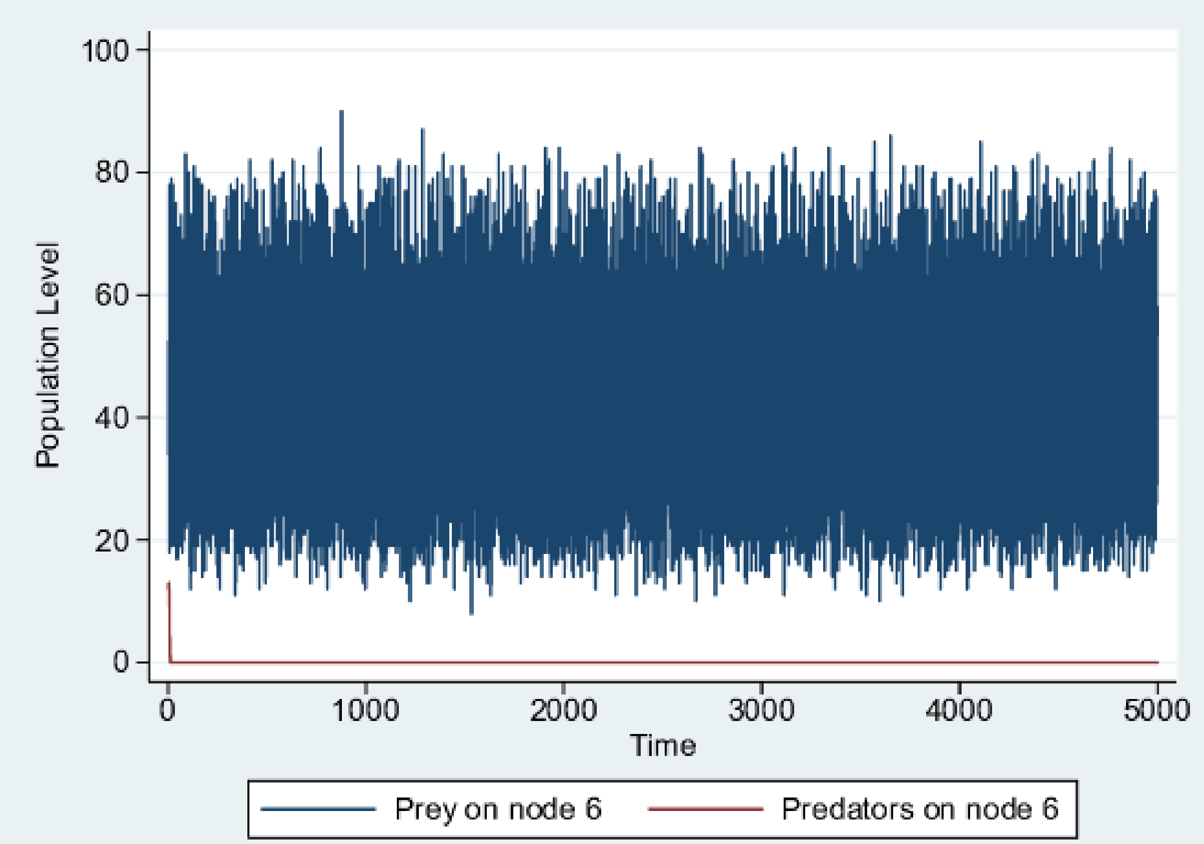


80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 3
Predators on node 3

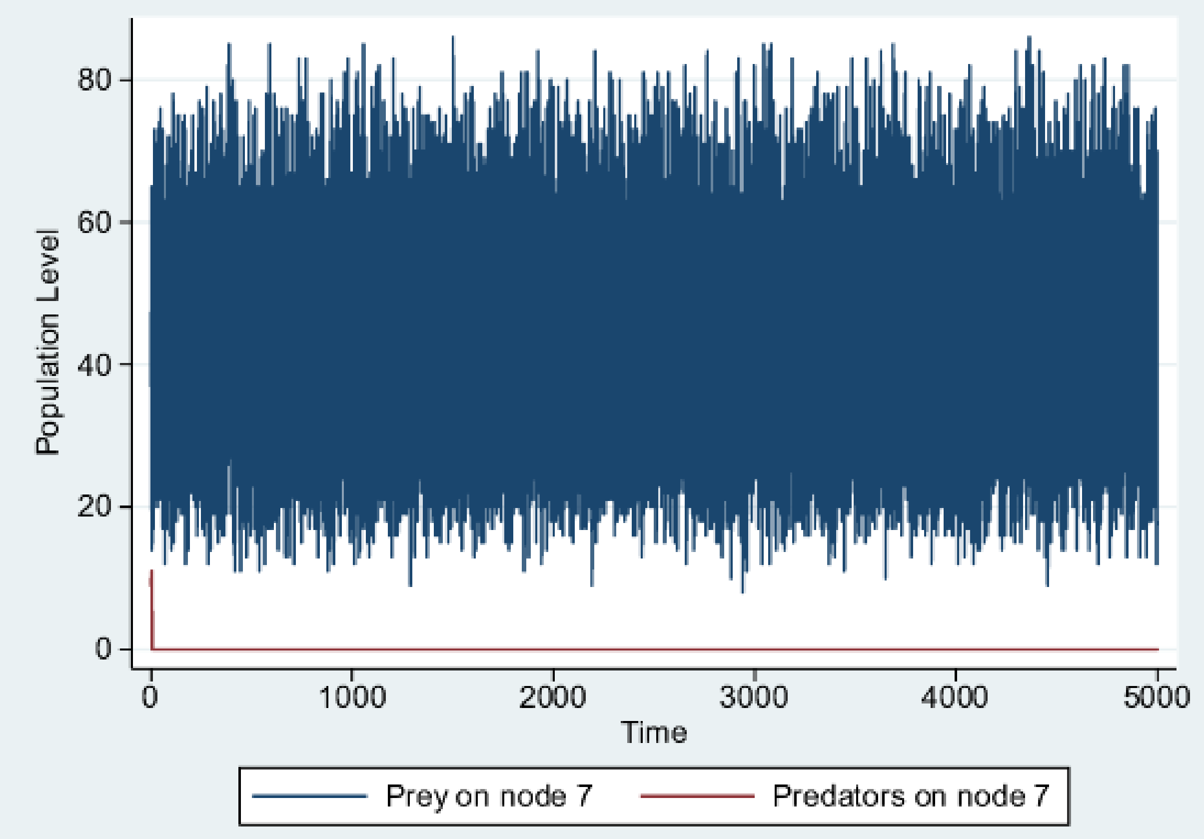
2


Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 4
Predators on node 4
1

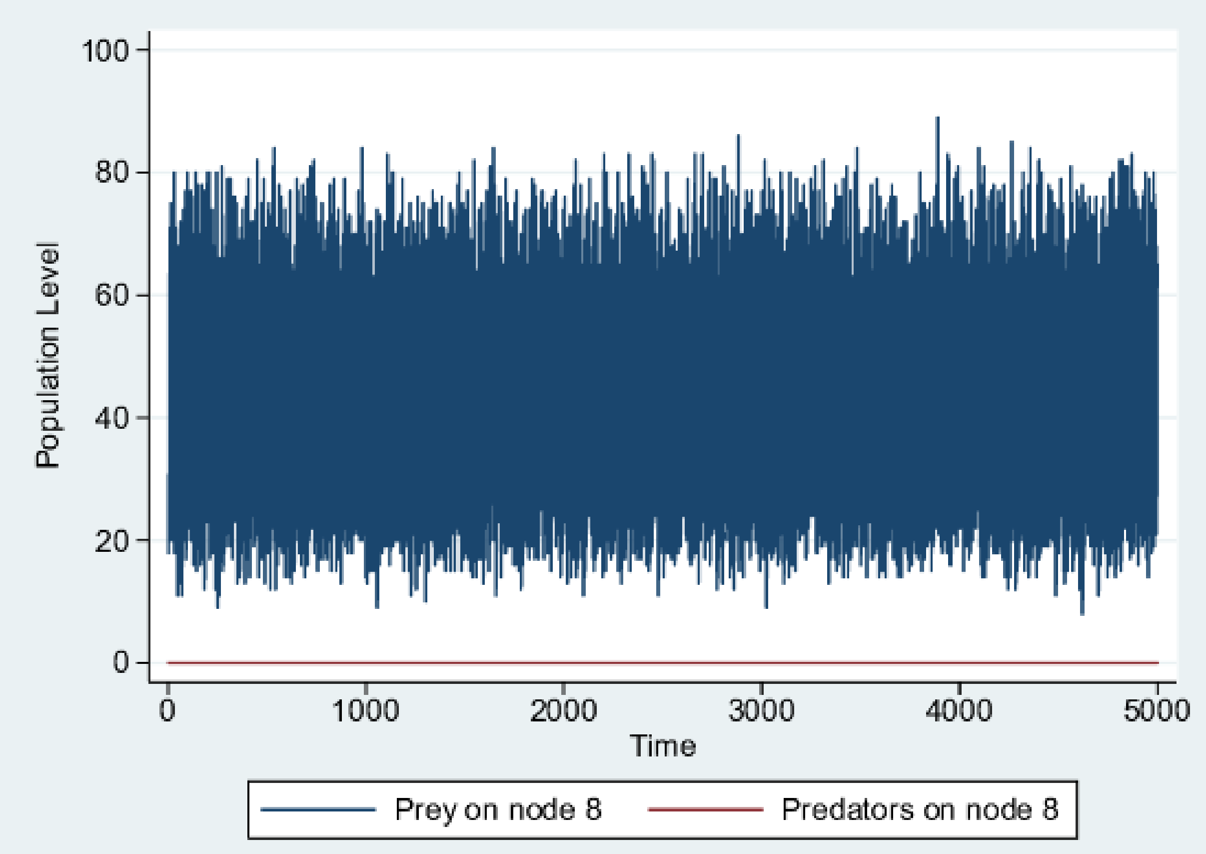

Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 5
Predators on node 5
2


Population Level
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 6
Predators on node 6

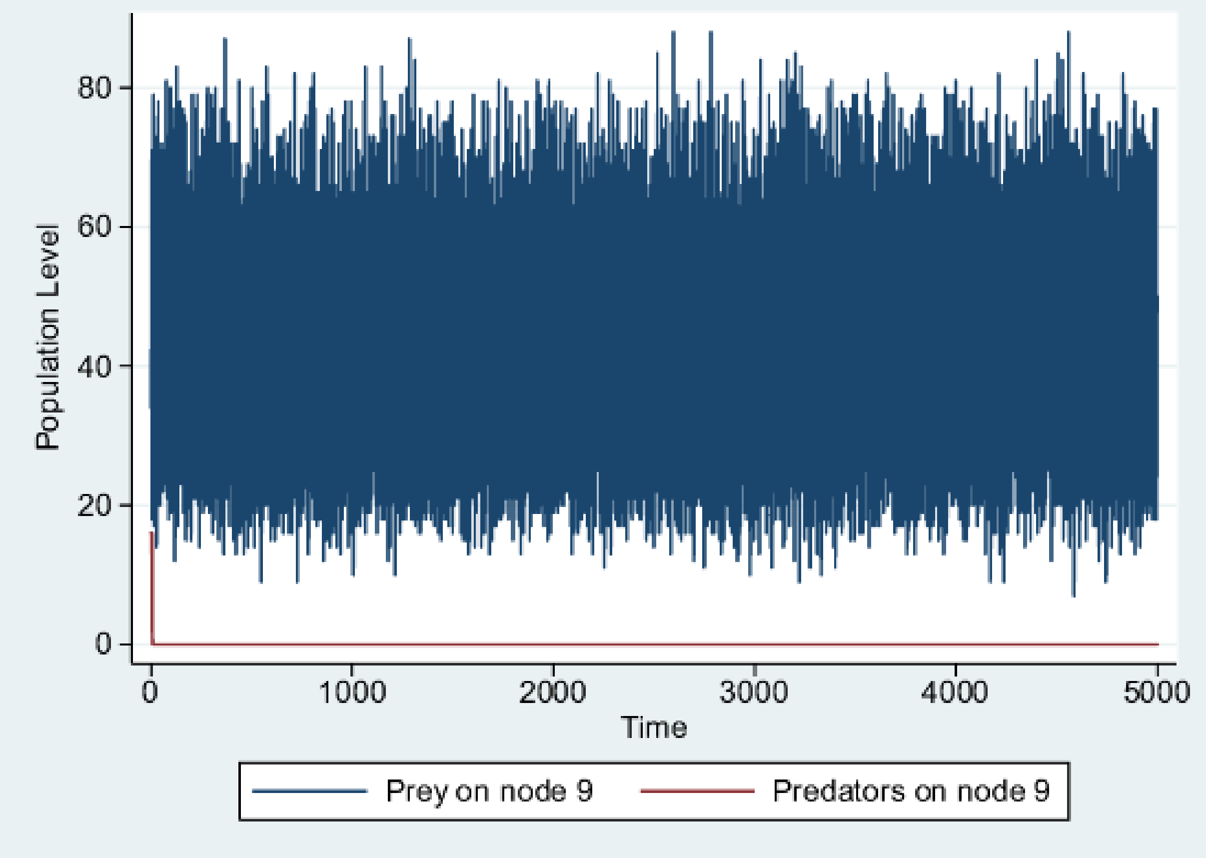
1


Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 7
Predators on node 7

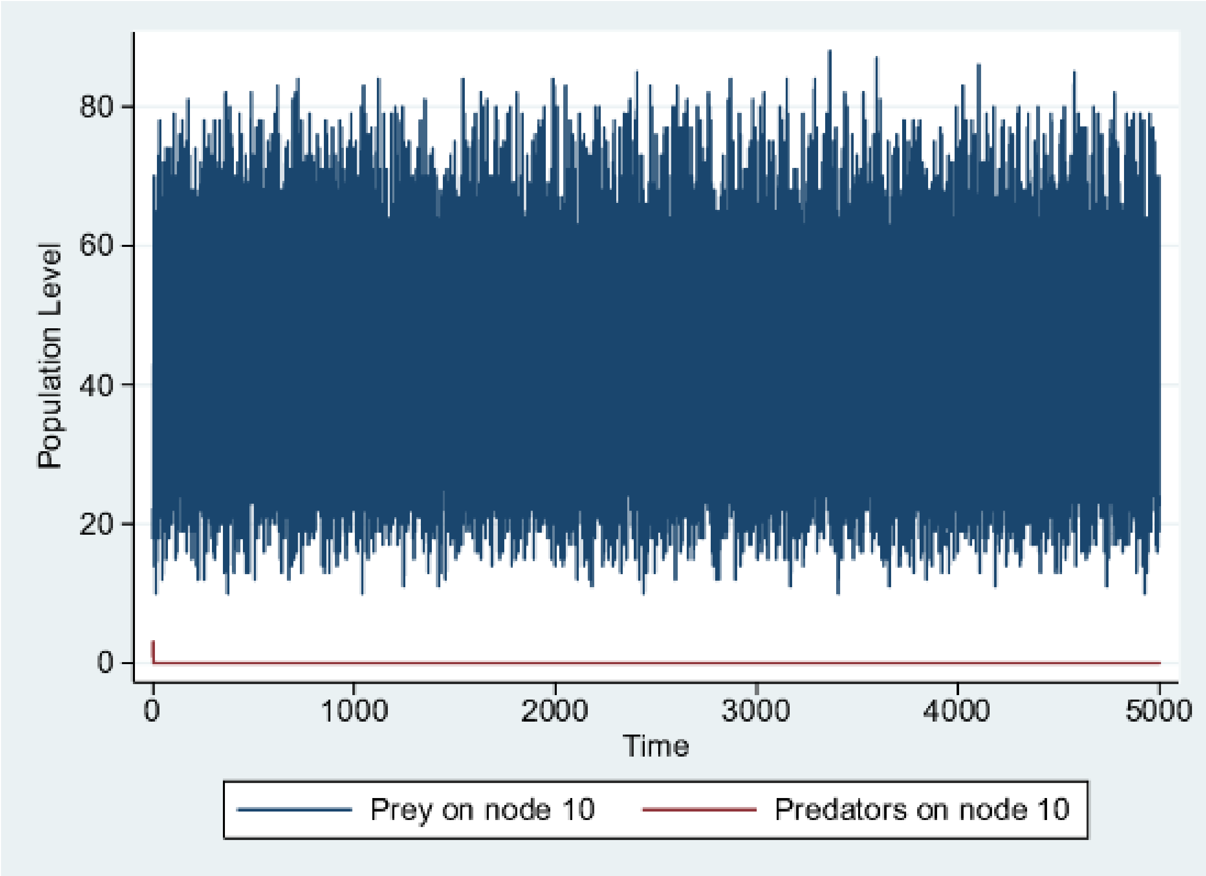
2


100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 8
Predators on node 8

1


80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 9
Predators on node 9

2



Population Level
80
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40
20
0
0
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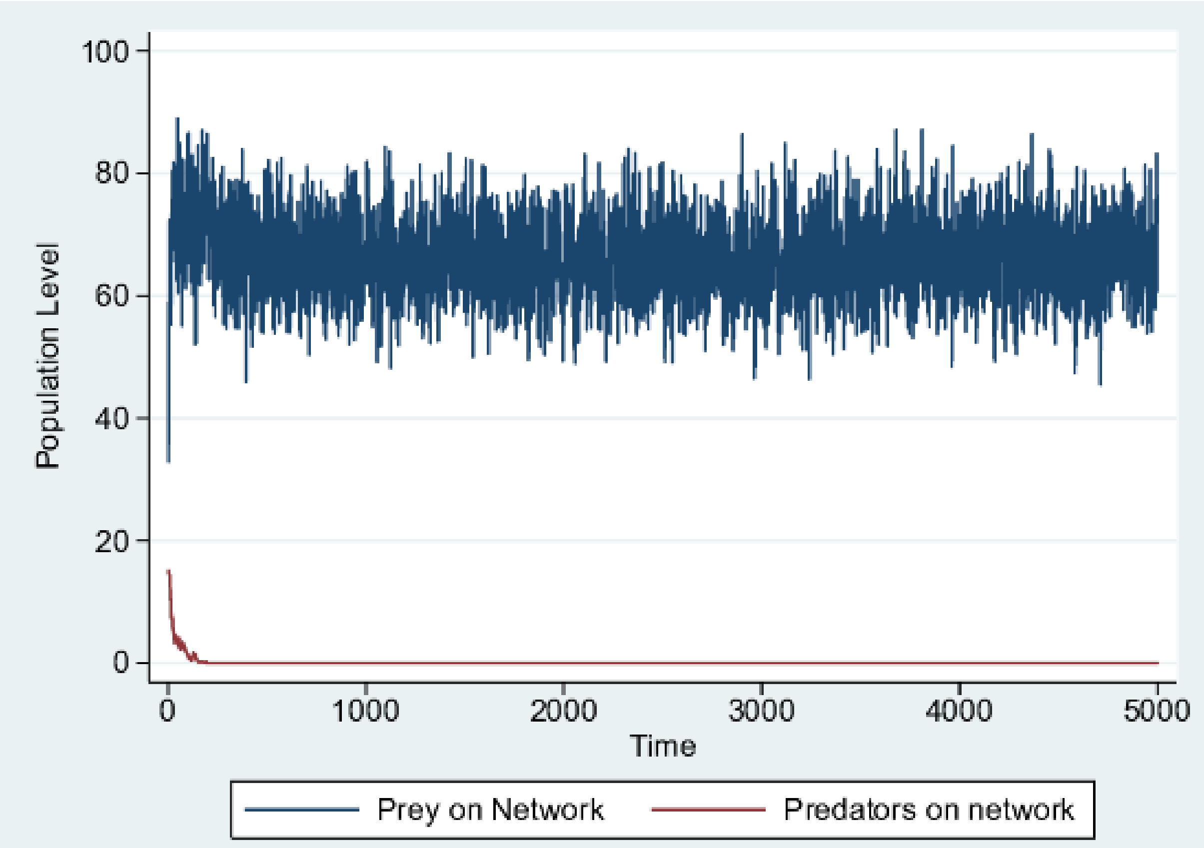
2000
3000
4000
5000
Time
Prey on node 10
Predators on node 10

1

RUN 2


Population Level
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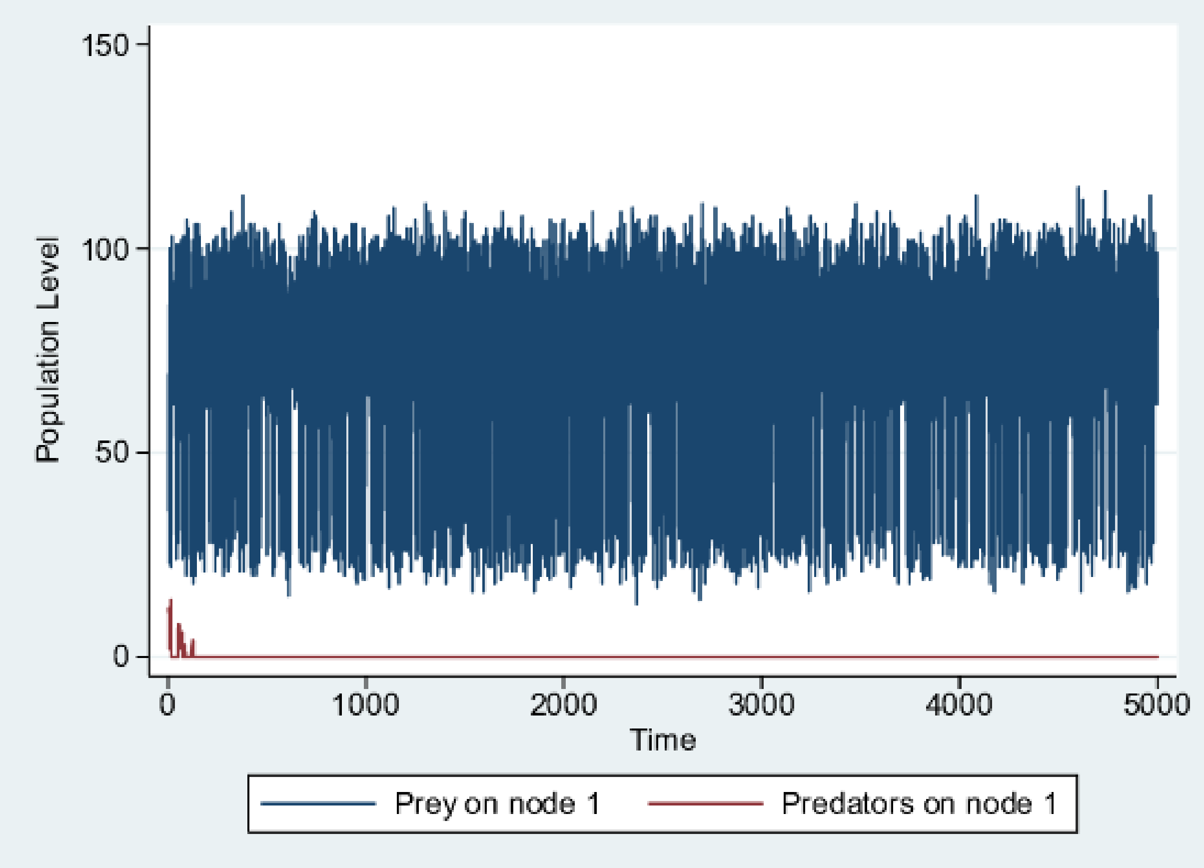
5000
Time
Prey on Network
Predators on network


Population Level
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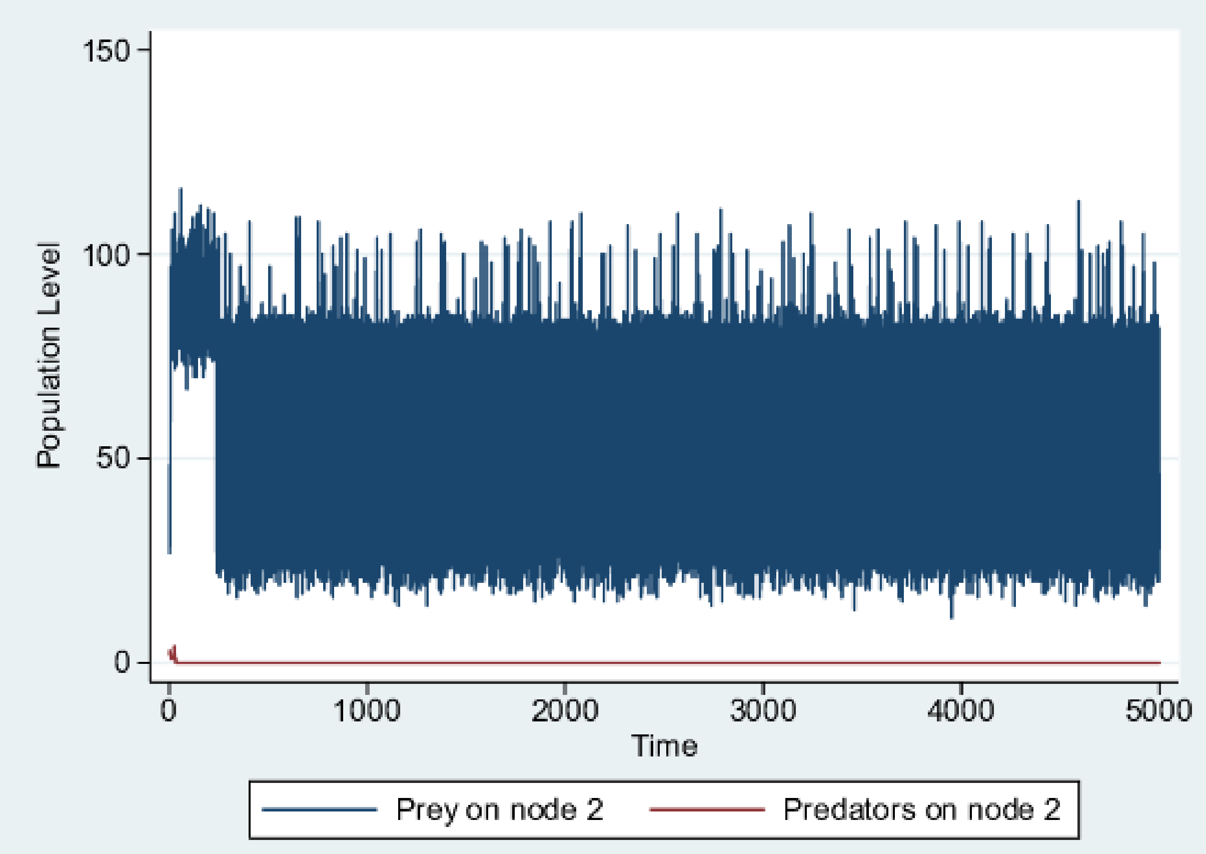
Time
Prey on node 1
Predators on node 1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Population Level
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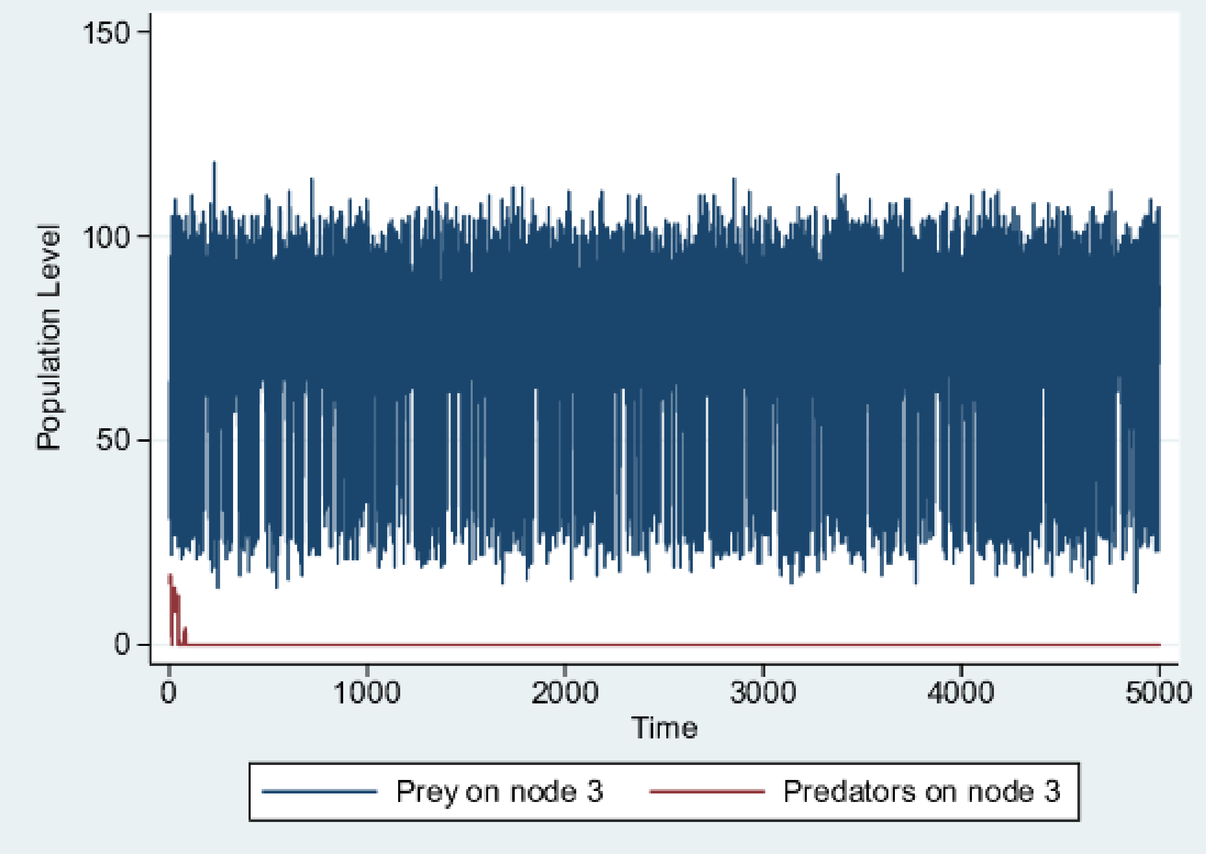
Time
Prey on node 2
Predators on node 2

1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Population Level
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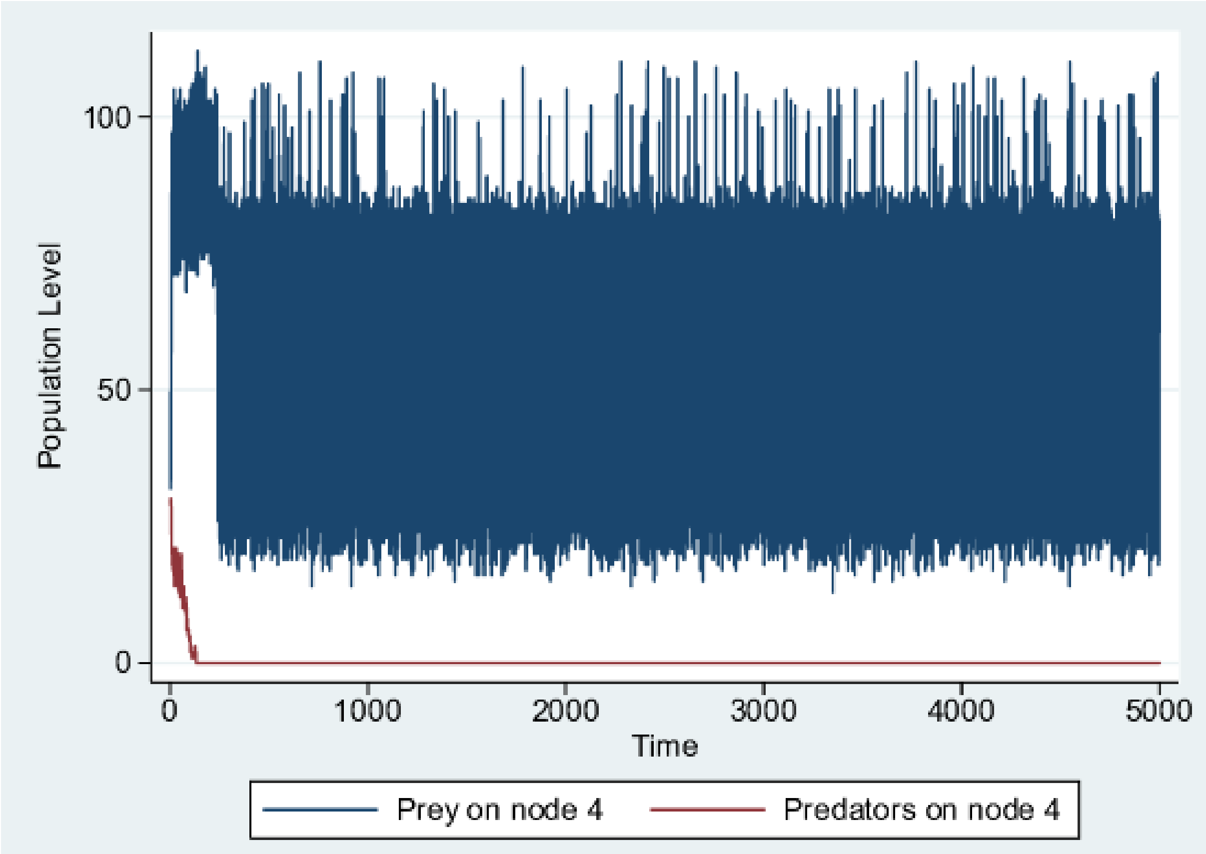
5000
Time
Prey on node 3
Predators on node 3

2



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Population Level
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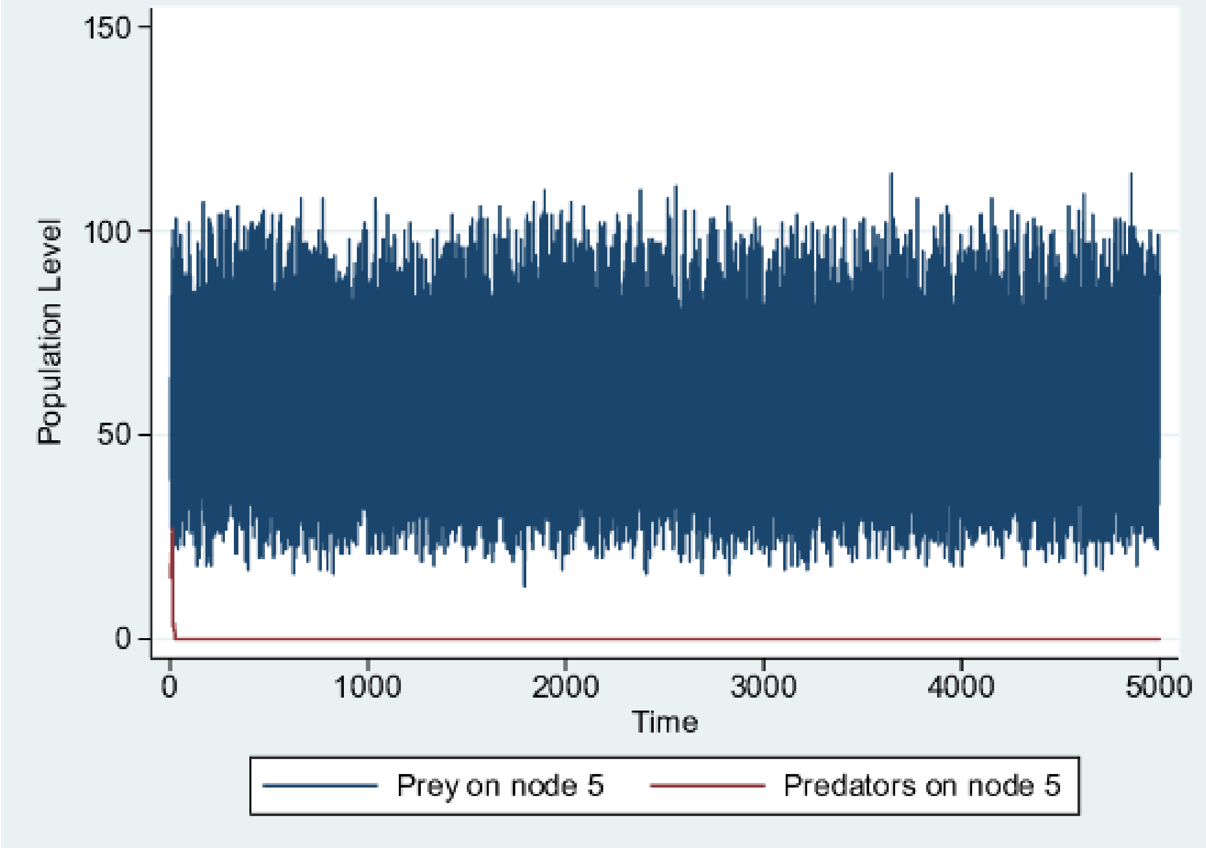
Time
Prey on node 4
Predators on node 4

1



150
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Population Level
0
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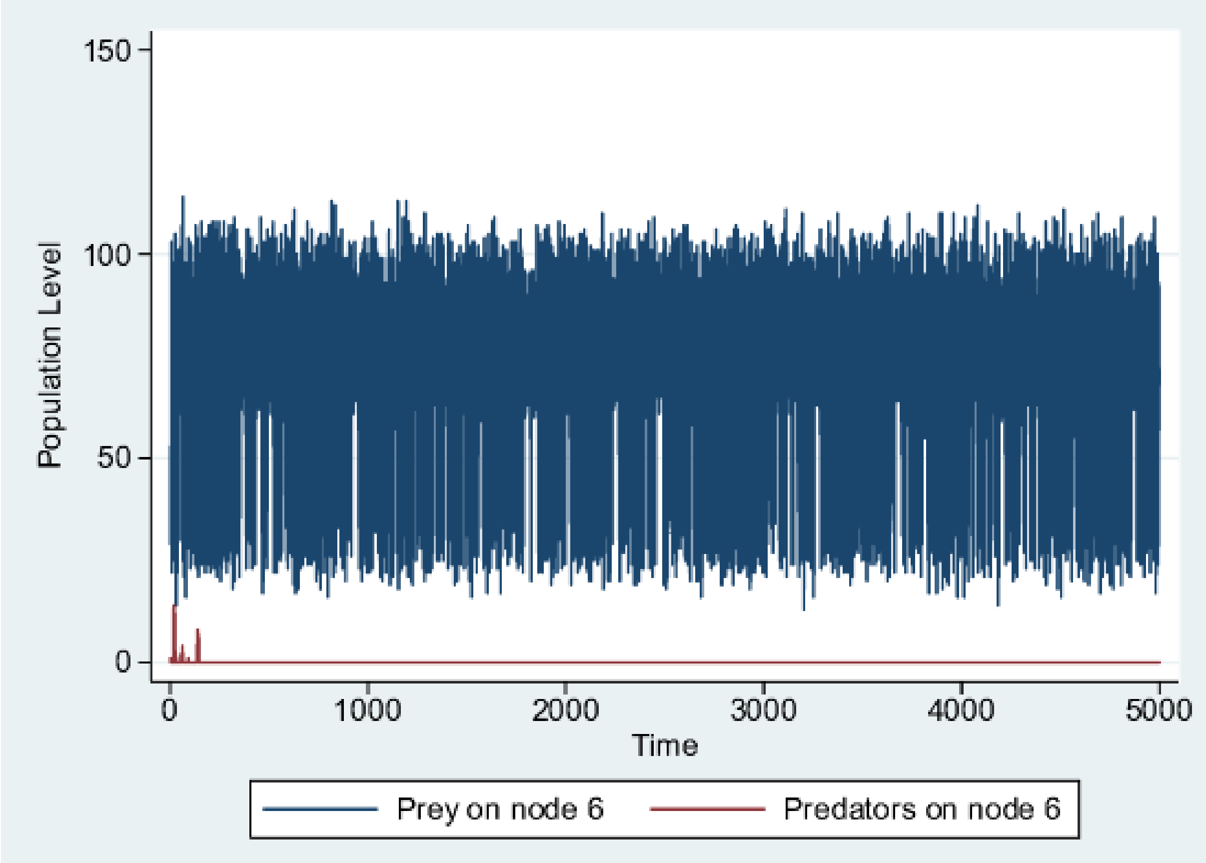
5000
Time
Prey on node 5
Predators on node 5

2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Population Level
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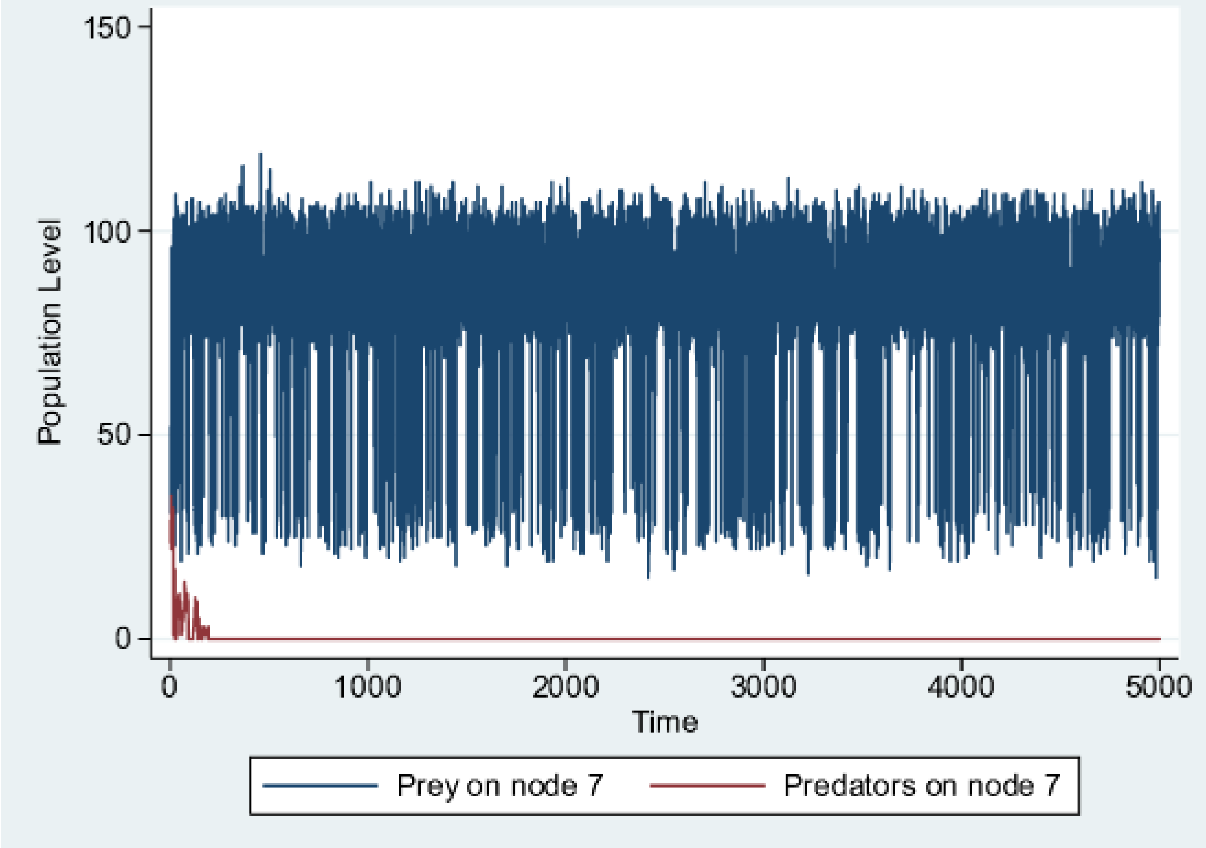
5000
Time
Prey on node 6
Predators on node 6

1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Population Level
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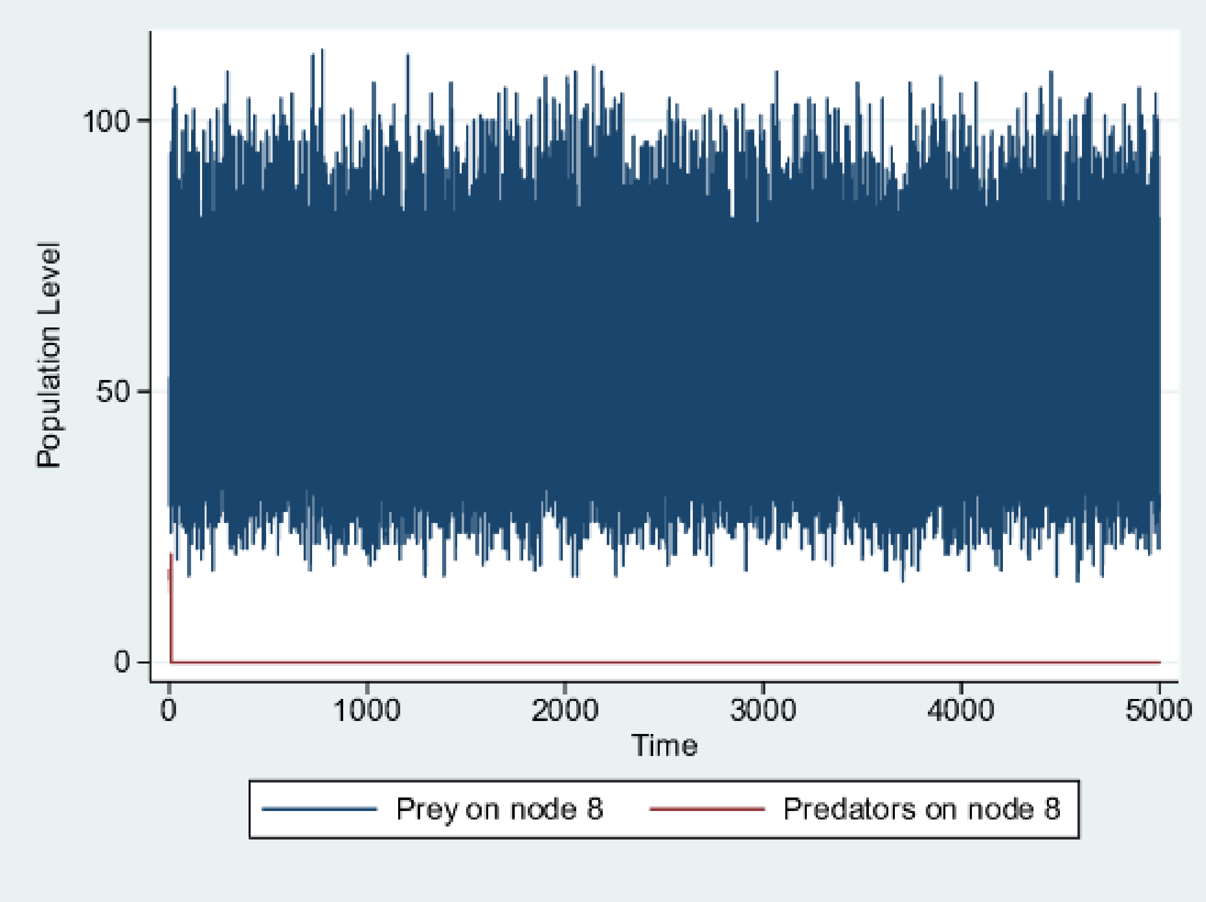
5000
Time
Prey on node 7
Predators on node 7

2


Population Level
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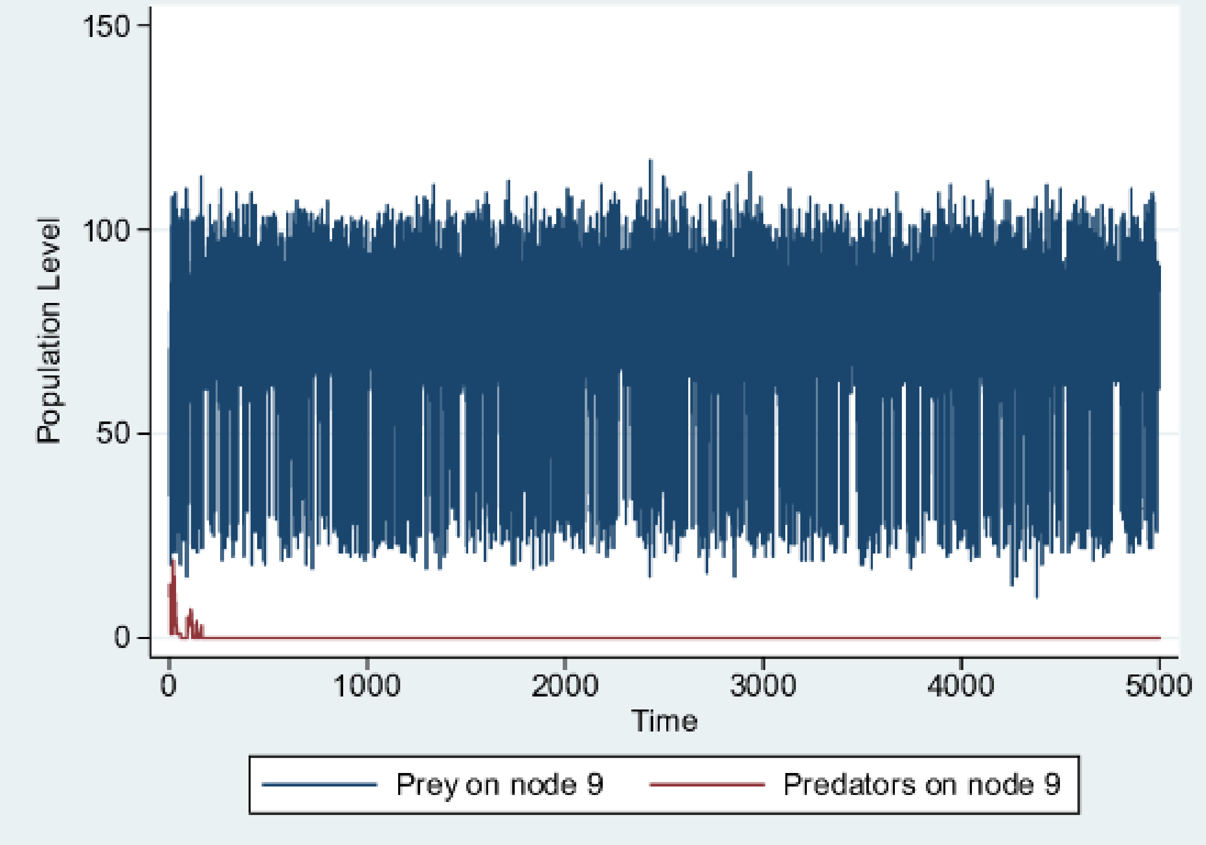
5000
Time
Prey on node 8
Predators on node 8

1


Population Level
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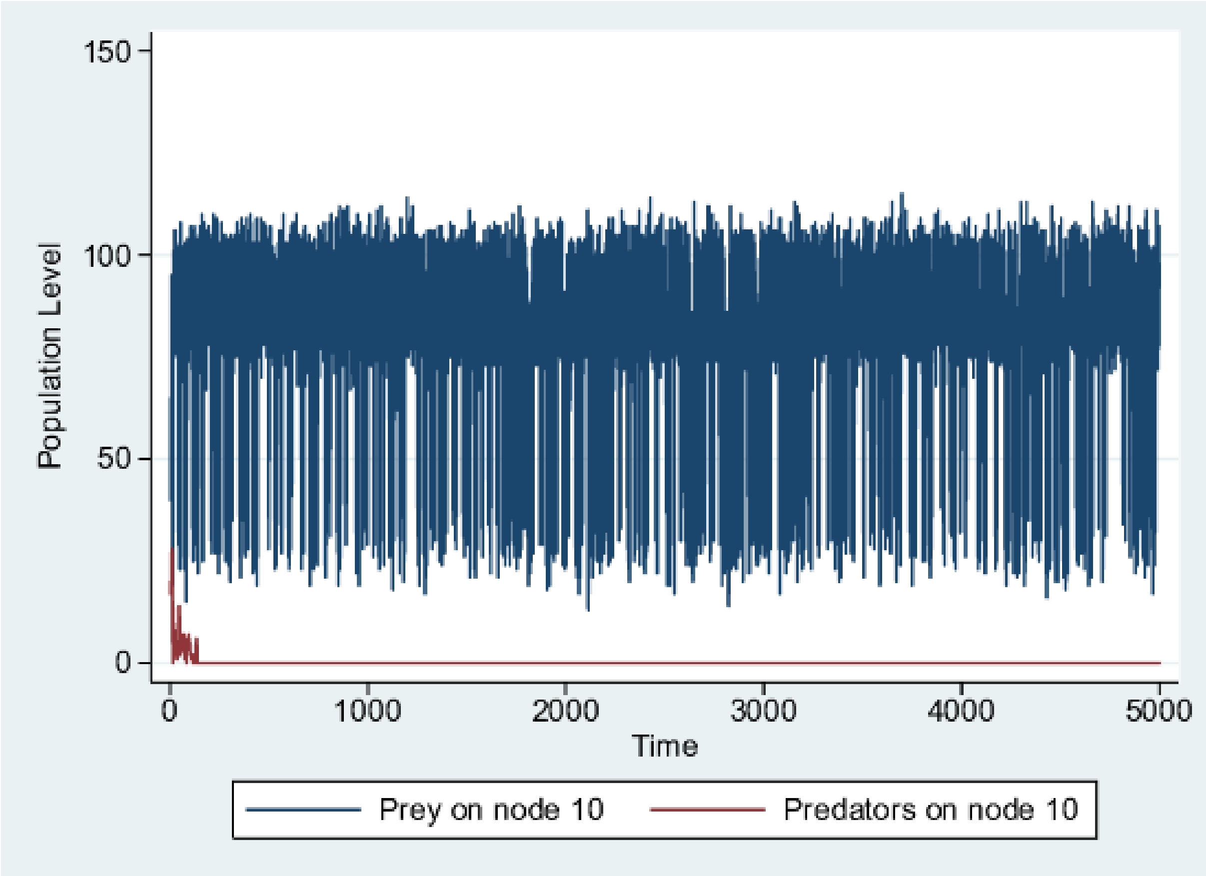
5000
Time
Prey on node 9
Predators on node 9

2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Population Level
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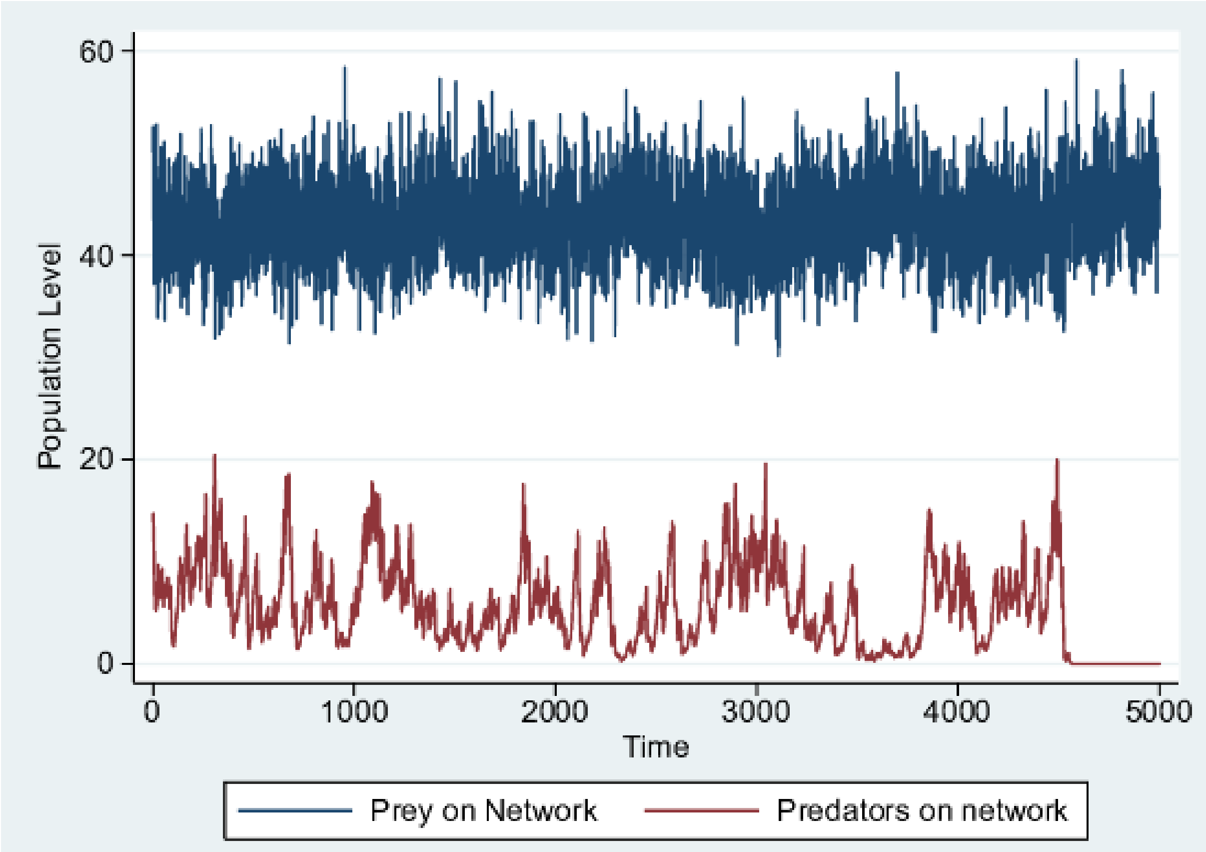
2000
3000
4000
5000
Time
Prey on node 10
Predators on node 10

1

RUN 3



Population Level
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3000
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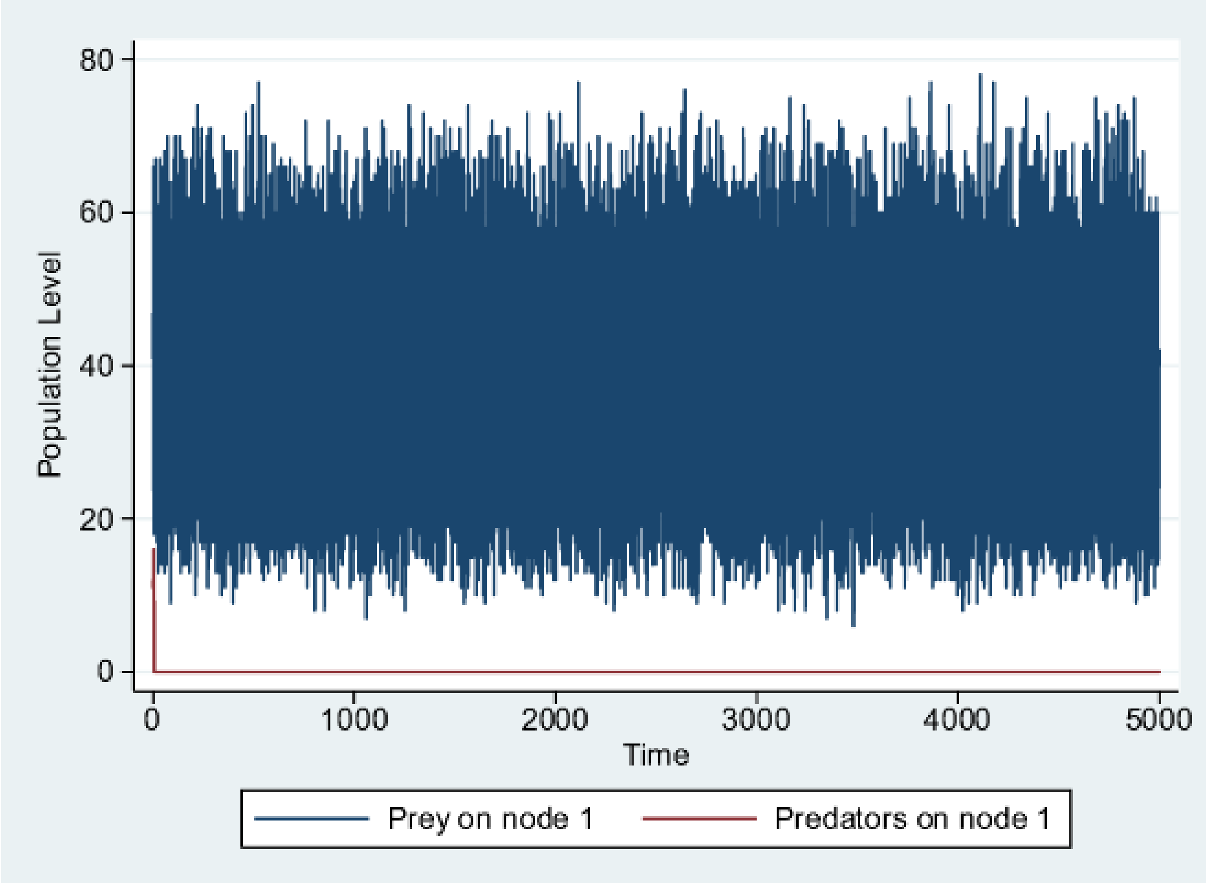
5000
Time
Prey on Network
Predators on network



Population Level
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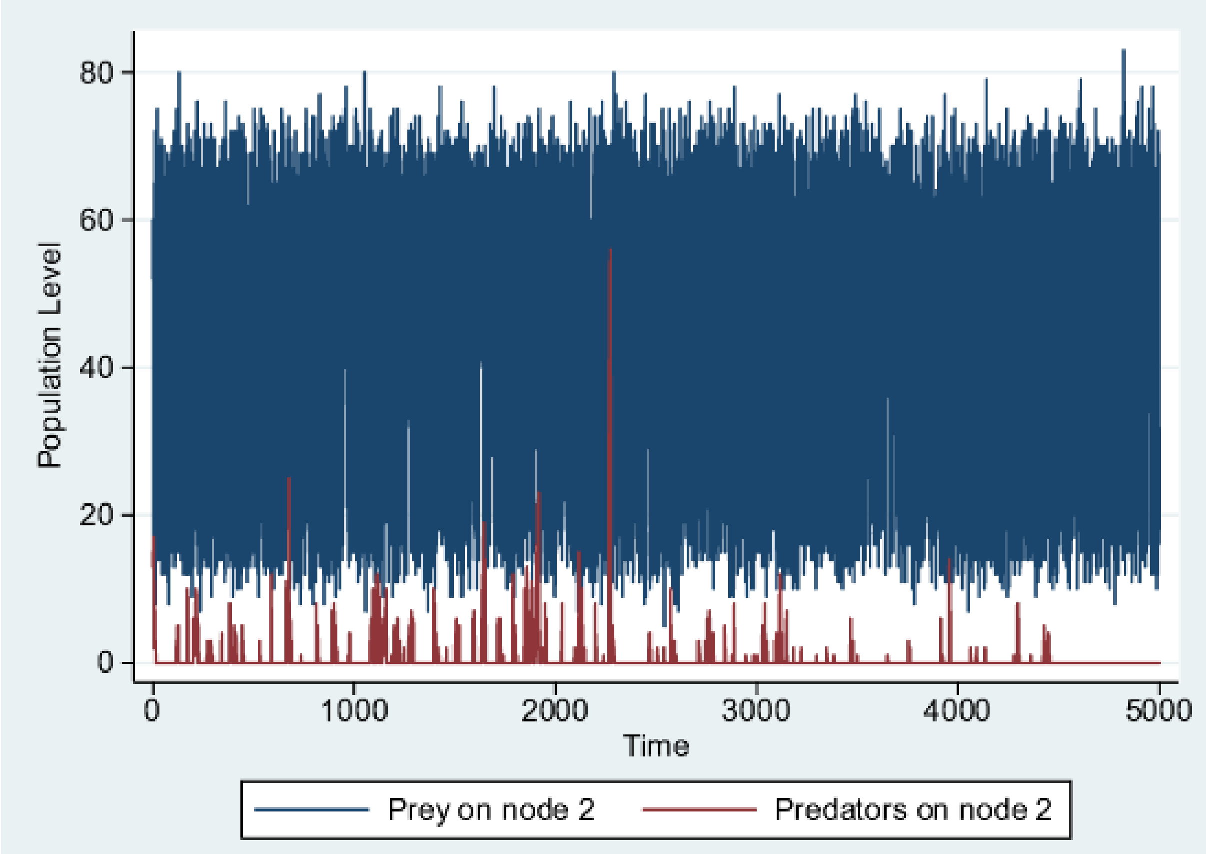
60
80
0
1000
2000
3000
4000
5000
Time
Prey on node 1
Predators on node 1



Population Level
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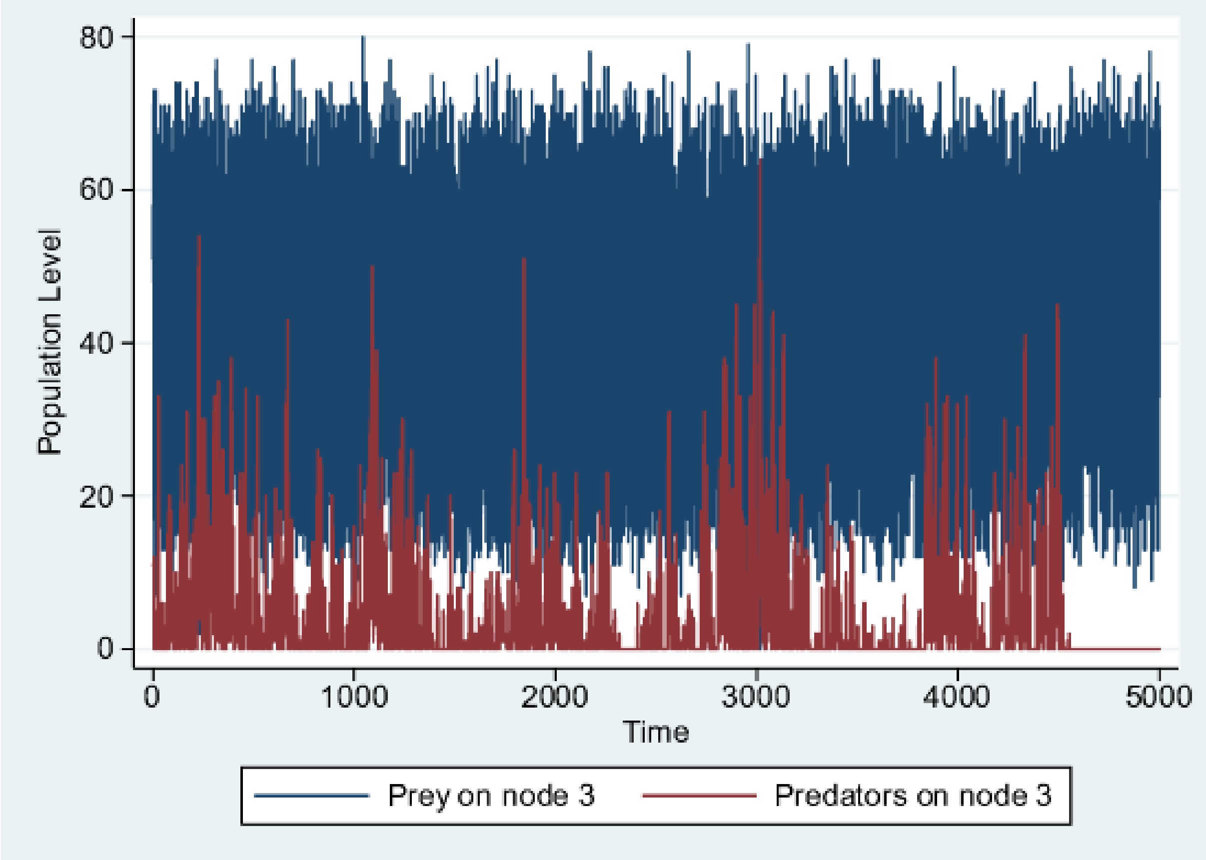
60
80
0
1000
2000
3000
4000
5000
Time
Prey on node 2
Predators on node 2

1



Population Level
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40
60
80
0
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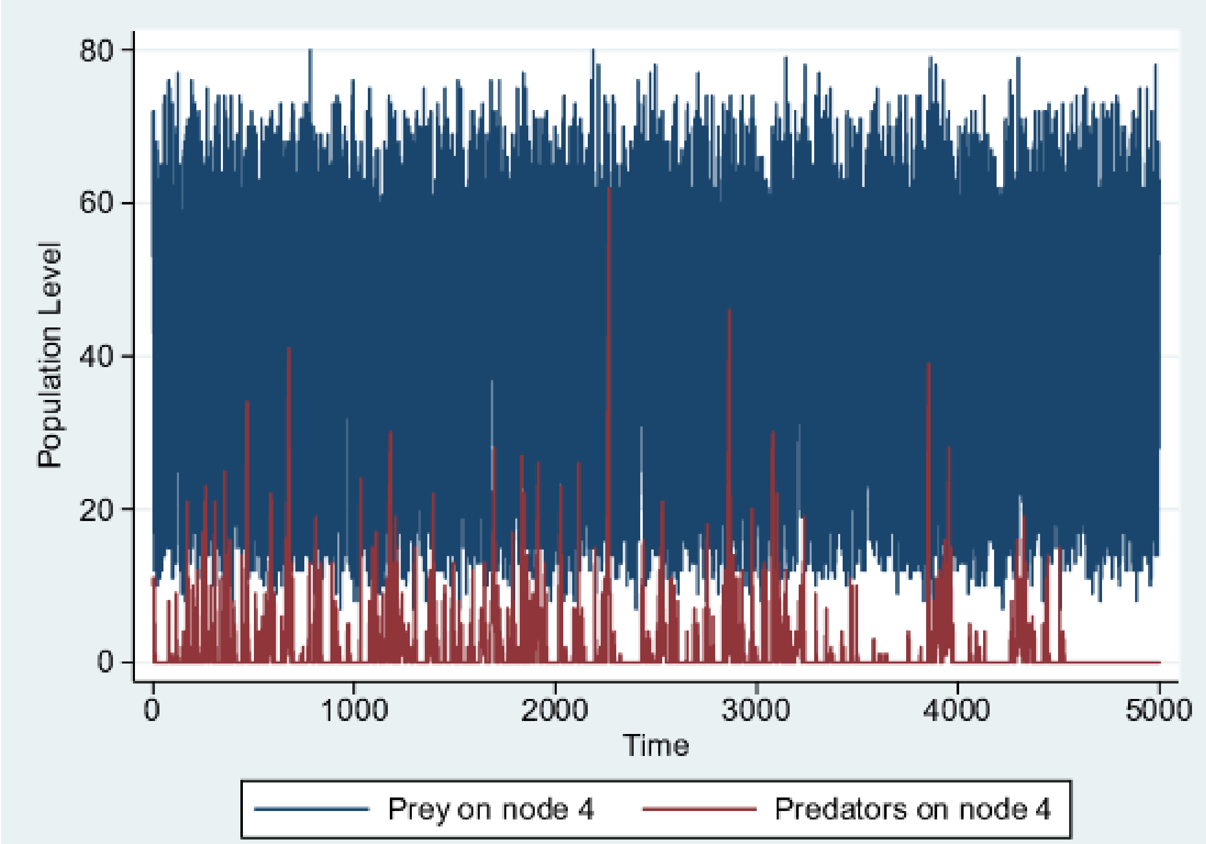
2000
3000
4000
5000
Time
Prey on node 3
Predators on node 3

2


Population Level
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60
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2000
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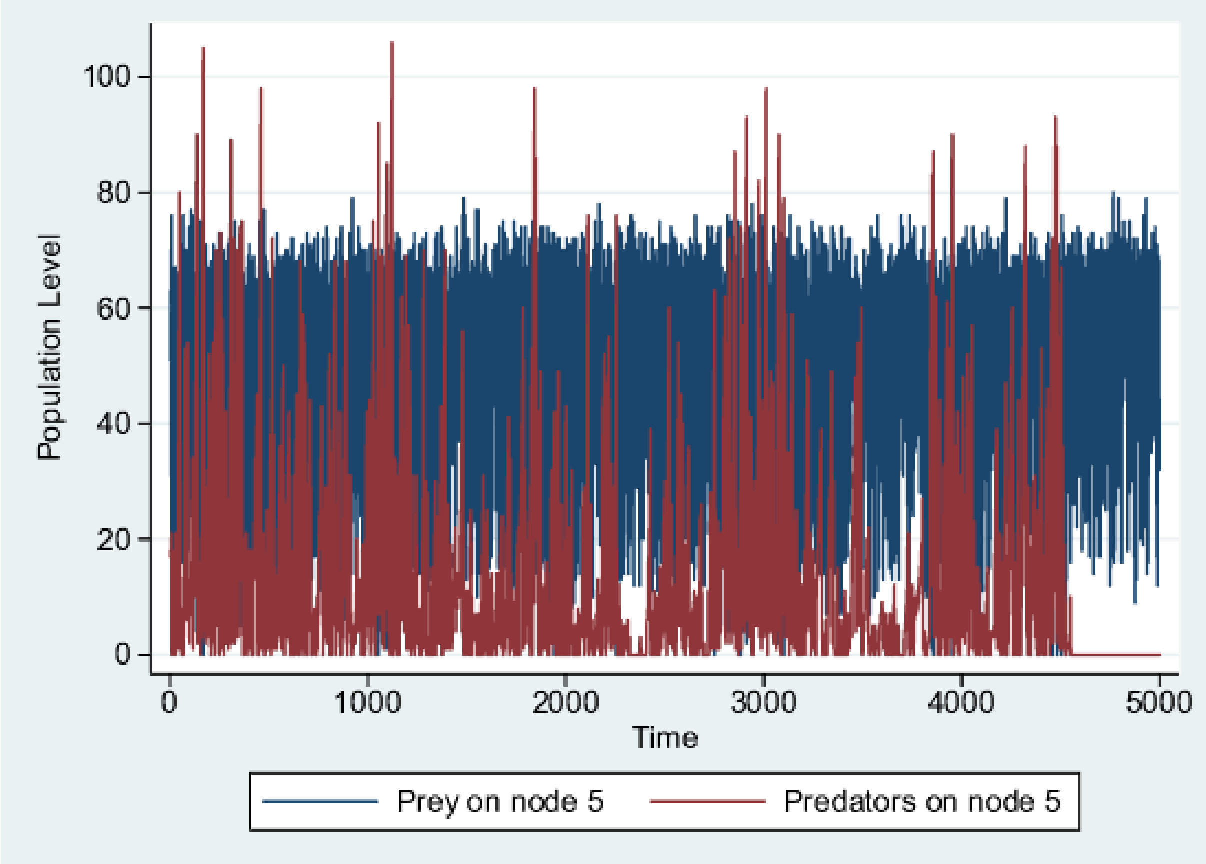
4000
5000
Time
Prey on node 4
Predators on node 4

1


Population Level
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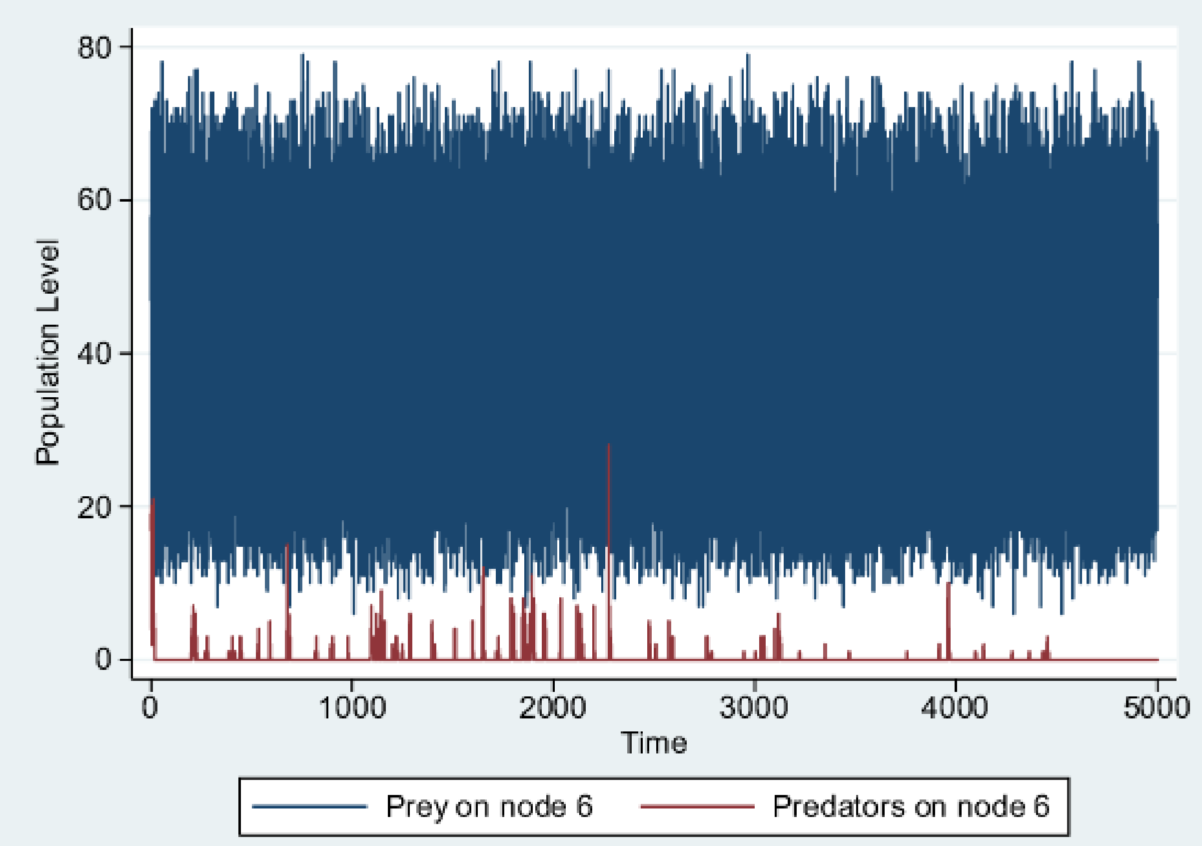
0
1000
2000
3000
4000
5000
Time
Prey on node 5
Predators on node 5

2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Population Level
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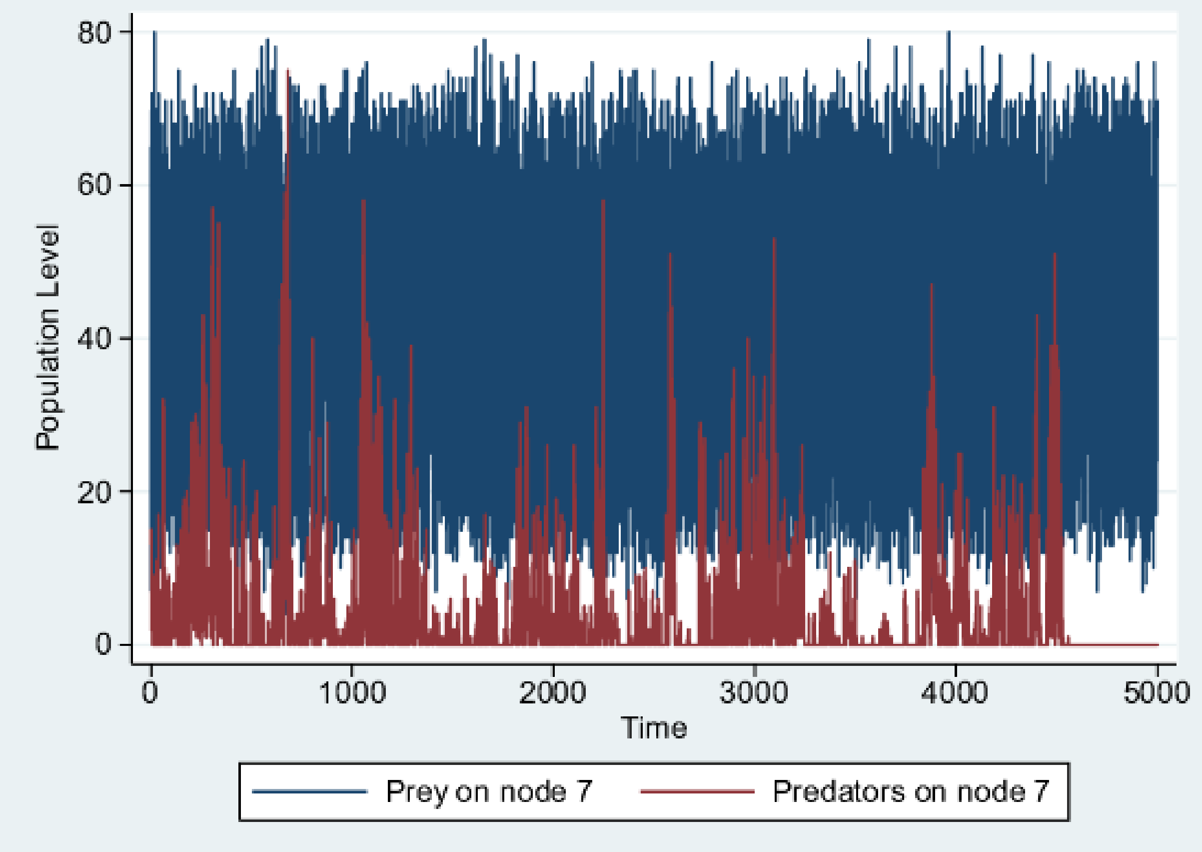
2000
3000
4000
5000
Time
Prey on node 6
Predators on node 6

1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0
Population Level
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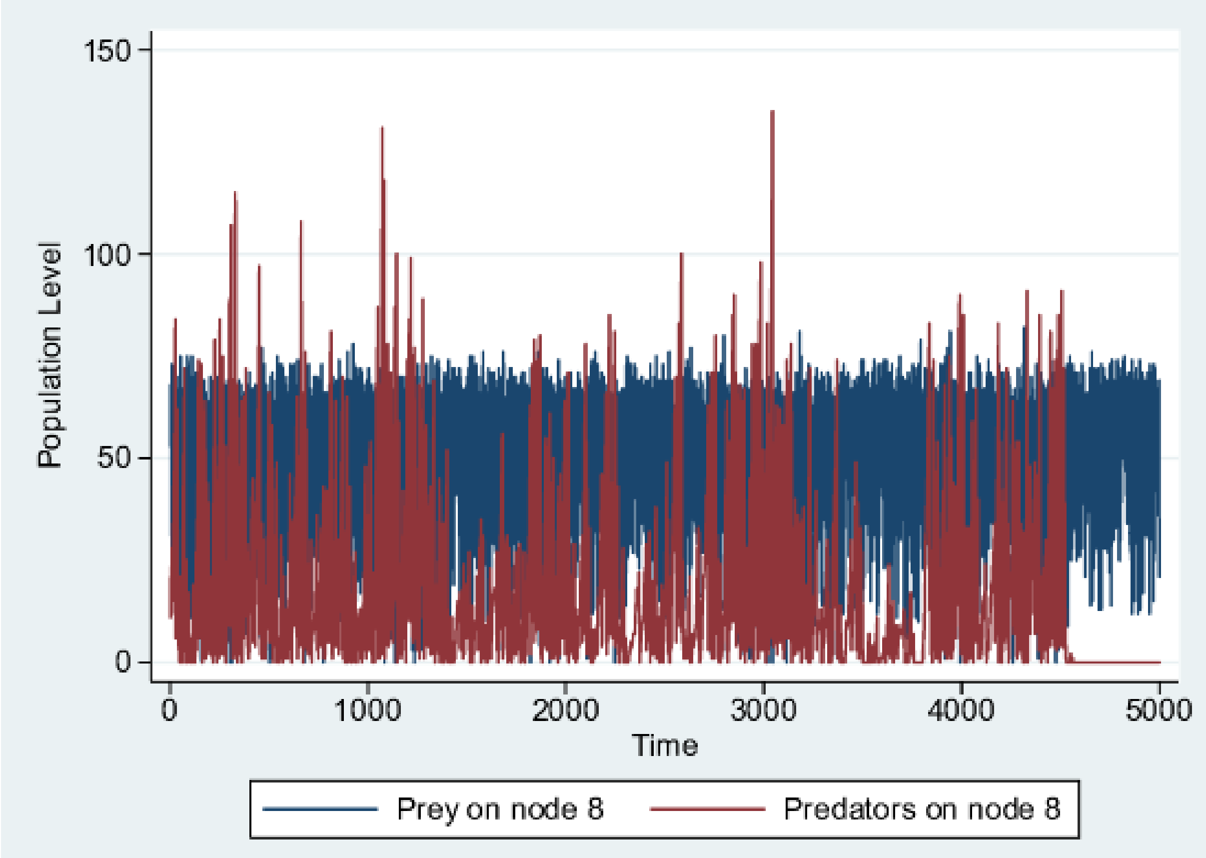
1000
2000
3000
4000
5000
Time
Prey on node 7
Predators on node 7

2


150
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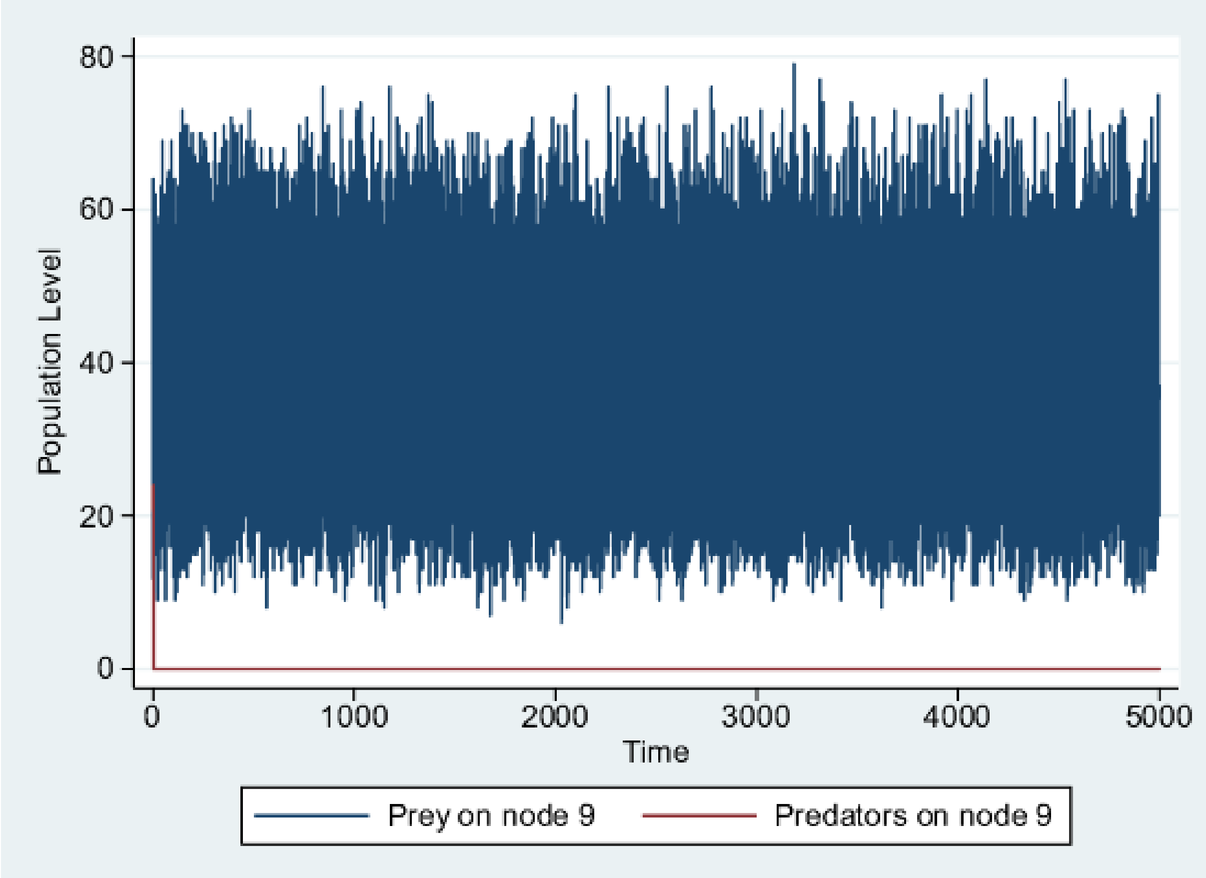
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 8
Predators on node 8

1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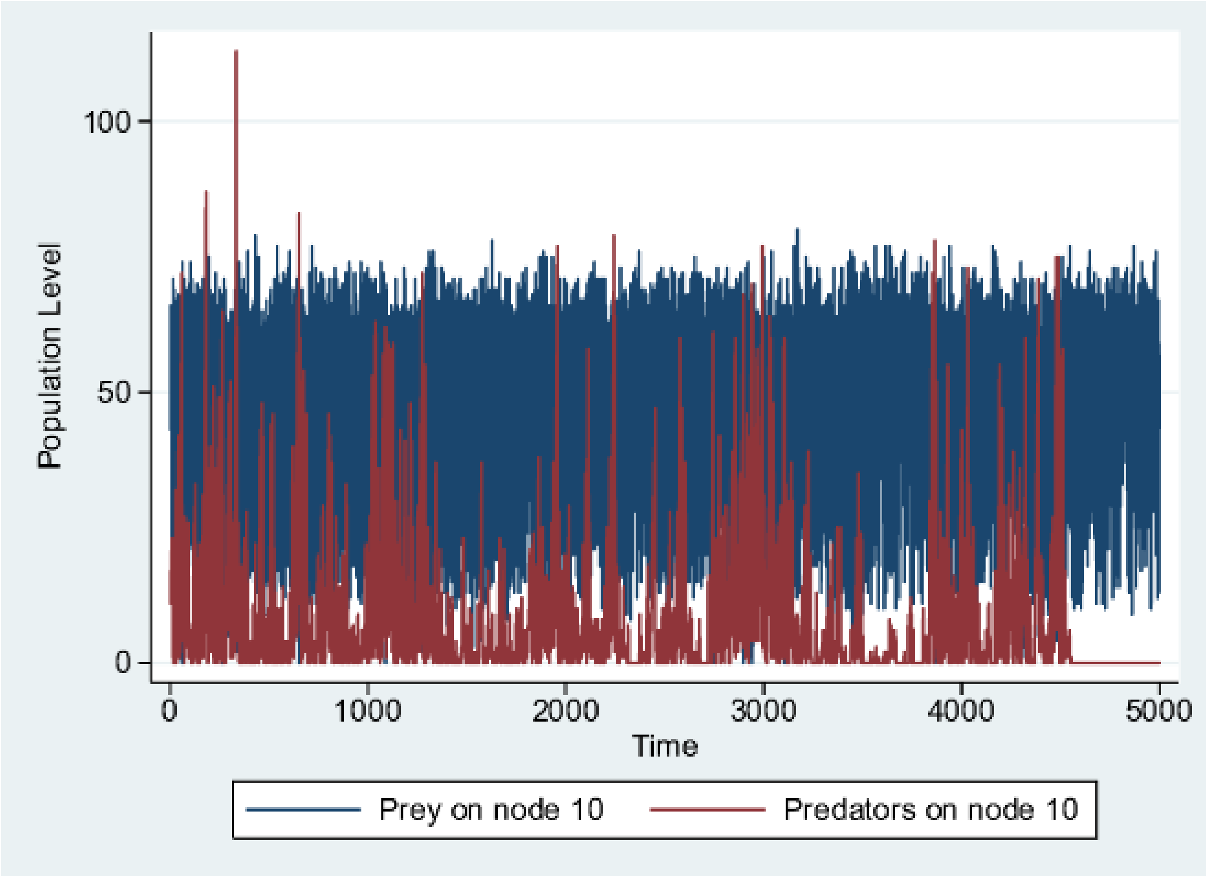
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 9
Predators on node 9

2


Population Level
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1000
2000
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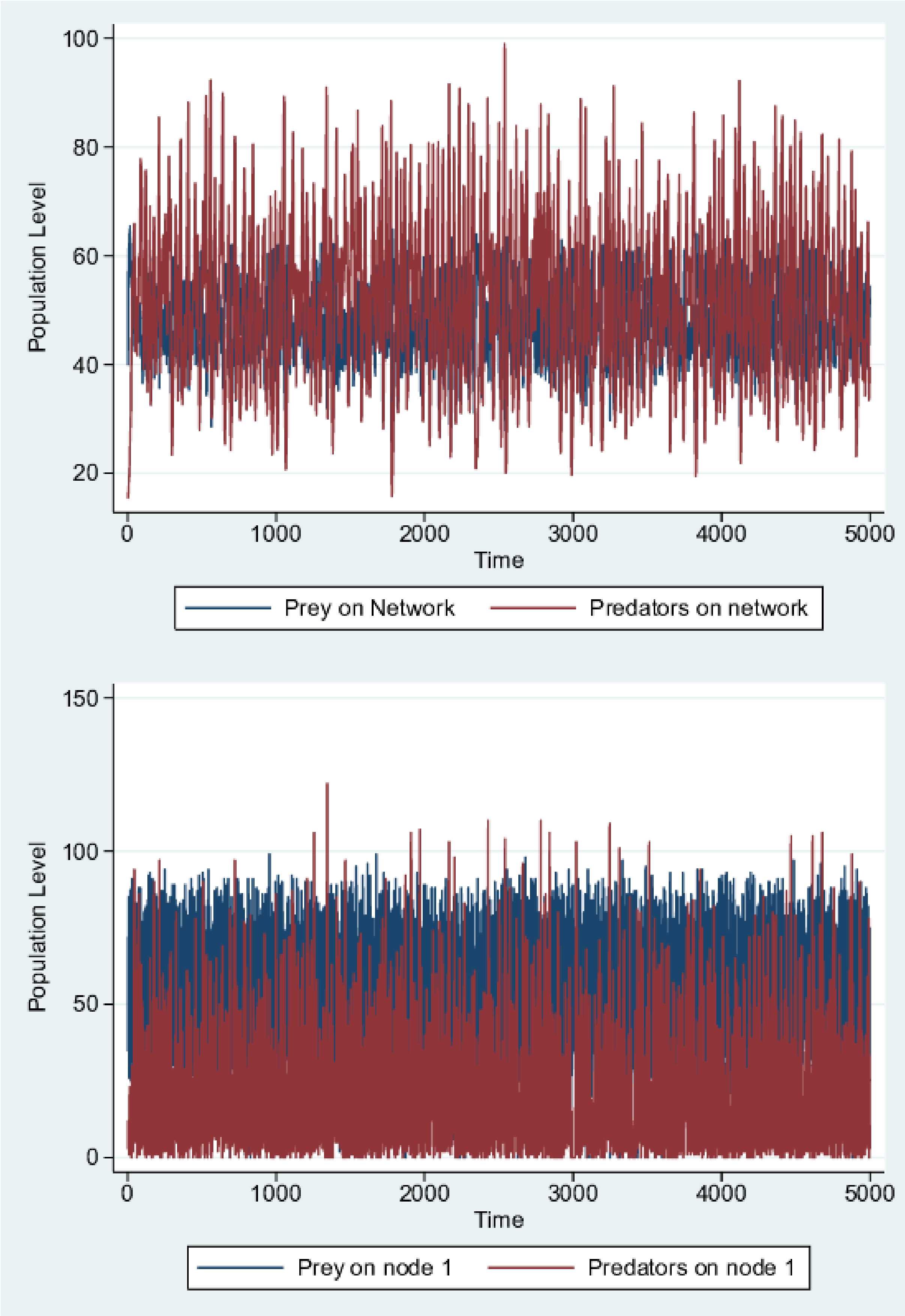
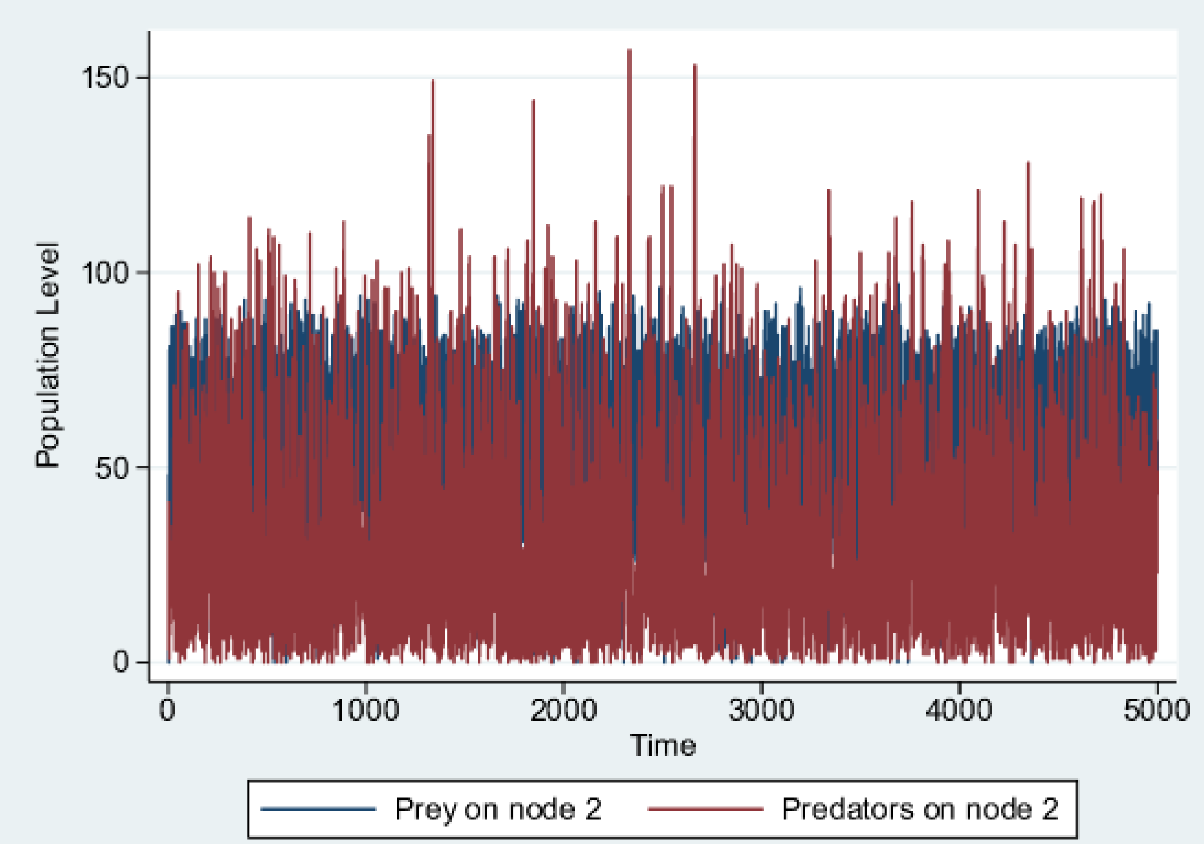
4000
5000
Time
Prey on node 10
Predators on node 10

RUN 4


Population Level
Time
Prey on Network
Predators on network
Population Level
Time
Prey on node 1
Predators on node 1



150
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Population Level
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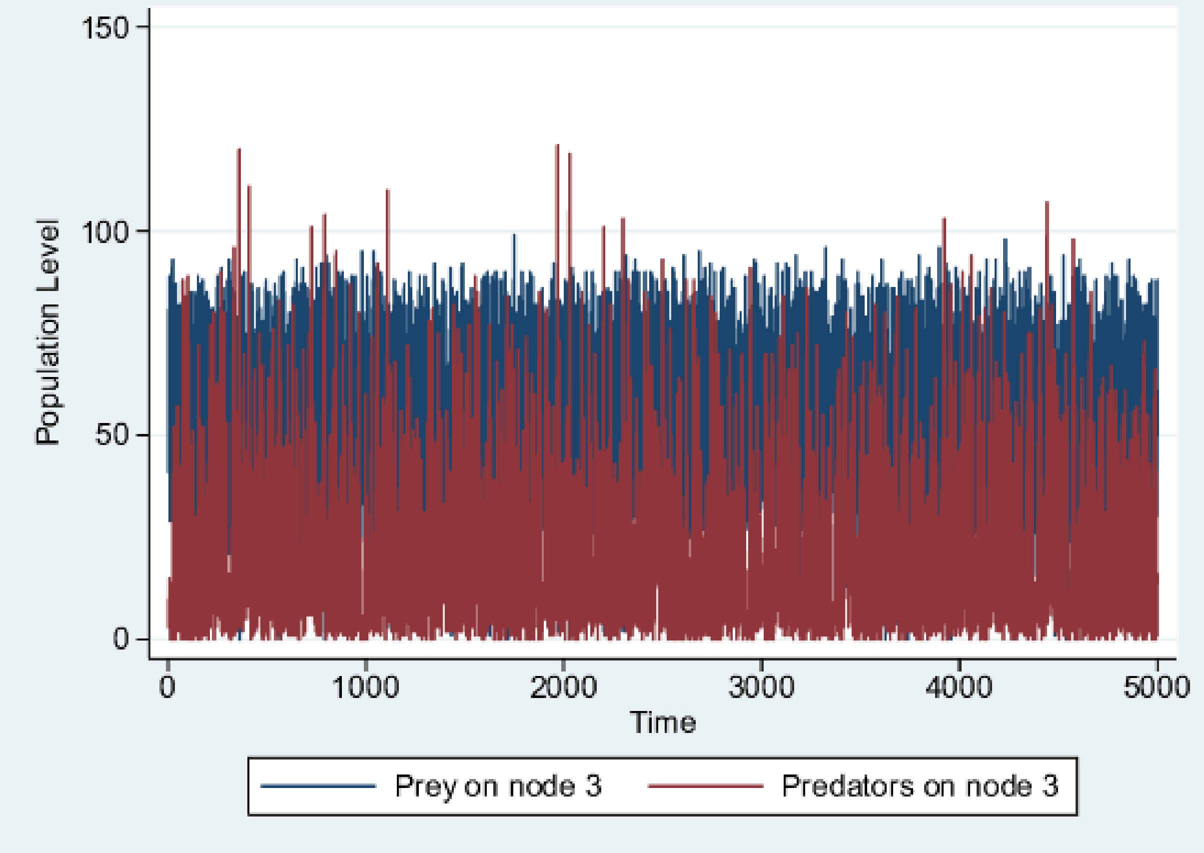
2000
3000
4000
5000
Time
Prey on node 2
Predators on node 2

1



150
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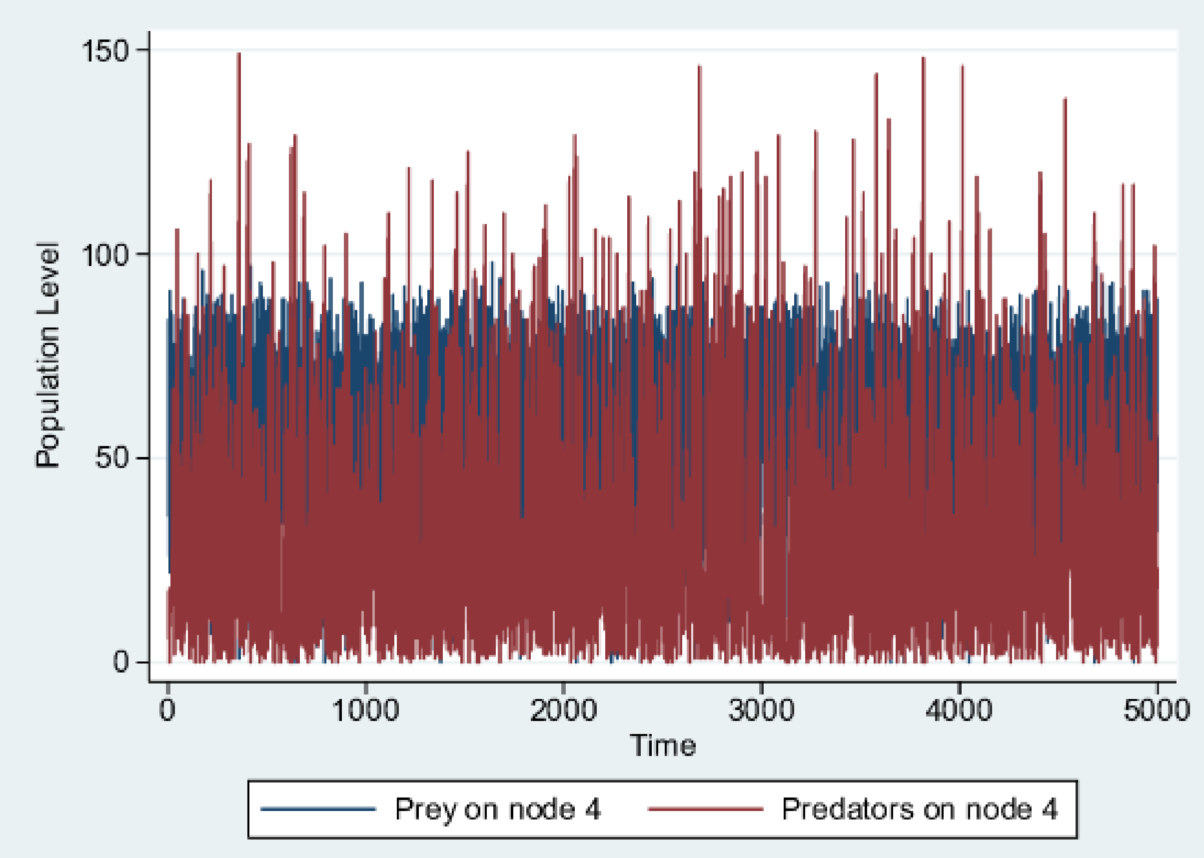
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 3
Predators on node 3

2


150
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Population Level
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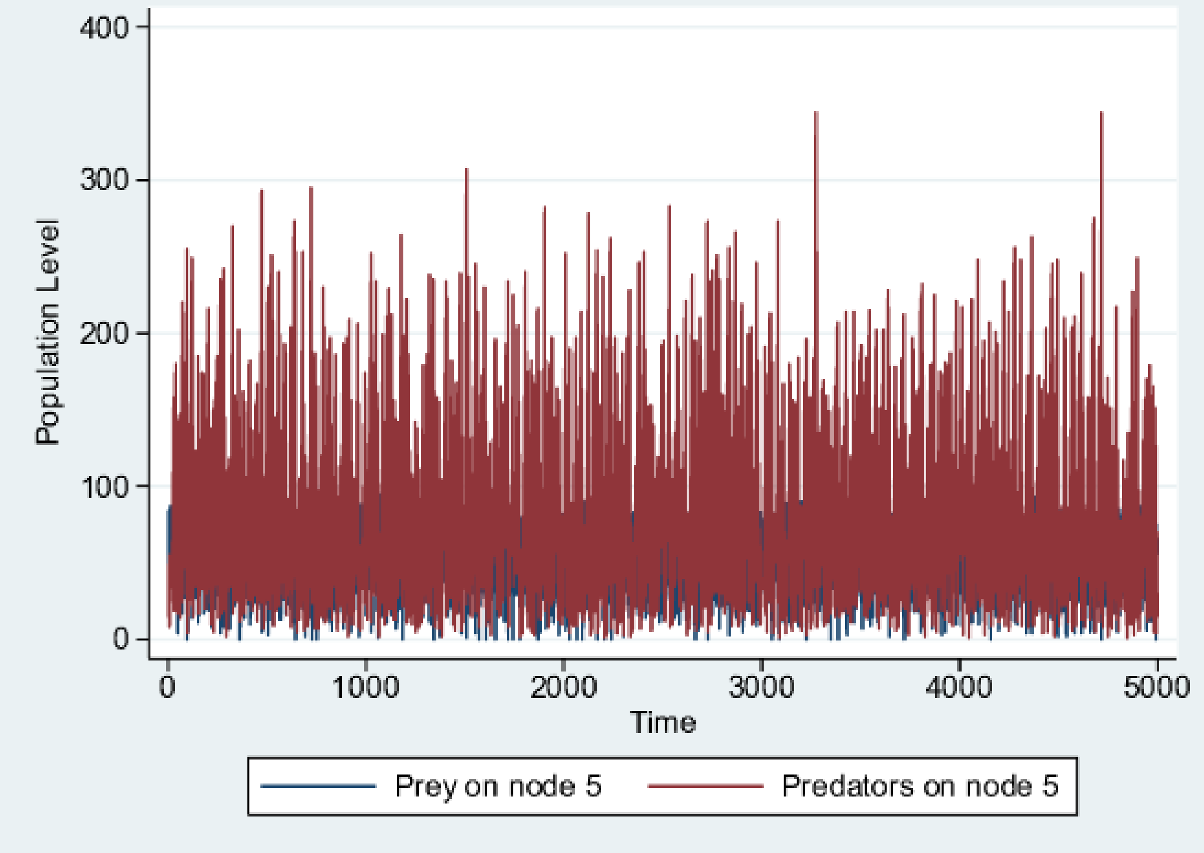
2000
3000
4000
5000
Time
Prey on node 4
Predators on node 4

1


400
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100
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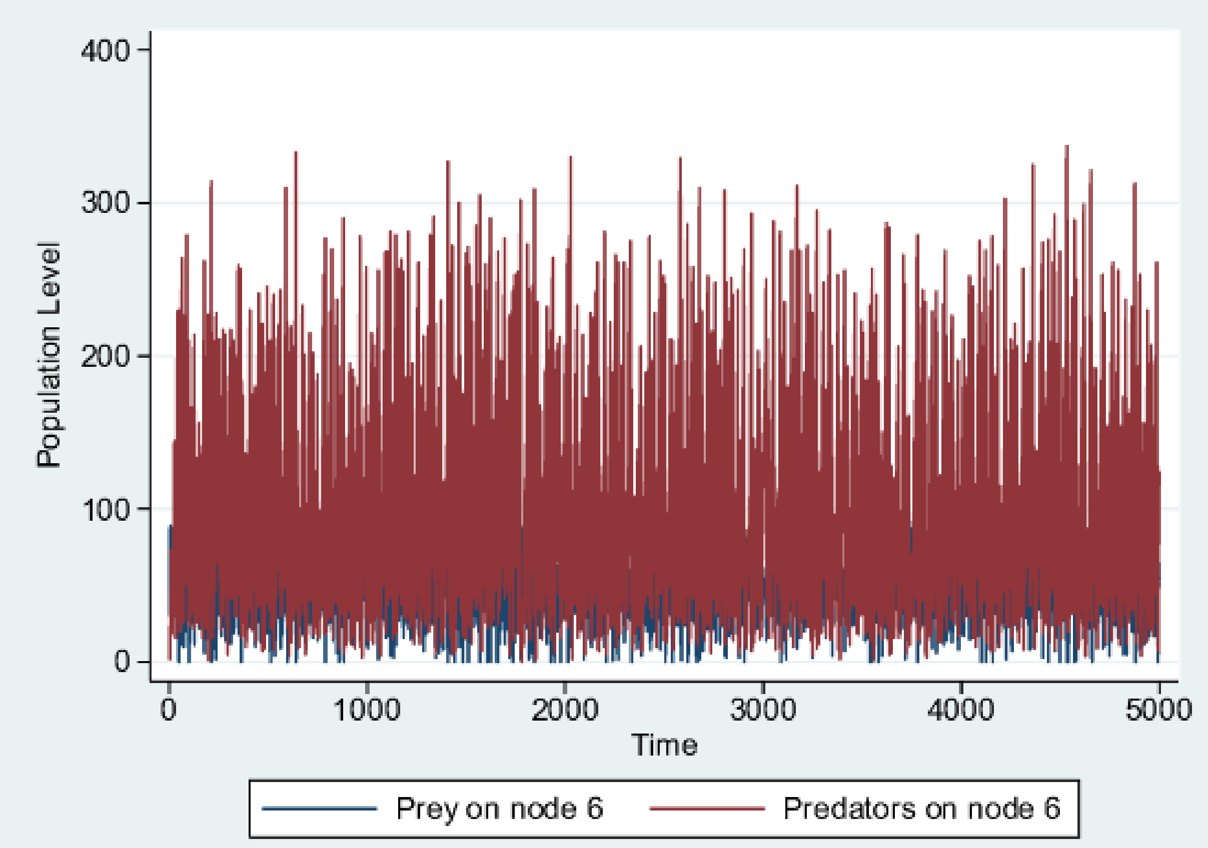
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 5
Predators on node 5

2


400
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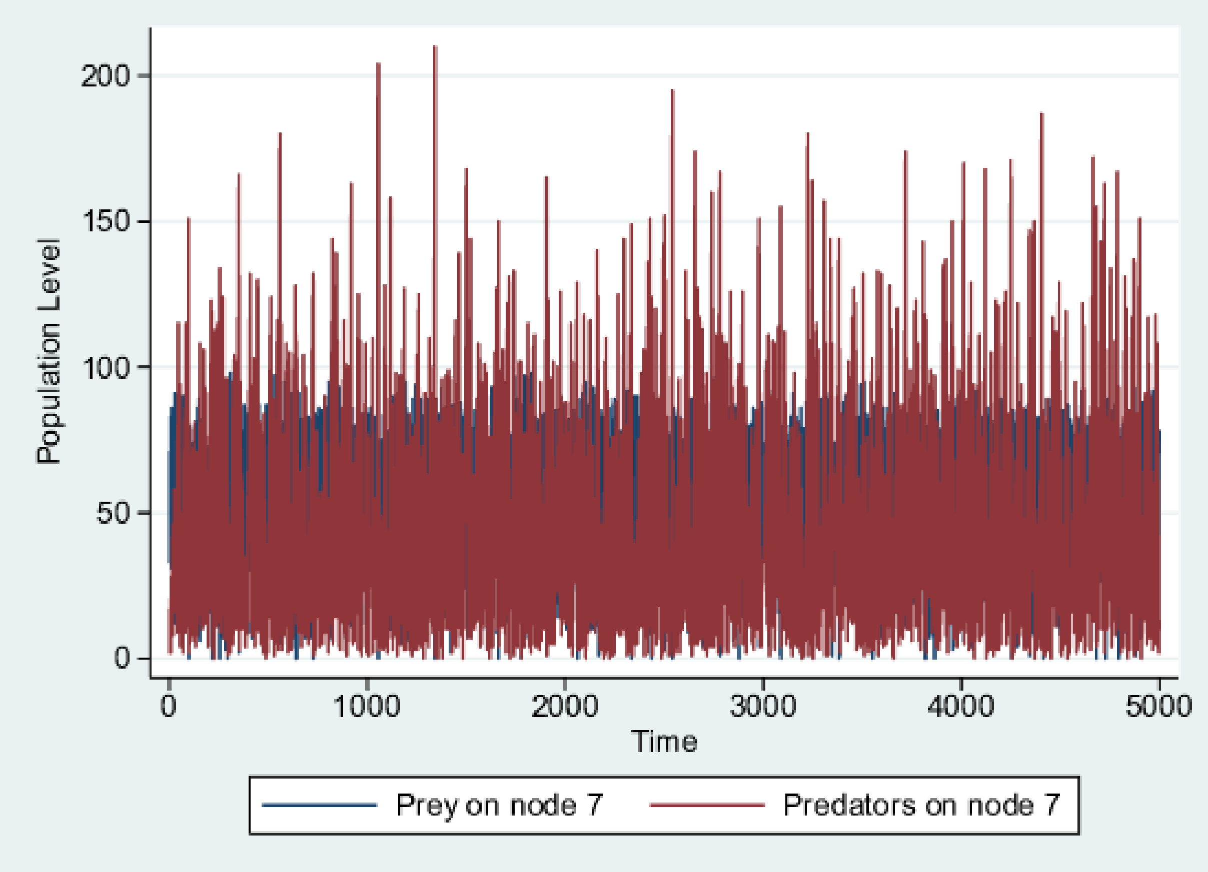
100
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 6
Predators on node 6

1


200
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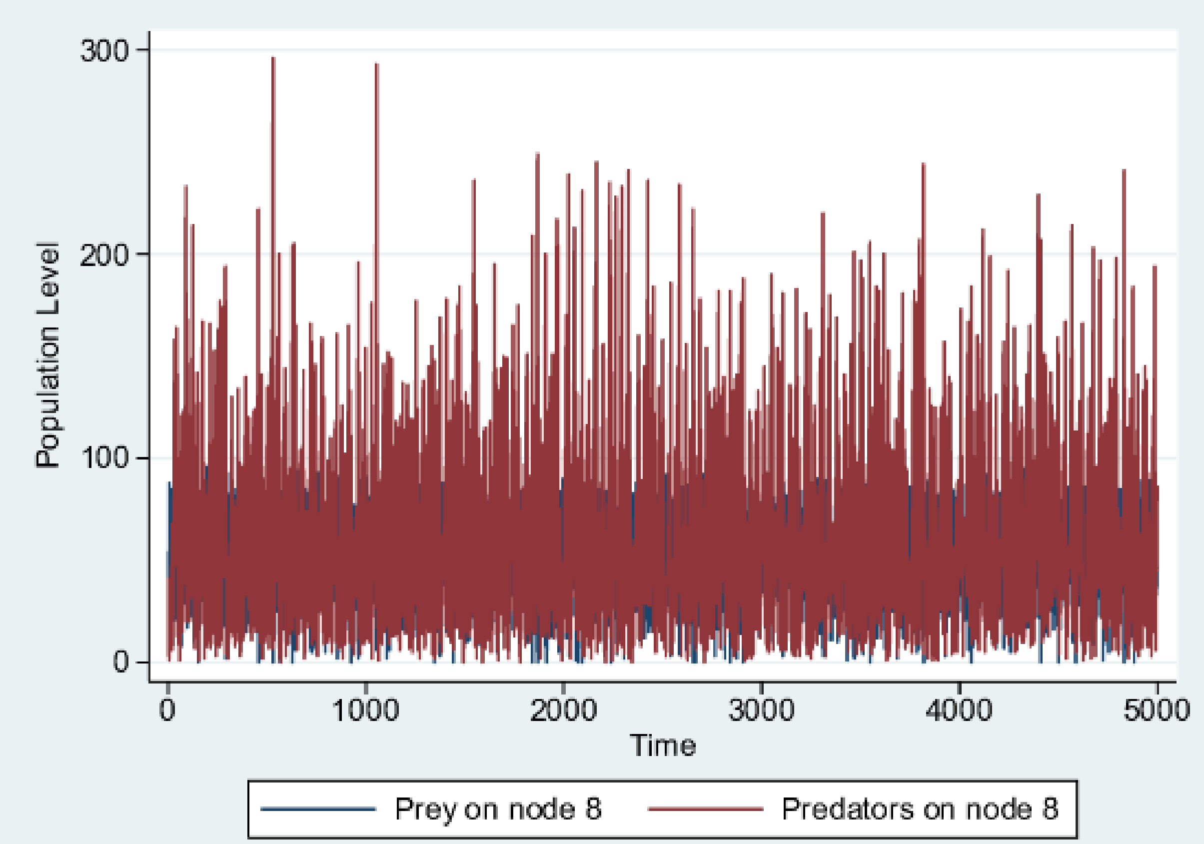
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 7
Predators on node 7

2



300
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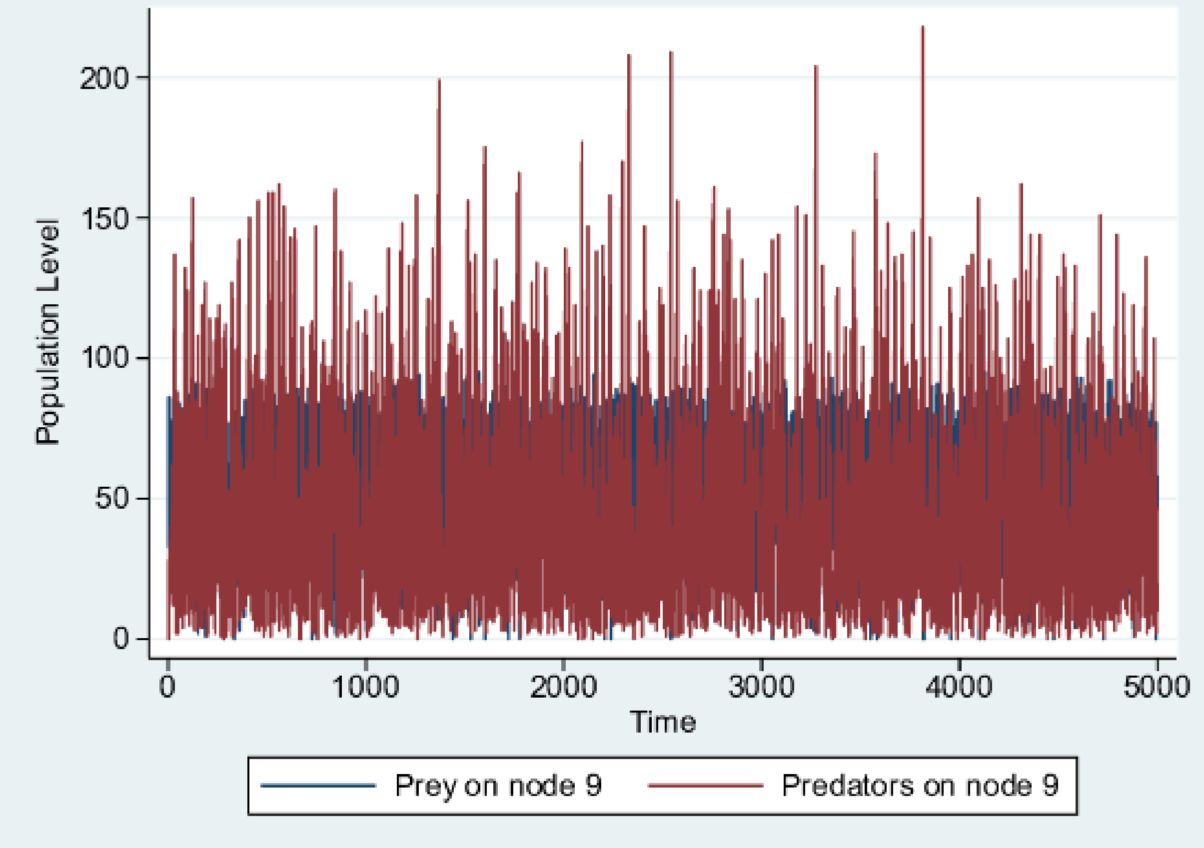
100
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 8
Predators on node 8

1



200
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0
Population Level
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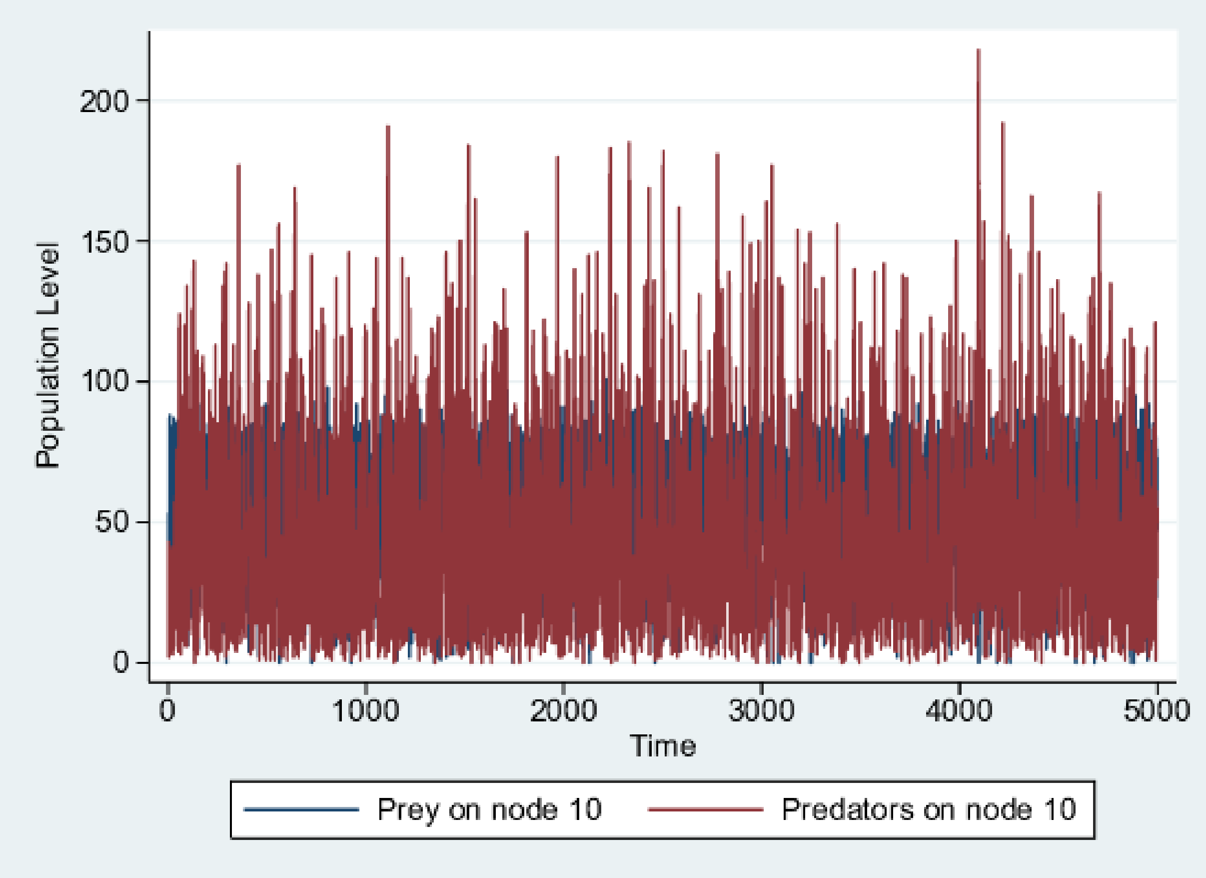
2000
3000
4000
5000
Time
Prey on node 9
Predators on node 9

2

1 

Population Level
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50
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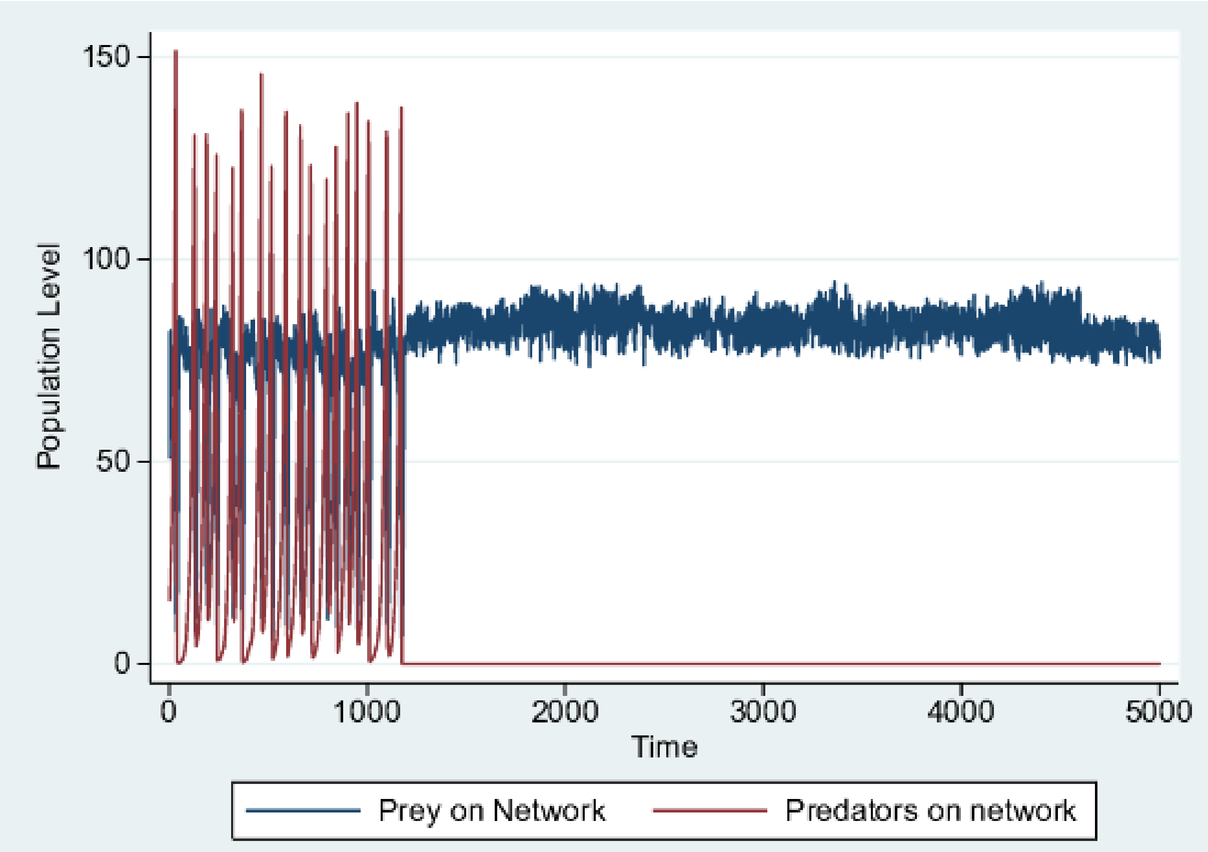
2000
3000
4000
5000
Time
Prey on node 10
Predators on node 10

RUN 5


Population Level
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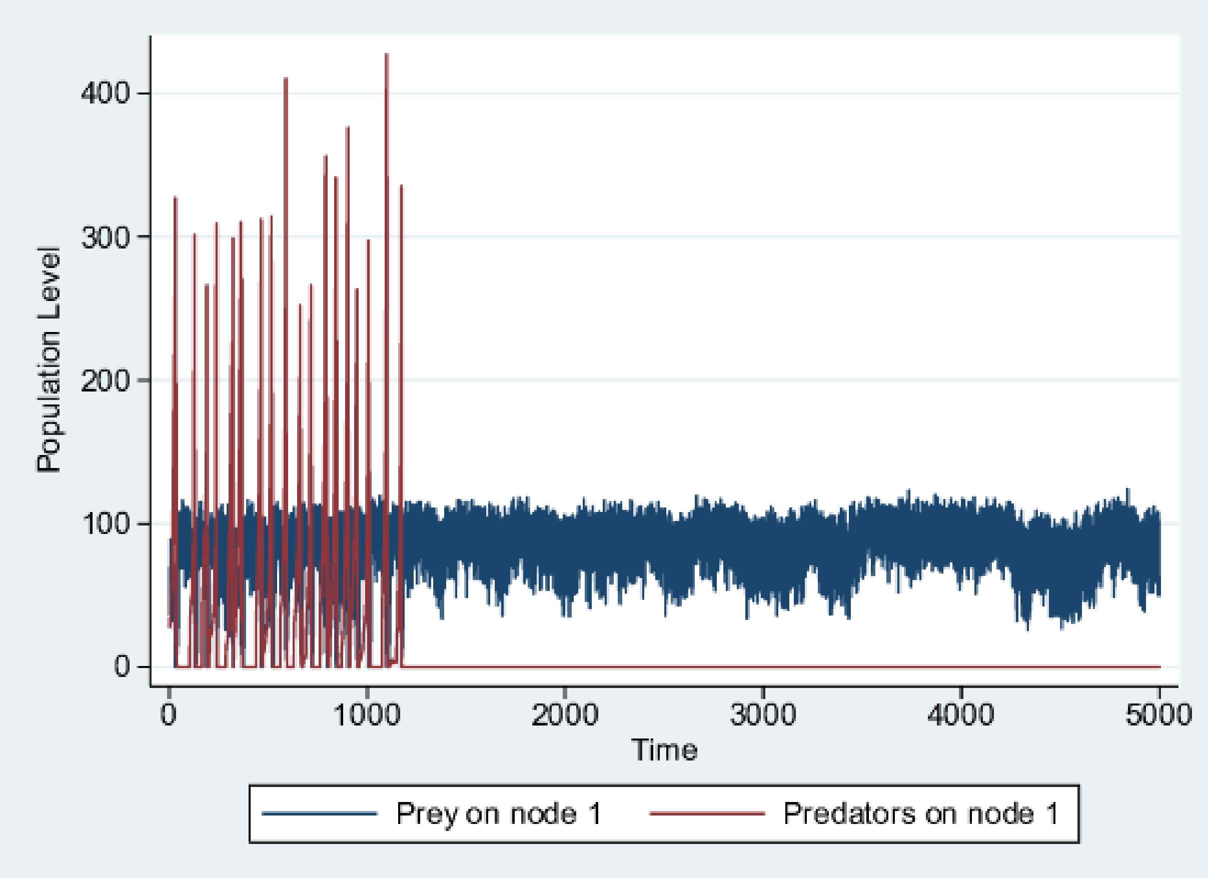
Time
Prey on Network
Predators on network


Population Level
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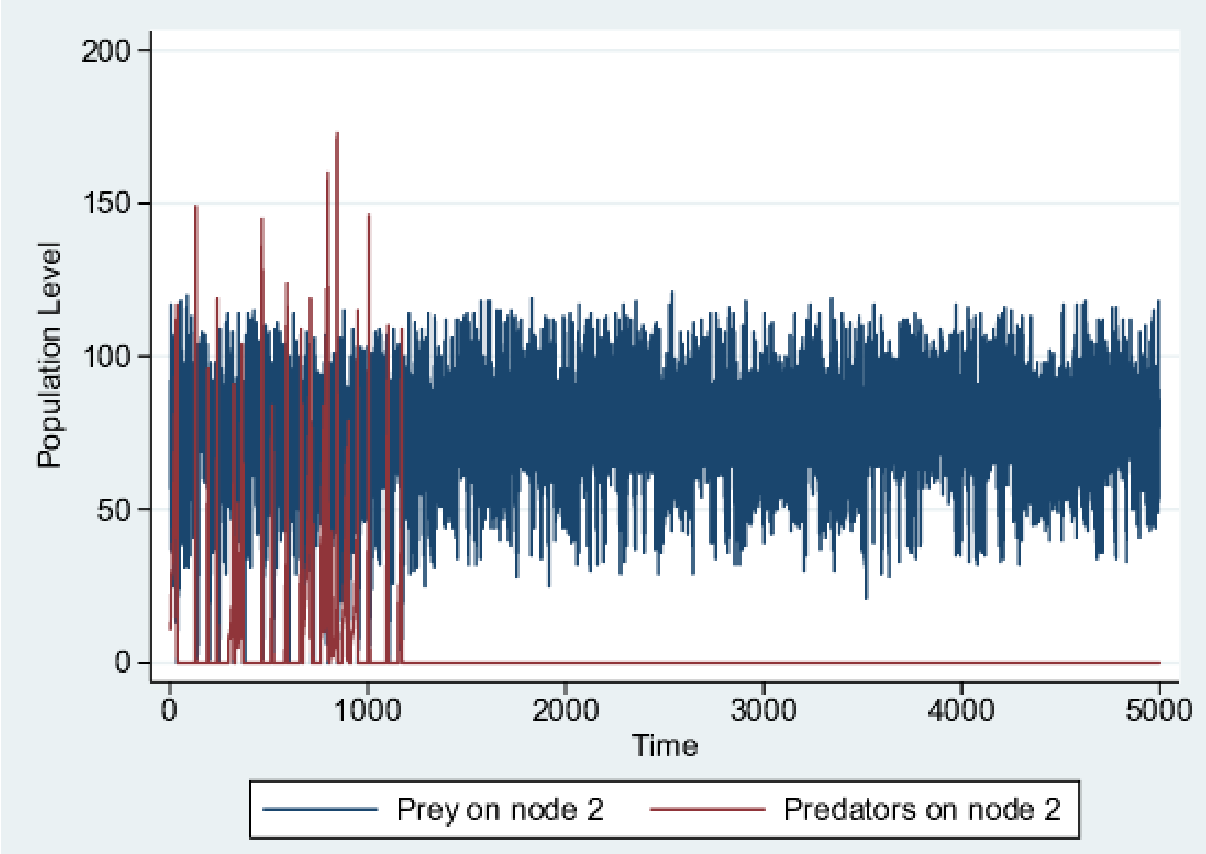
5000
Time
Prey on node 1
Predators on node 1


Population Level
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50
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0
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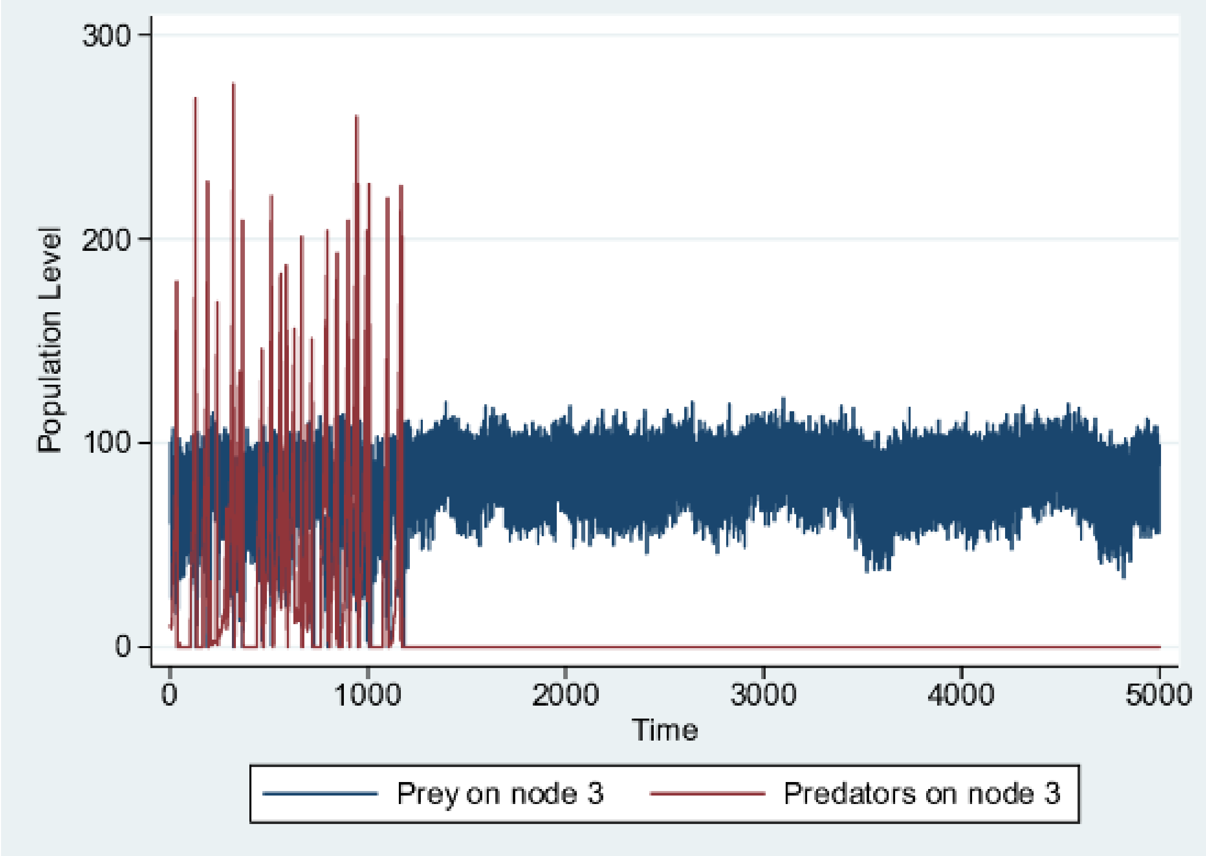
2000
3000
4000
5000
Time
Prey on node 2
Predators on node 2

1


Population Level
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3000
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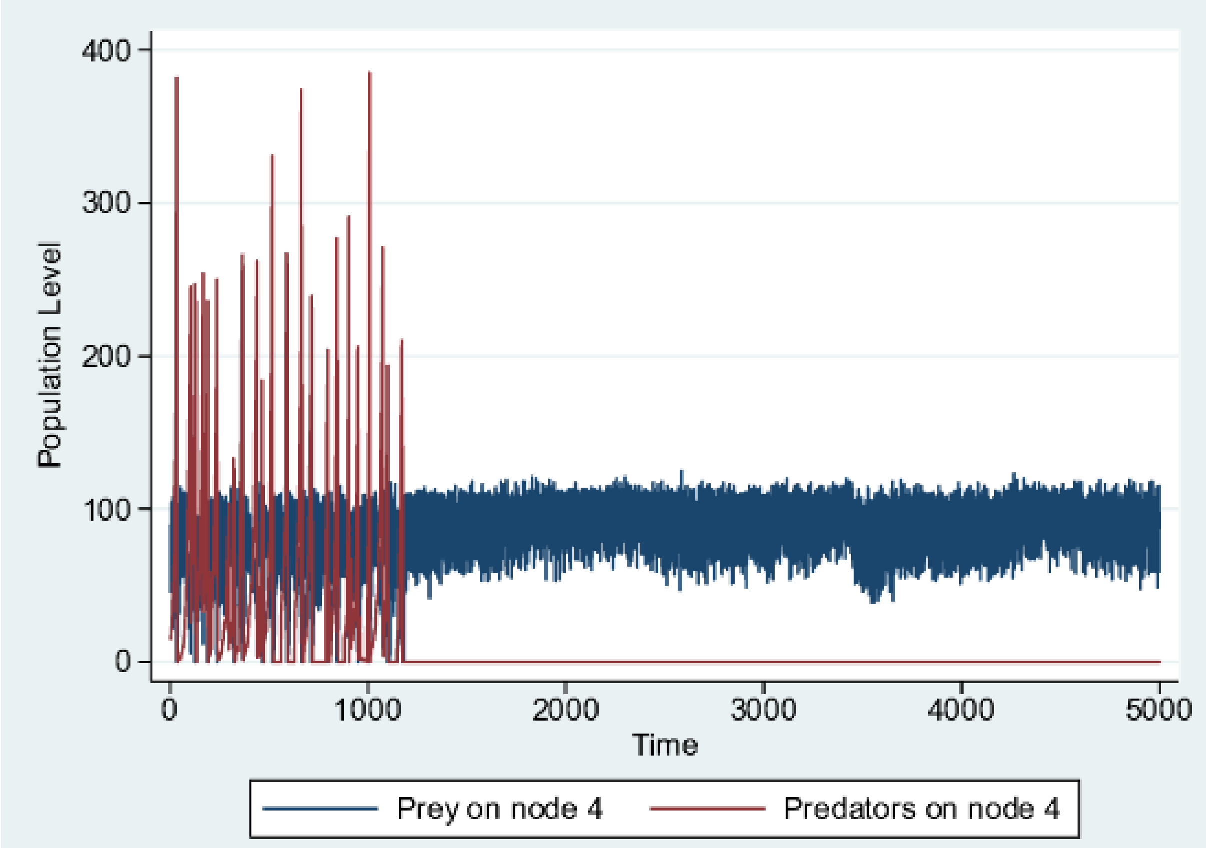
5000
Time
Prey on node 3
Predators on node 3

2


Population Level
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300
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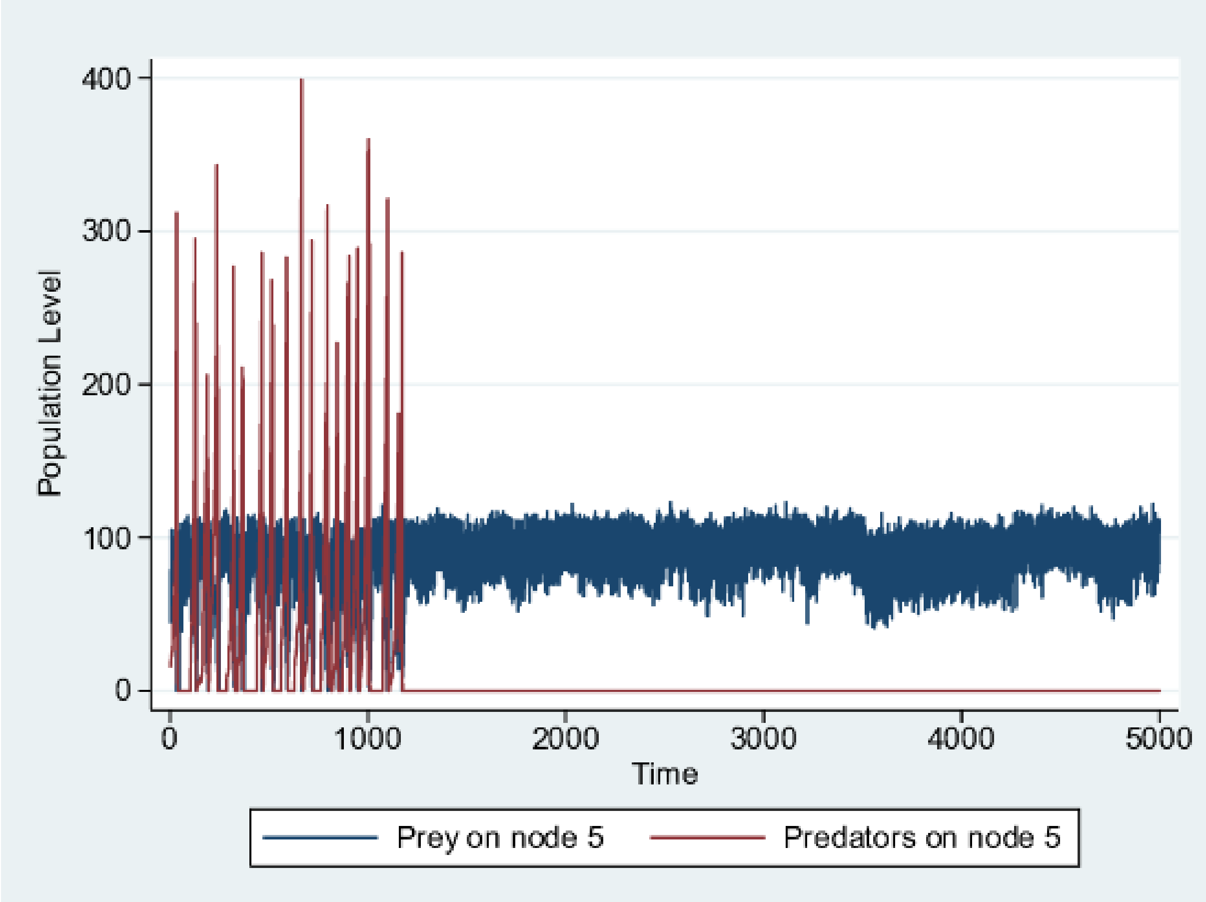
1000
2000
3000
4000
5000
Time
Prey on node 4
Predators on node 4

1


Population Level
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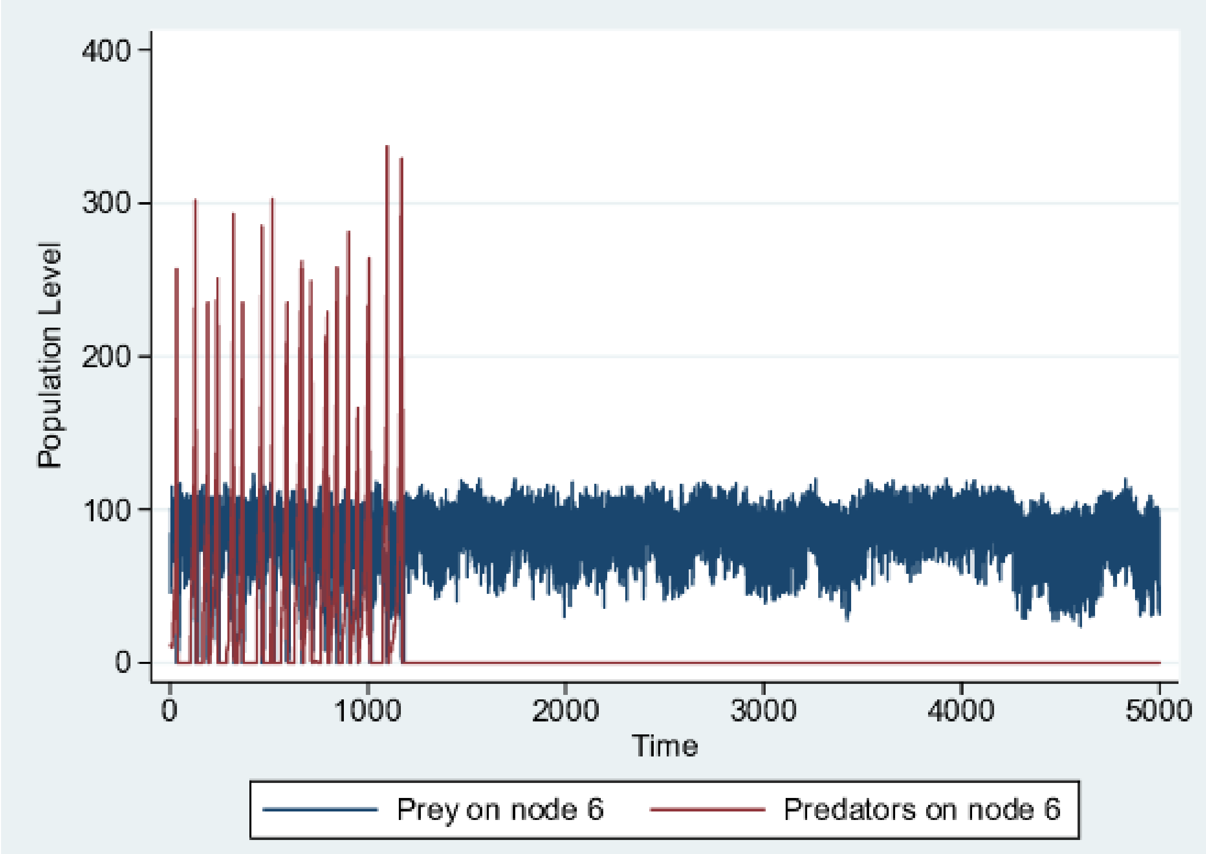
300
400
0
1000
2000
3000
4000
5000
Time
Prey on node 5
Predators on node 5

2


400
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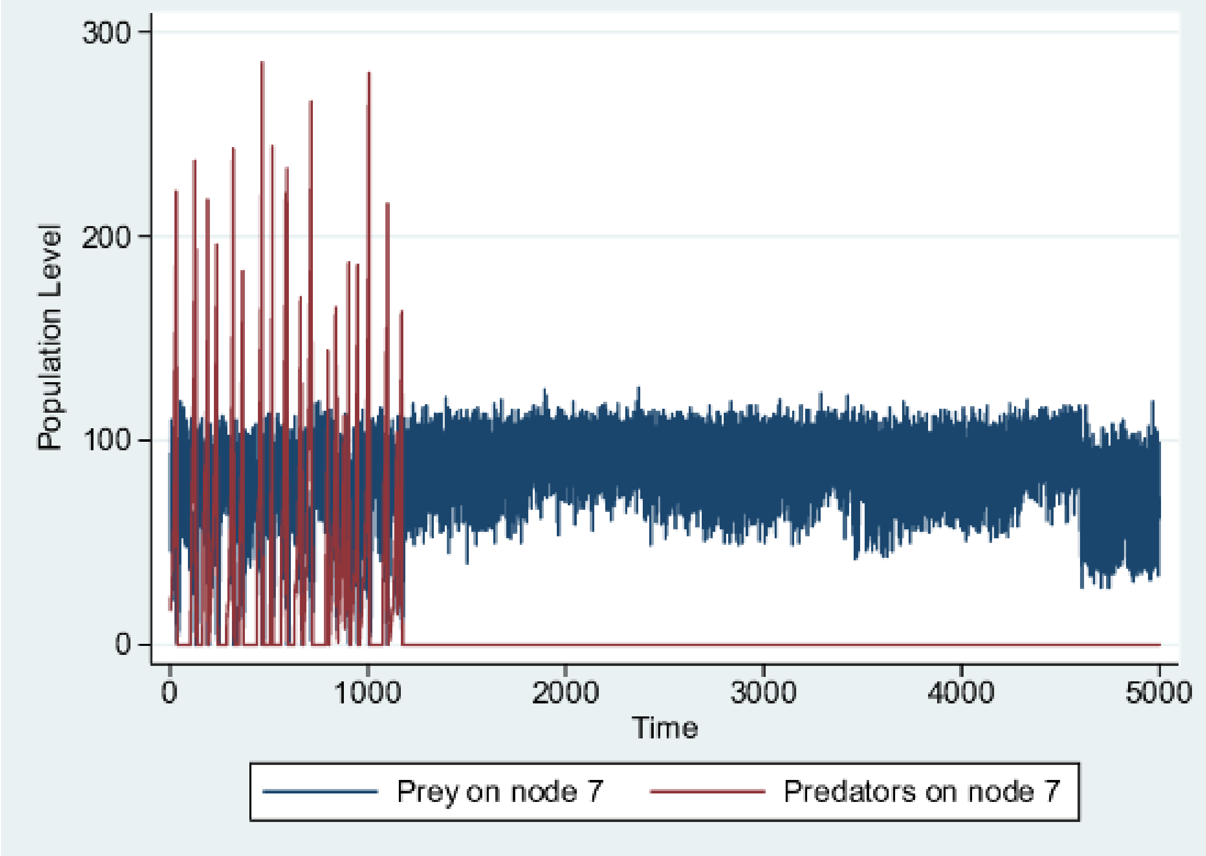
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 6
Predators on node 6

1


300
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100
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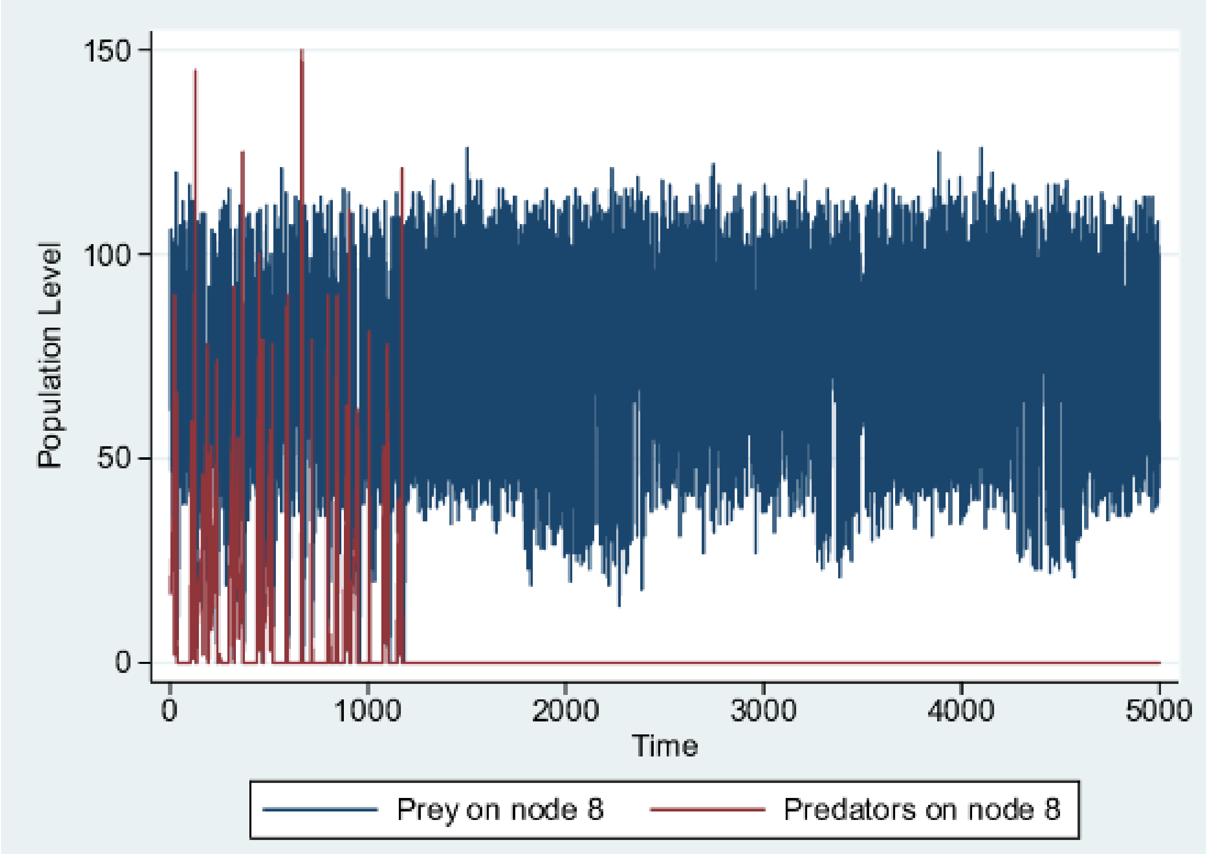
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 7
Predators on node 7

2


150
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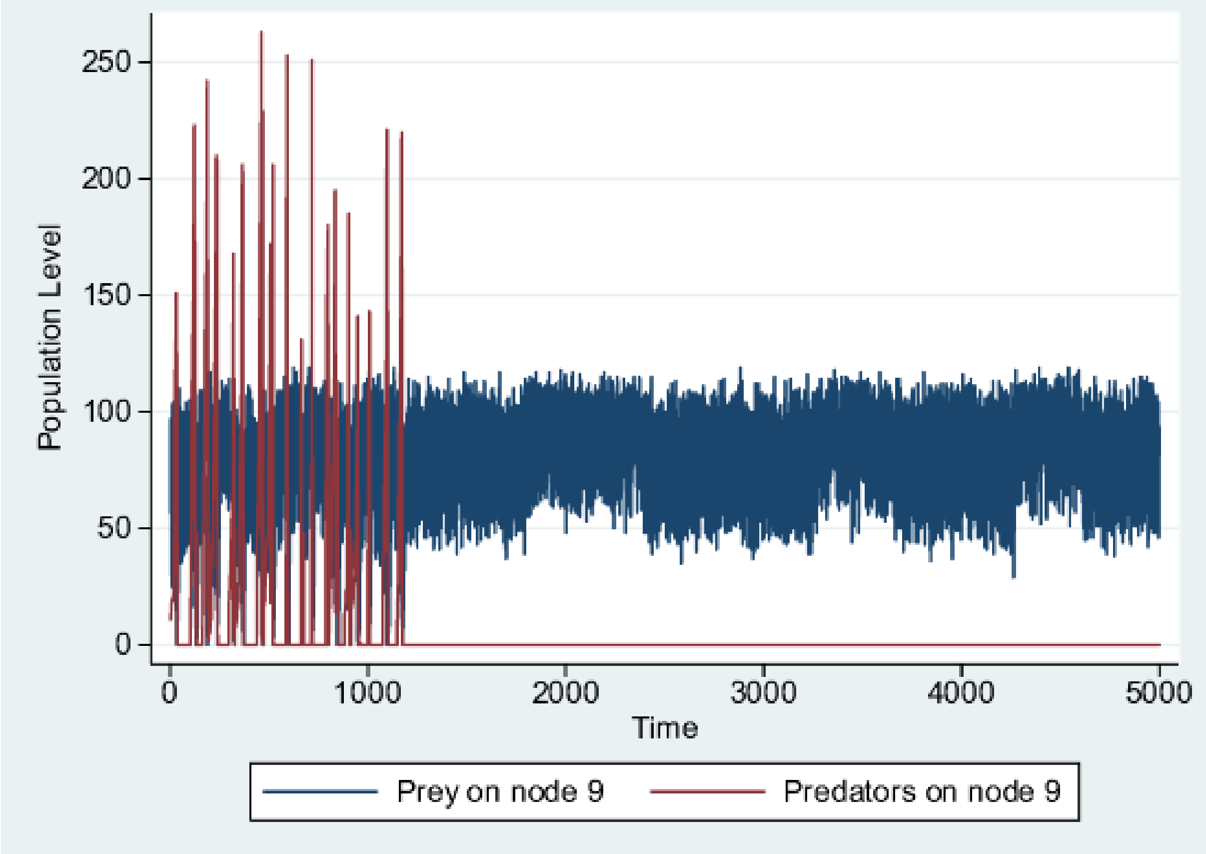
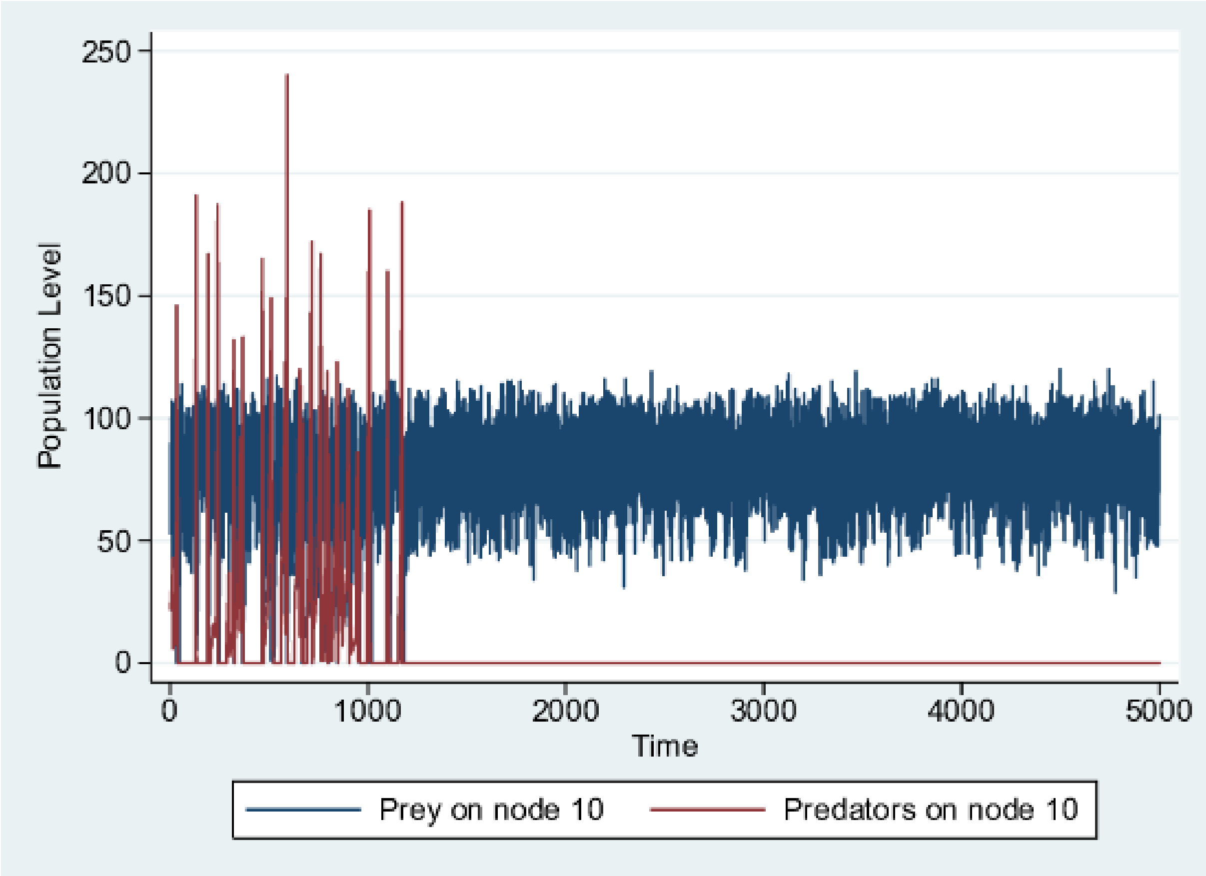
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 8
Predators on node 8
1


250
200
150
100
50
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 9
Predators on node 9
2



250
200
150
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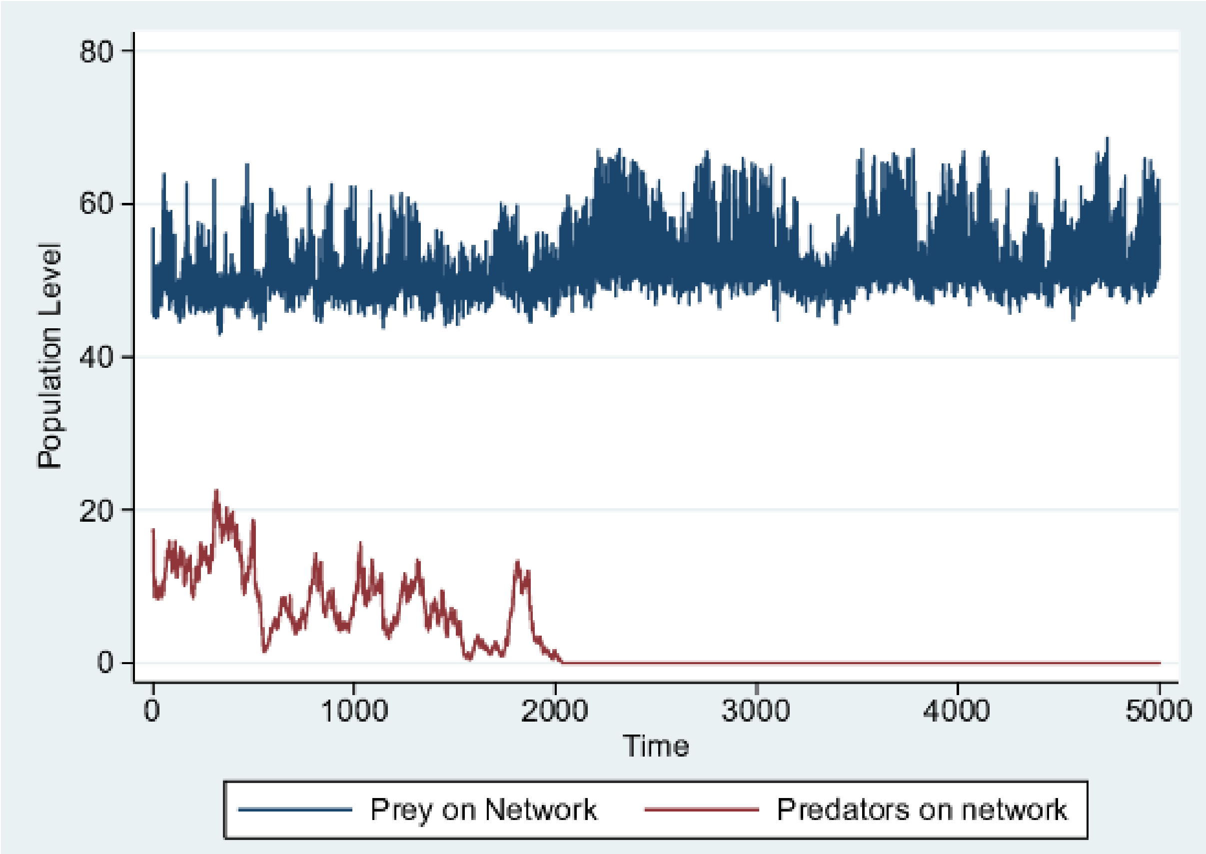
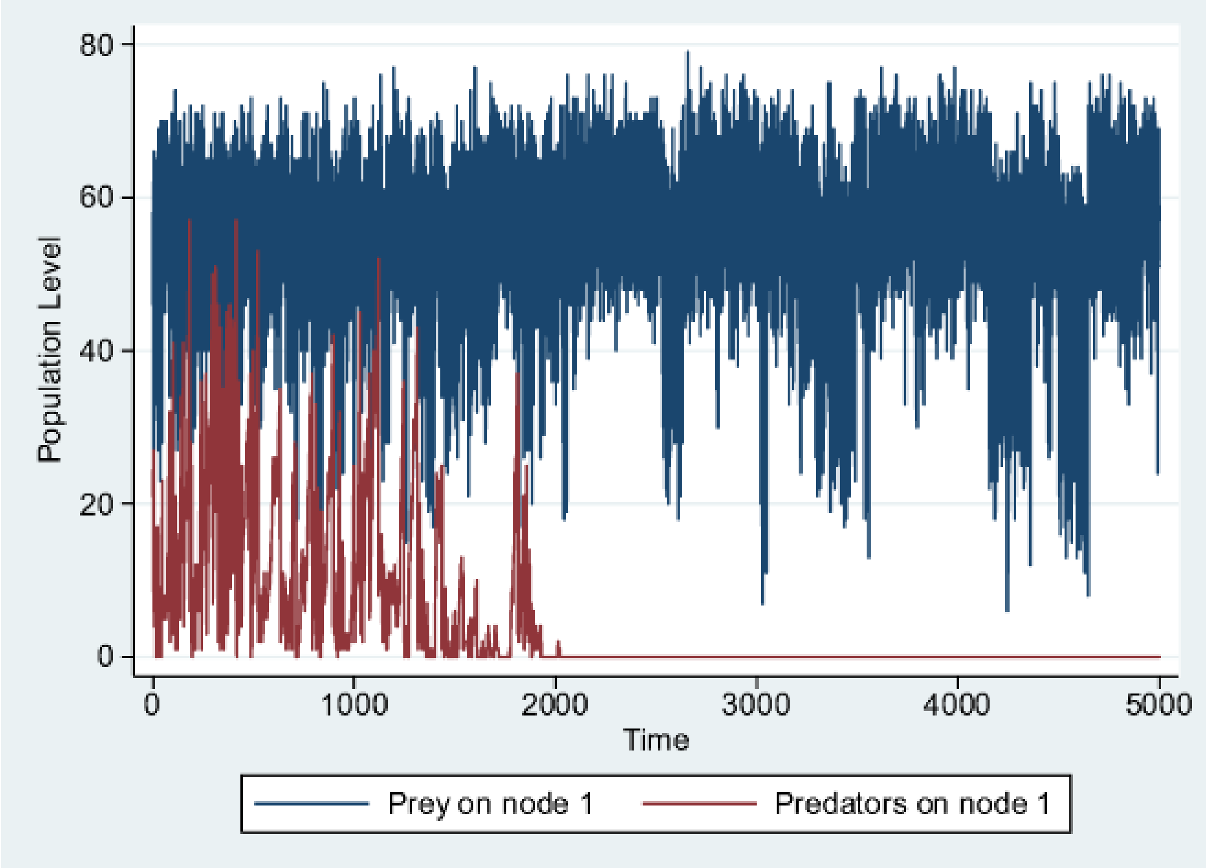
50
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 10
Predators on node 10

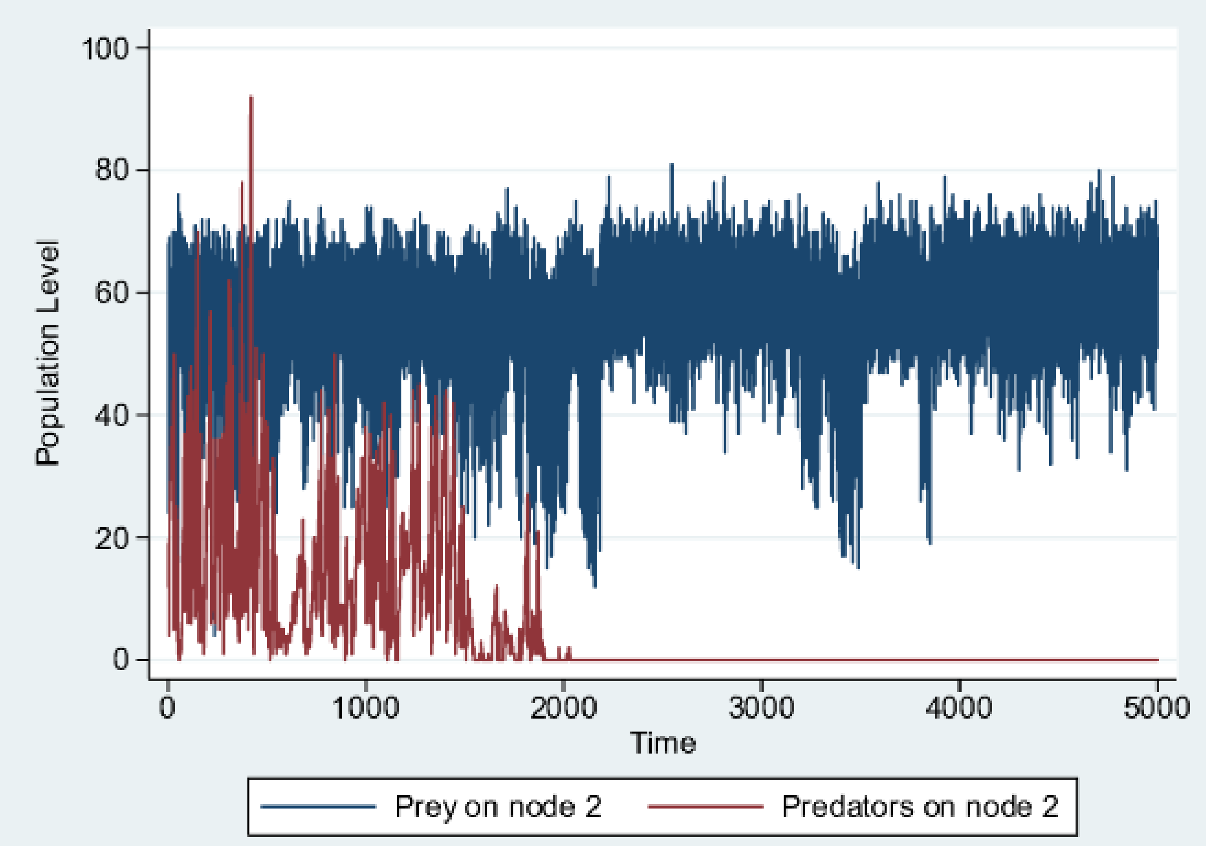
RUN 6



Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on Network
Predators on network



Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 1
Predators on node 1


100
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20
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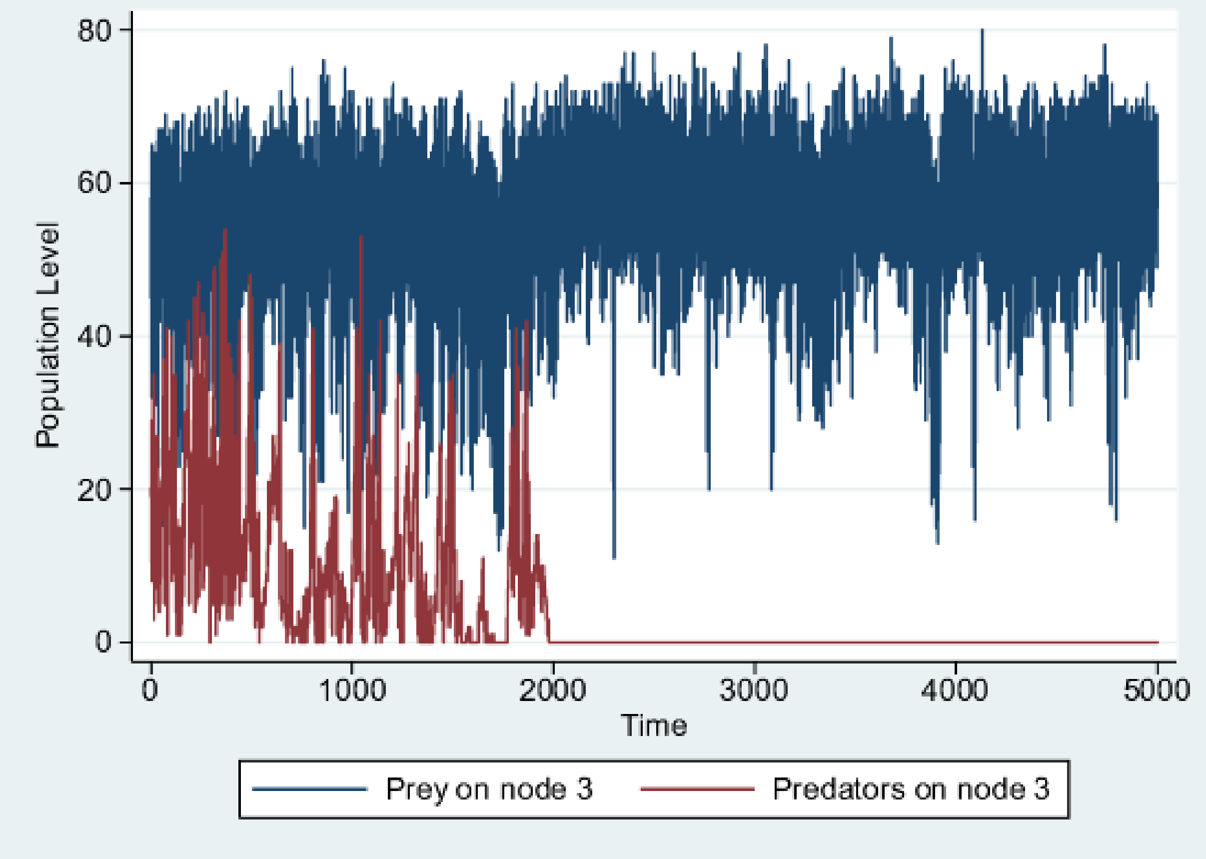
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 2
Predators on node 2
1


80
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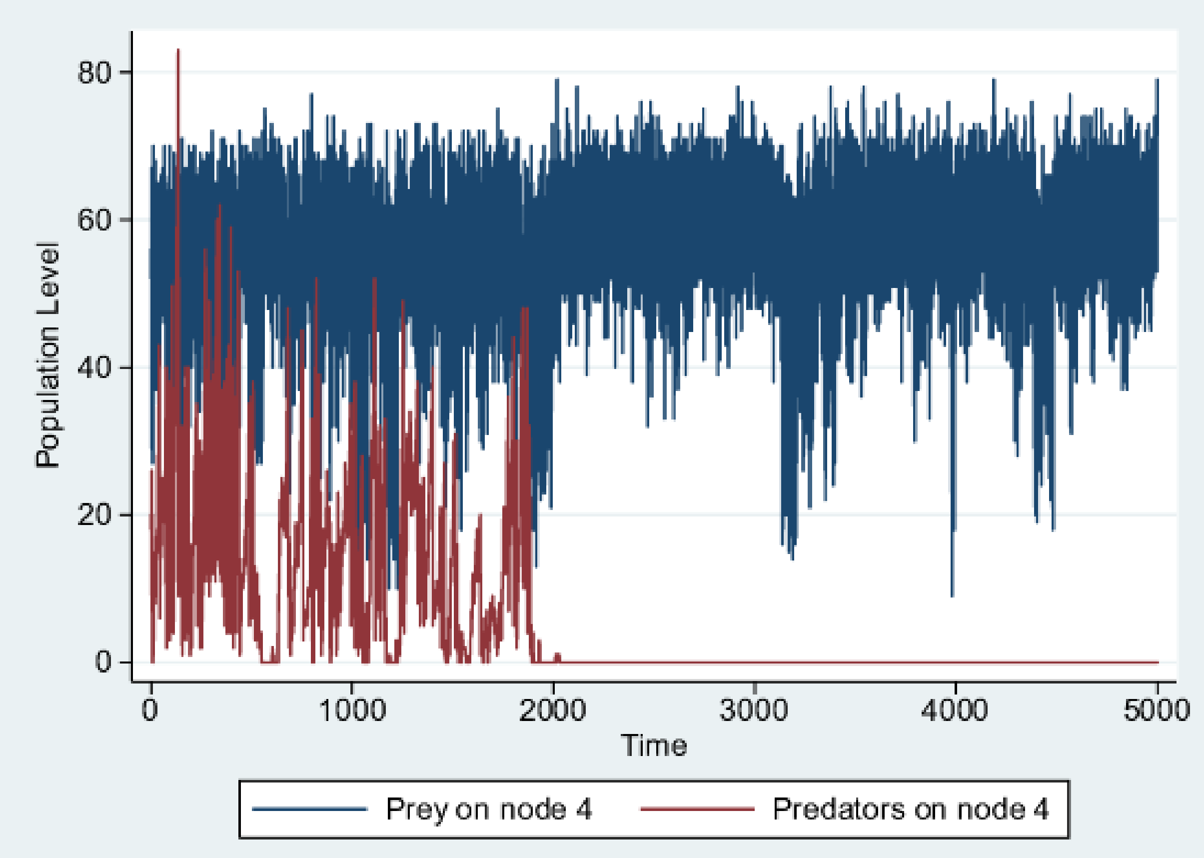
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 3
Predators on node 3
2


80
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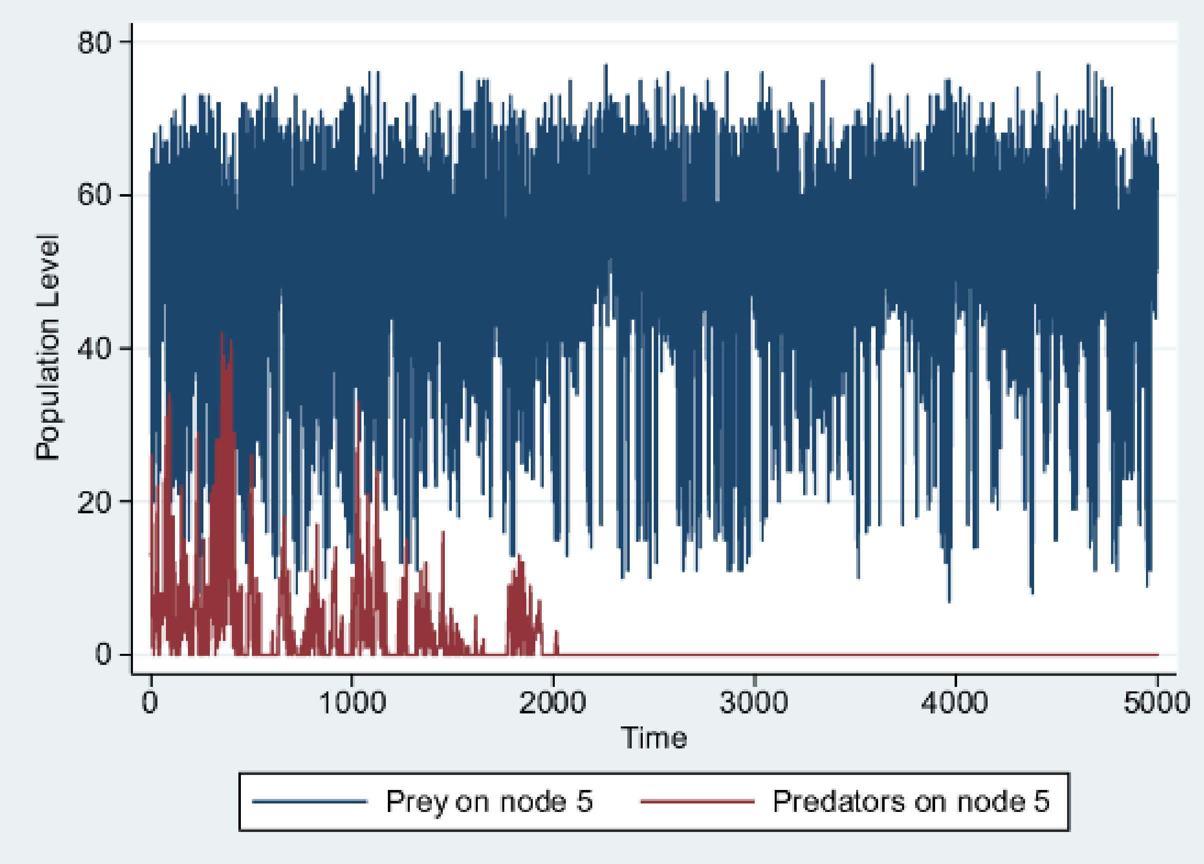
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 4
Predators on node 4

1


80
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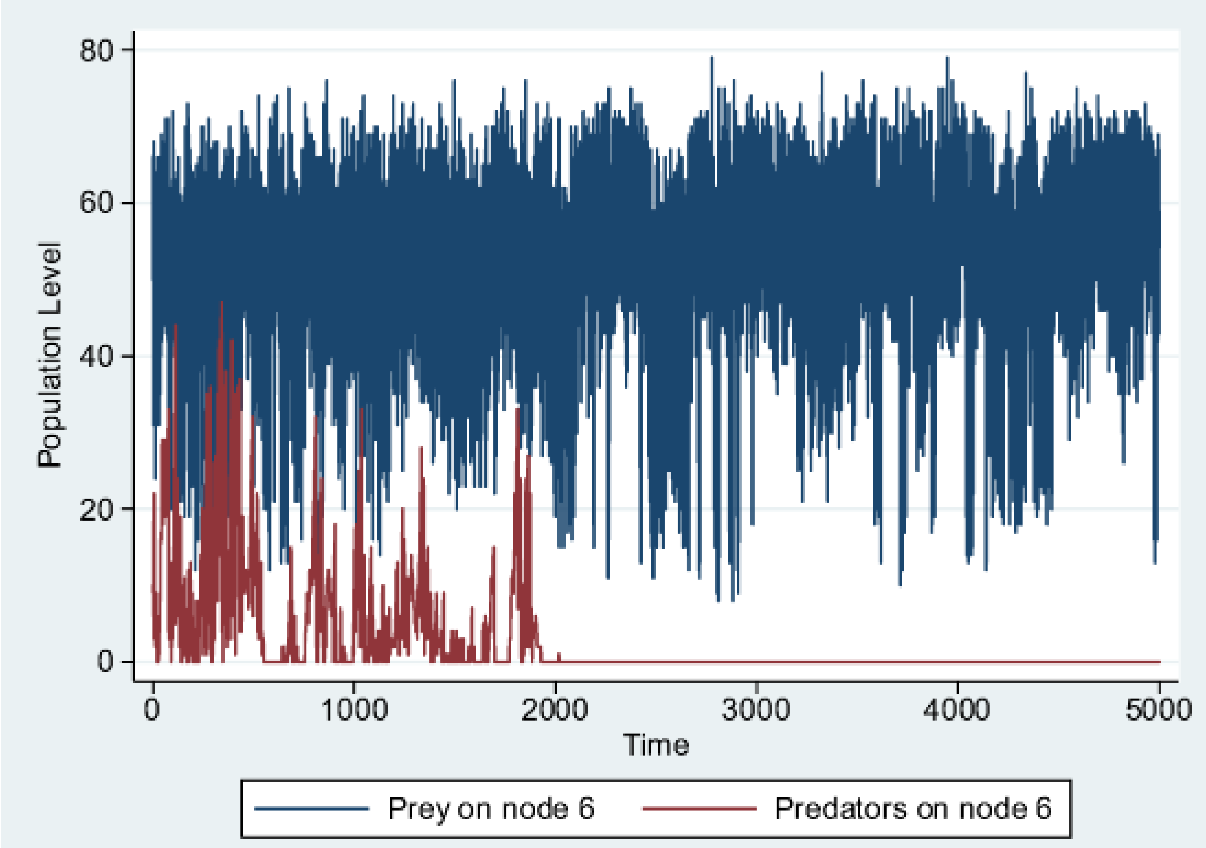
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 5
Predators on node 5

2


Population Level
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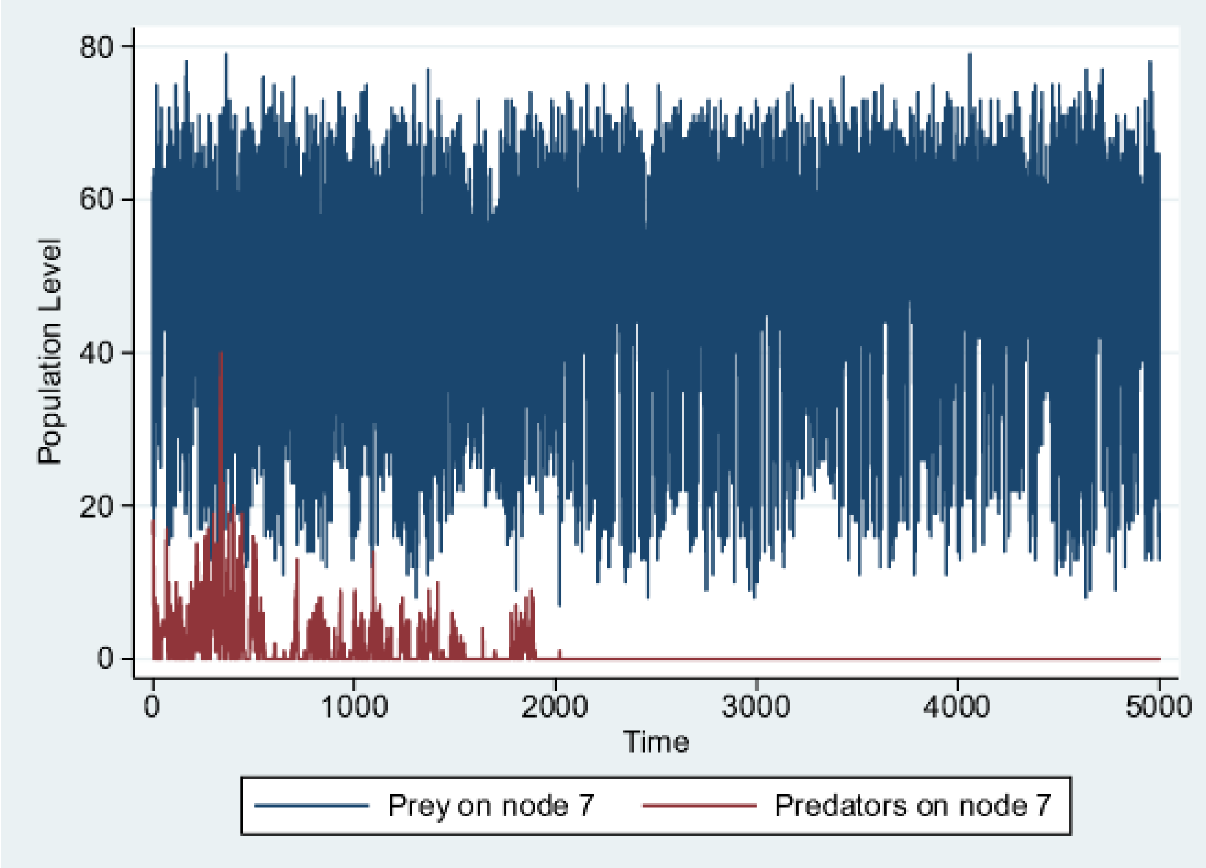
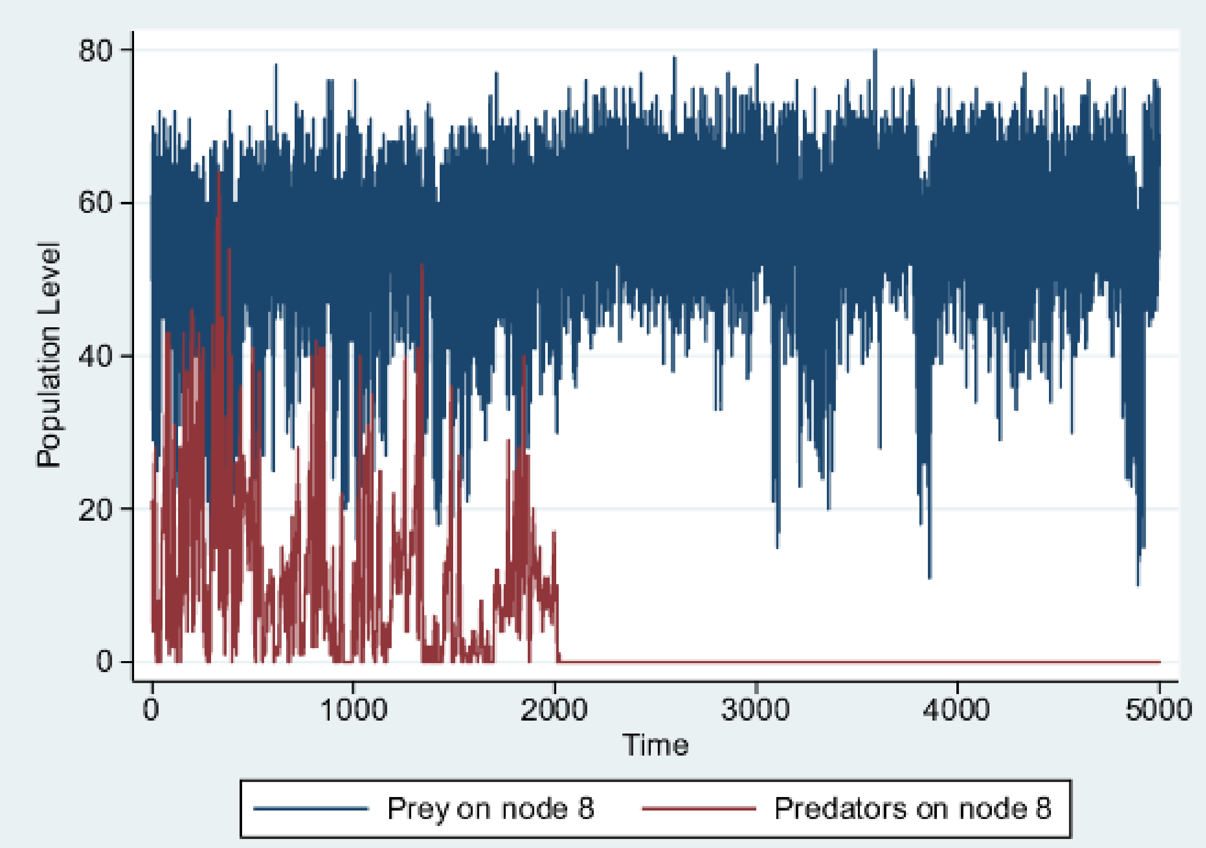
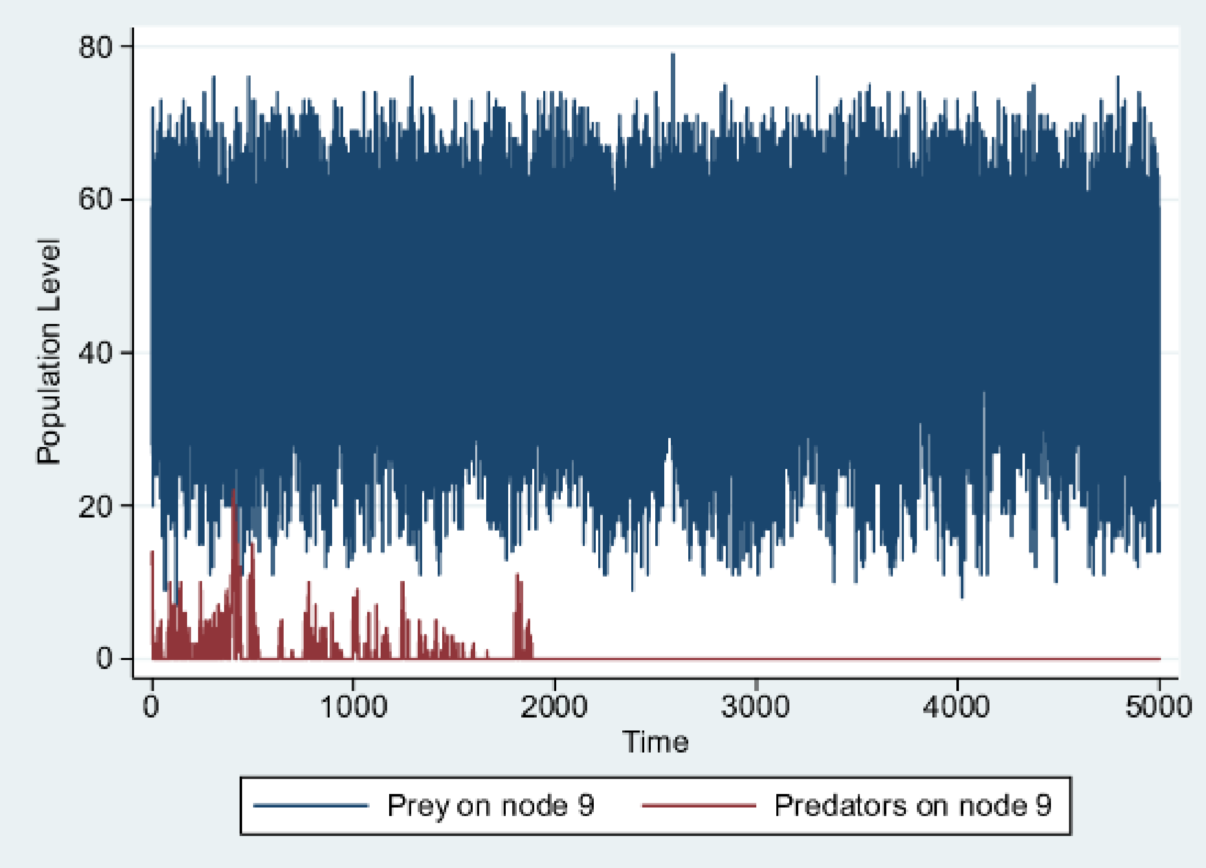
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 6
Predators on node 6


Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 7
Predators on node 7

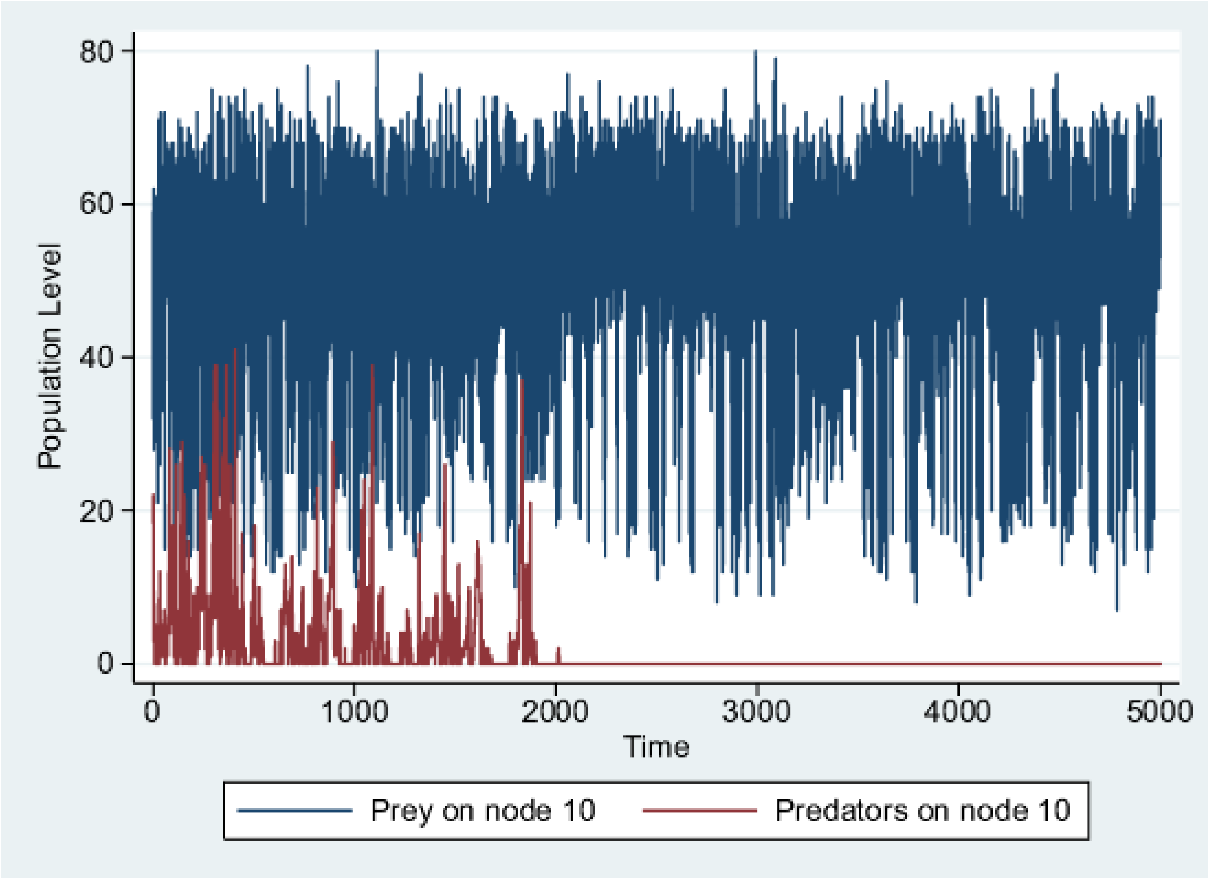

Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 8
Predators on node 8

1

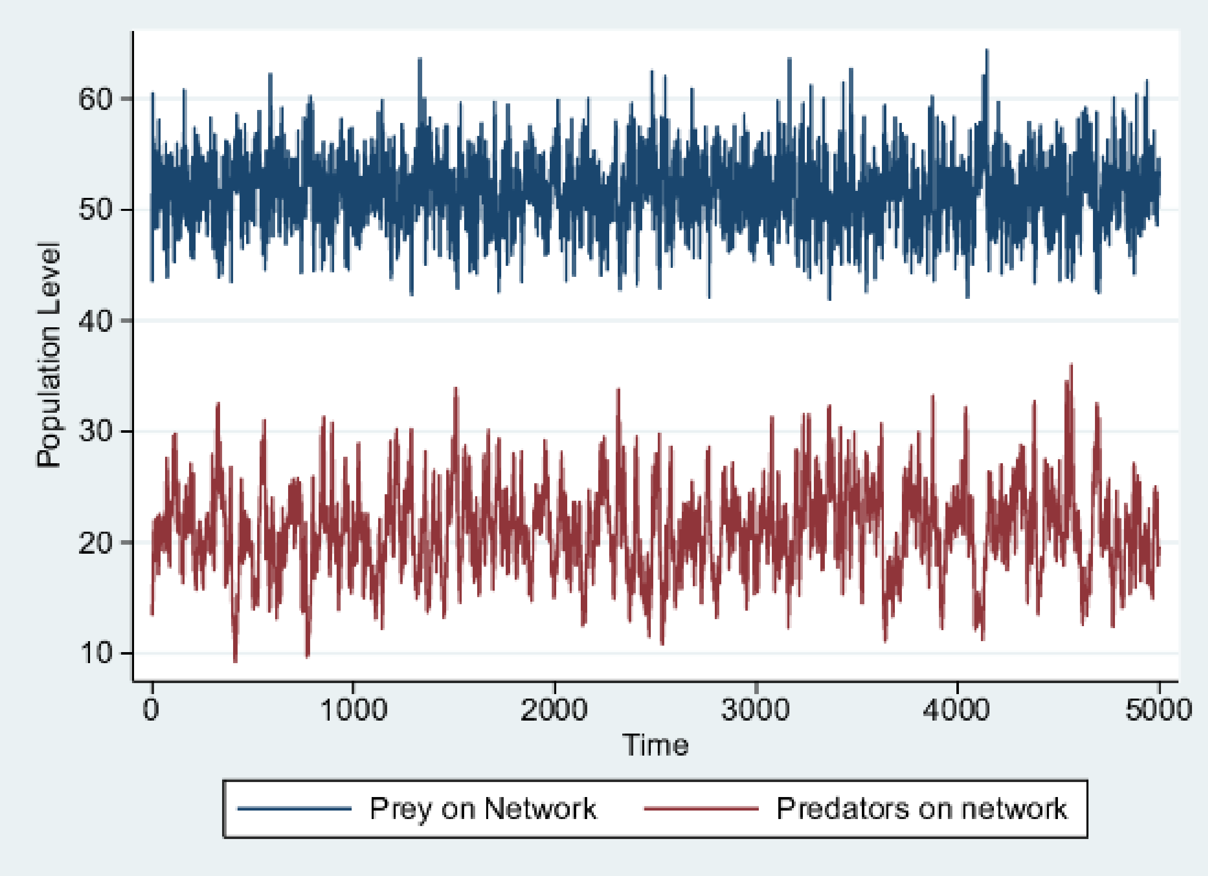

Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 9
Predators on node 9

2

1

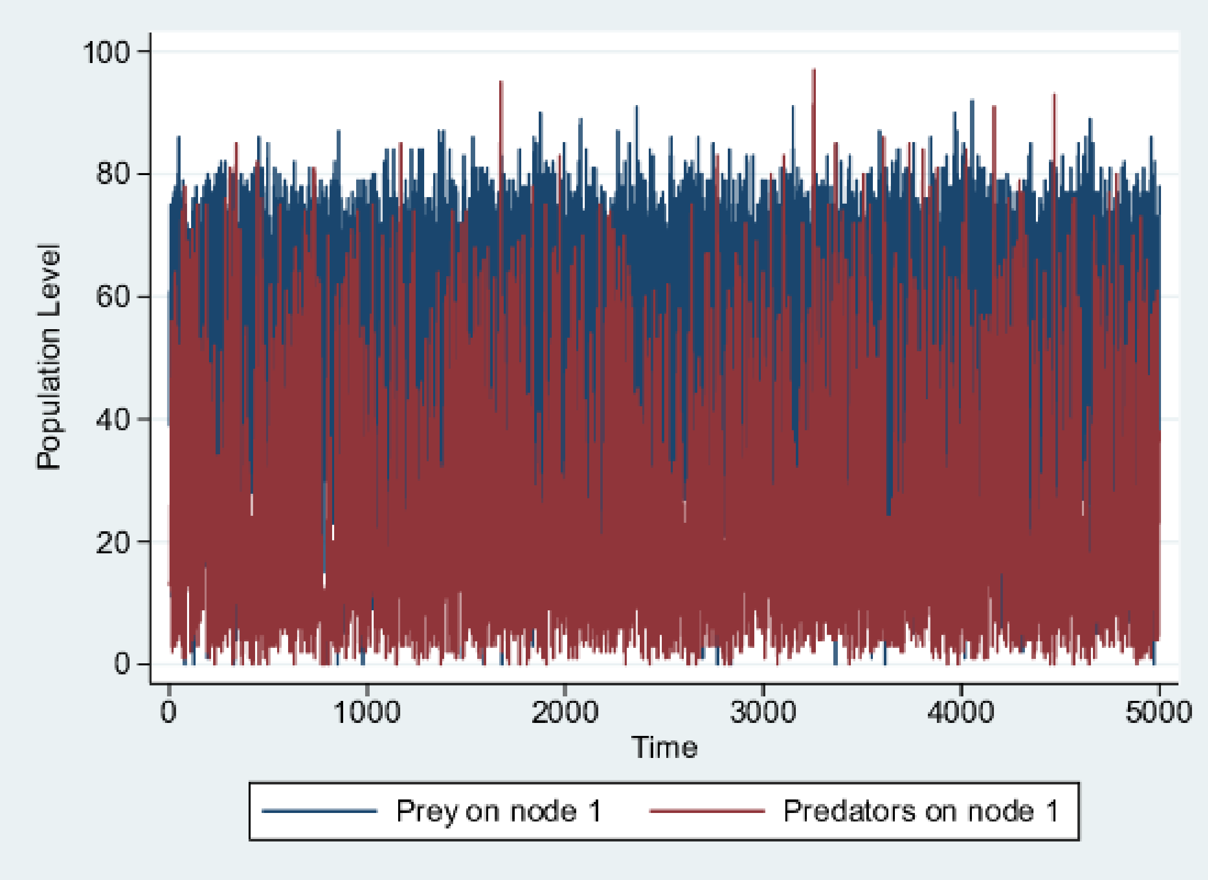

80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 10
Predators on node 10

1 RUN 7



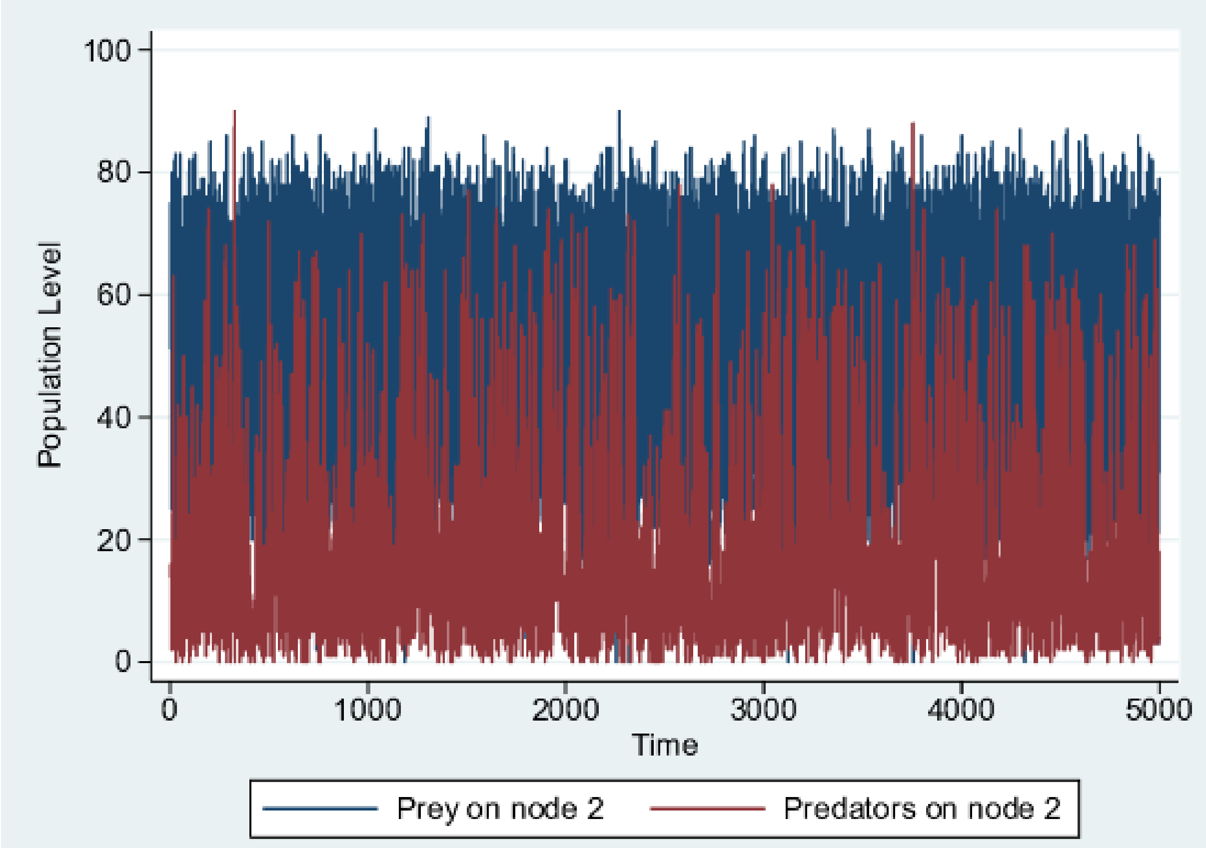
Population Level
60
50
40
30
20
10
0
1000
2000
3000
4000
5000
Time
Prey on Network
Predators on network

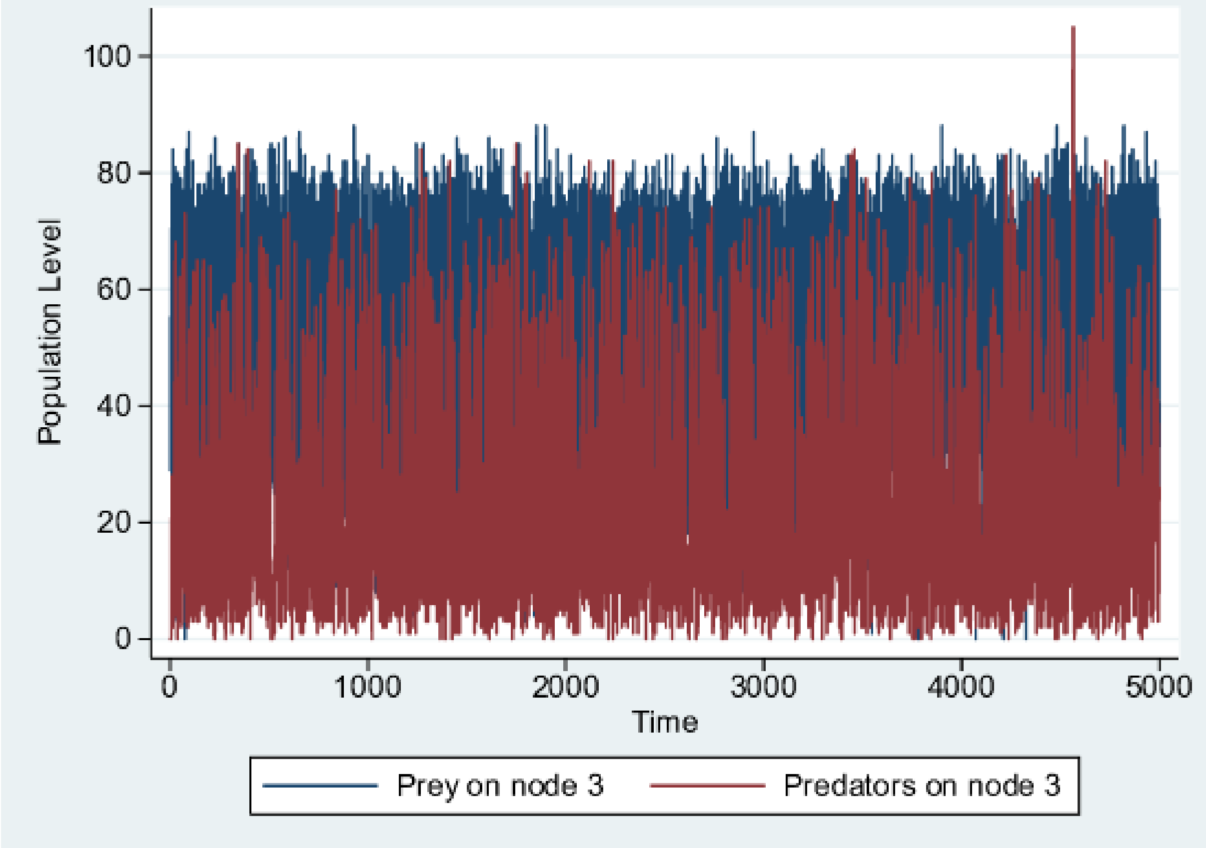
2

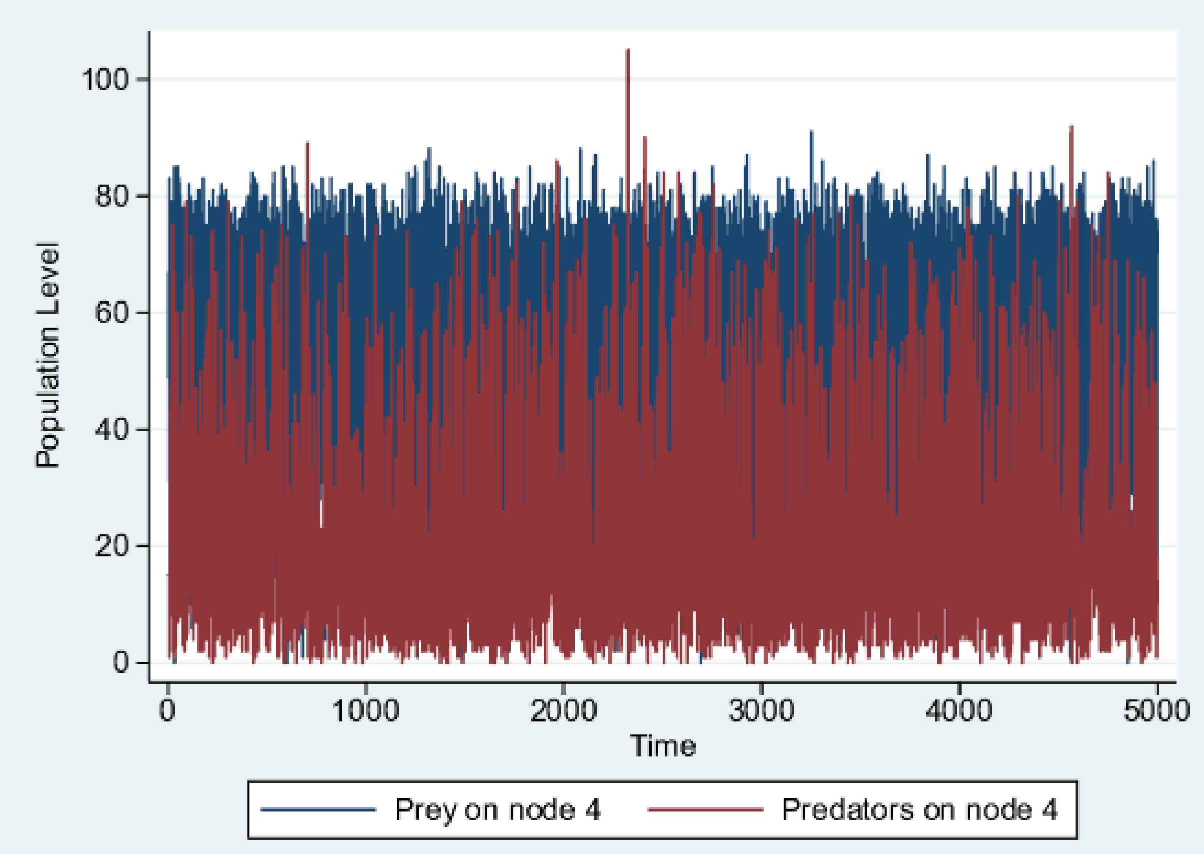


Population Level
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 1
Predators on node 1

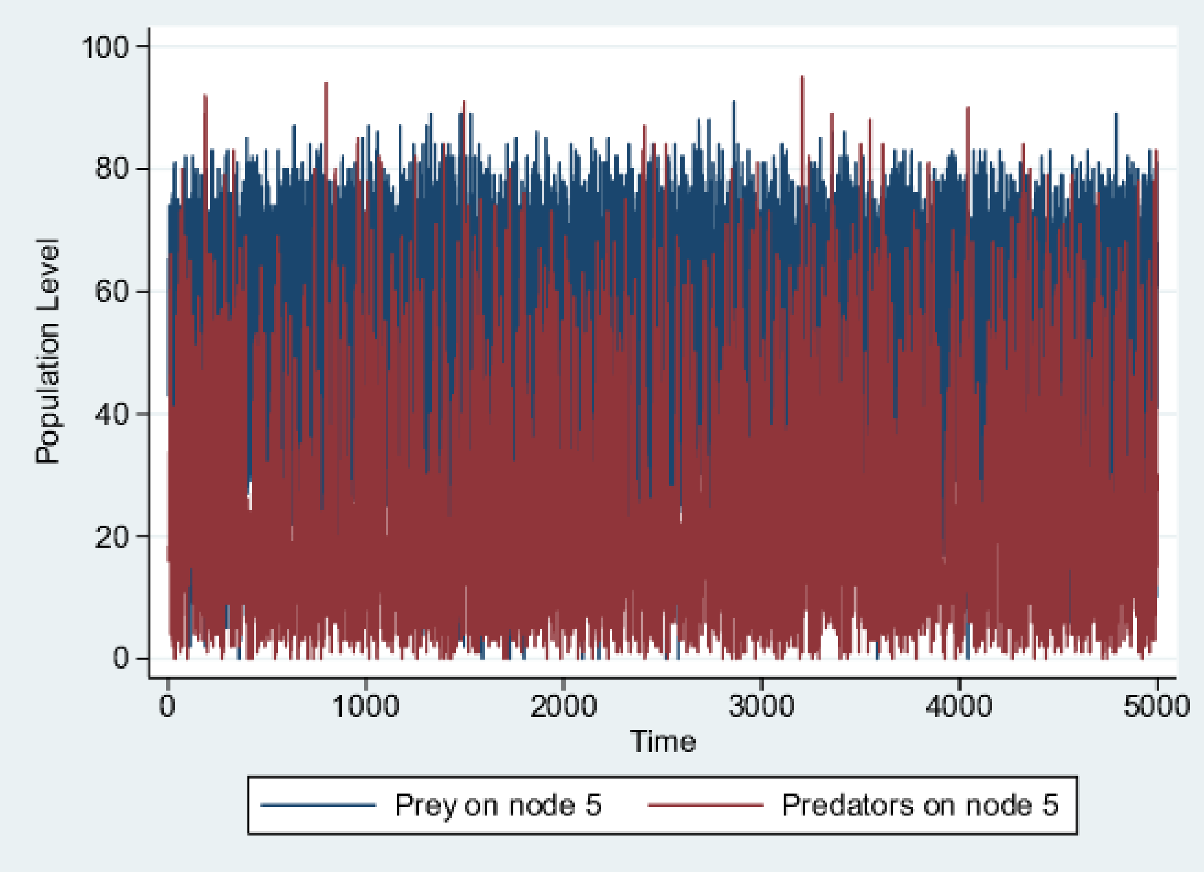
3


100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 2
Predators on node 2
1

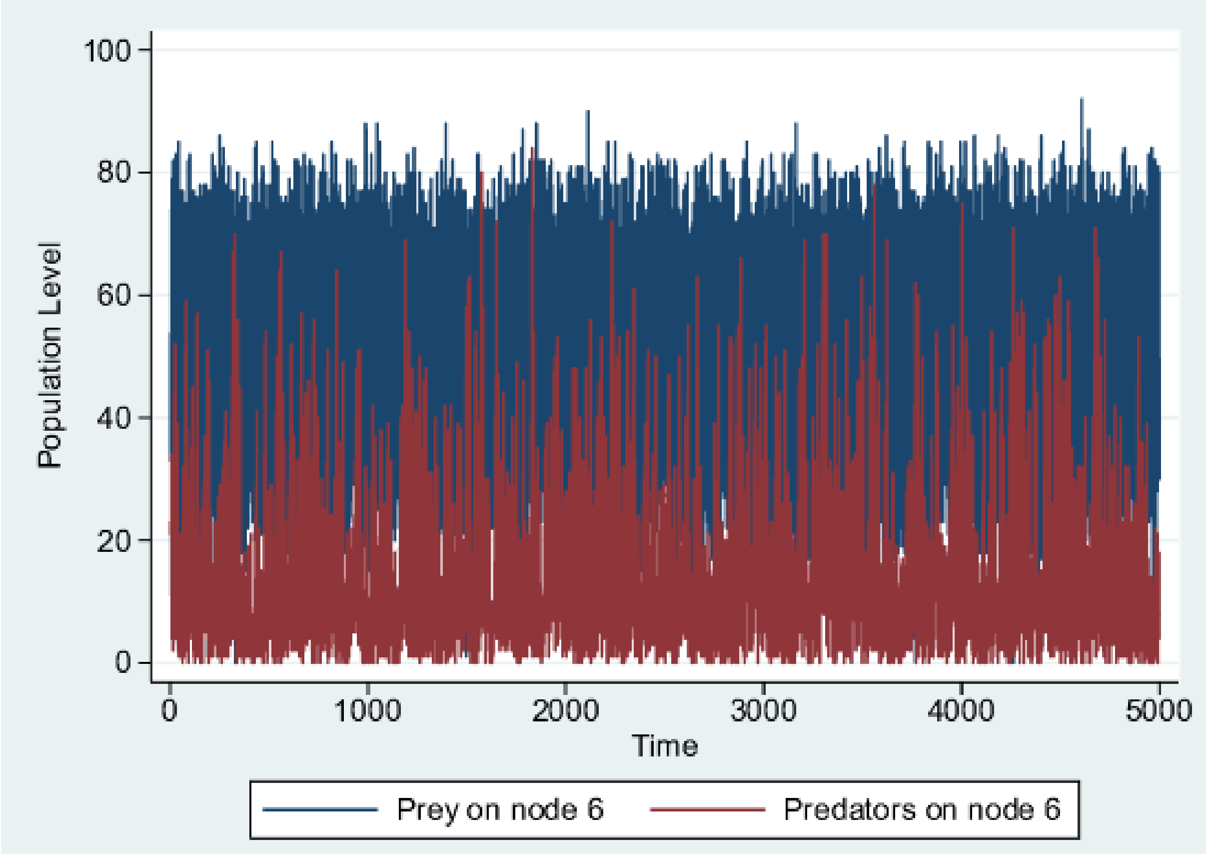

100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 3
Predators on node 3
2


100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 4
Predators on node 4

1

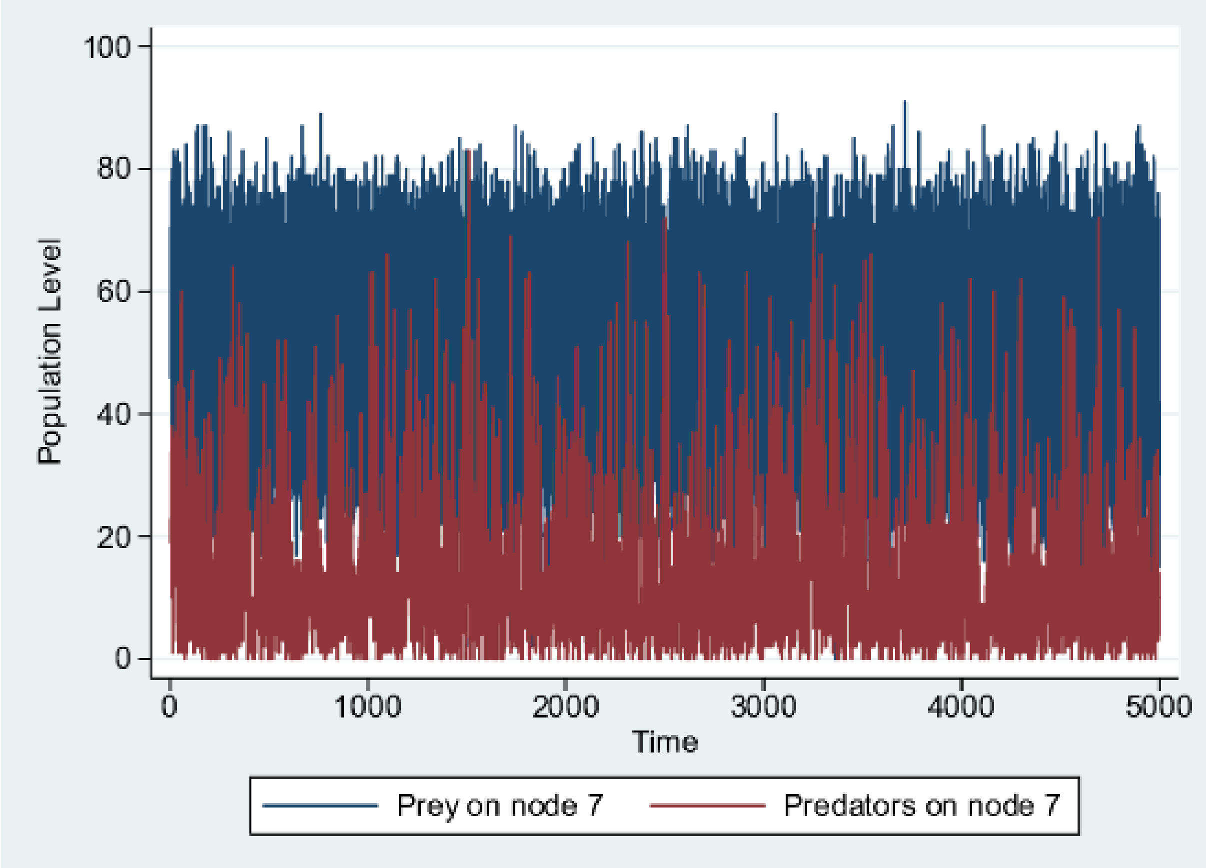

100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 5
Predators on node 5

2



100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 6
Predators on node 6

1



100
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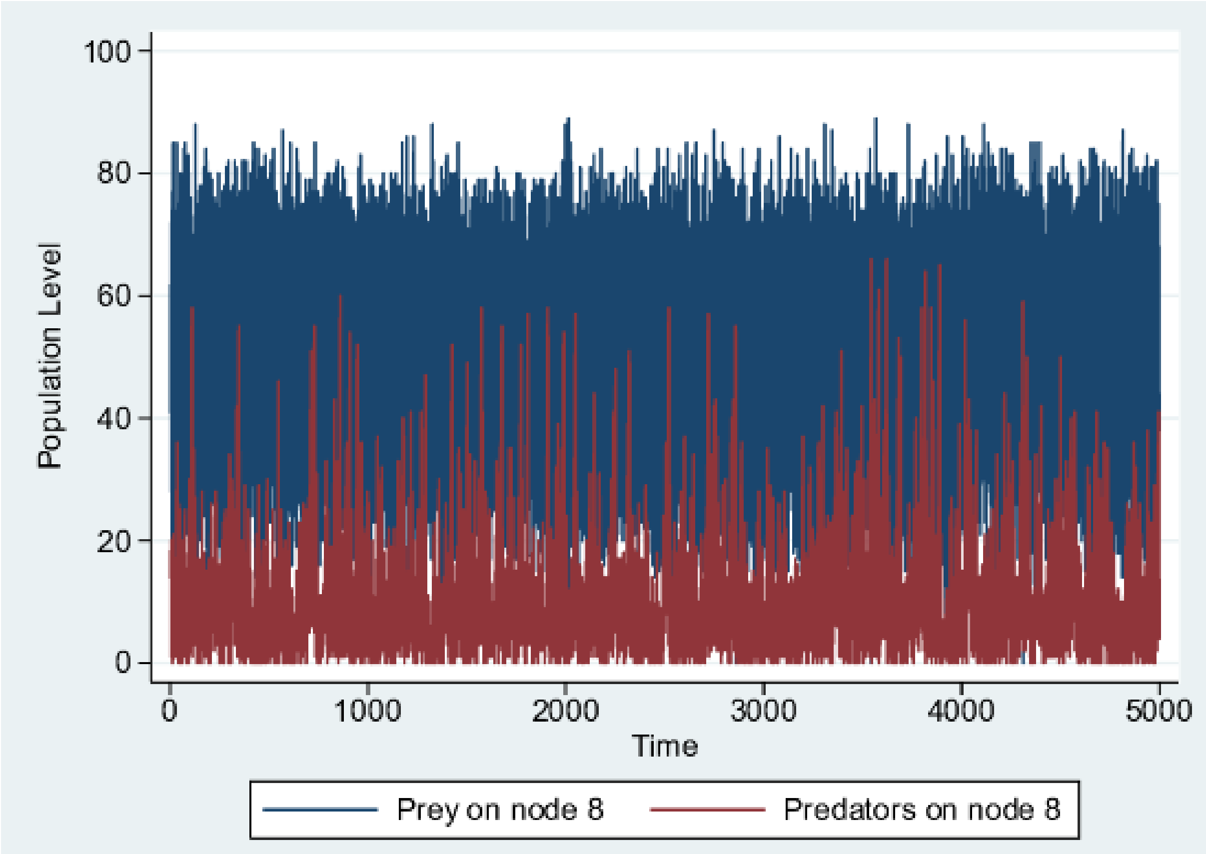
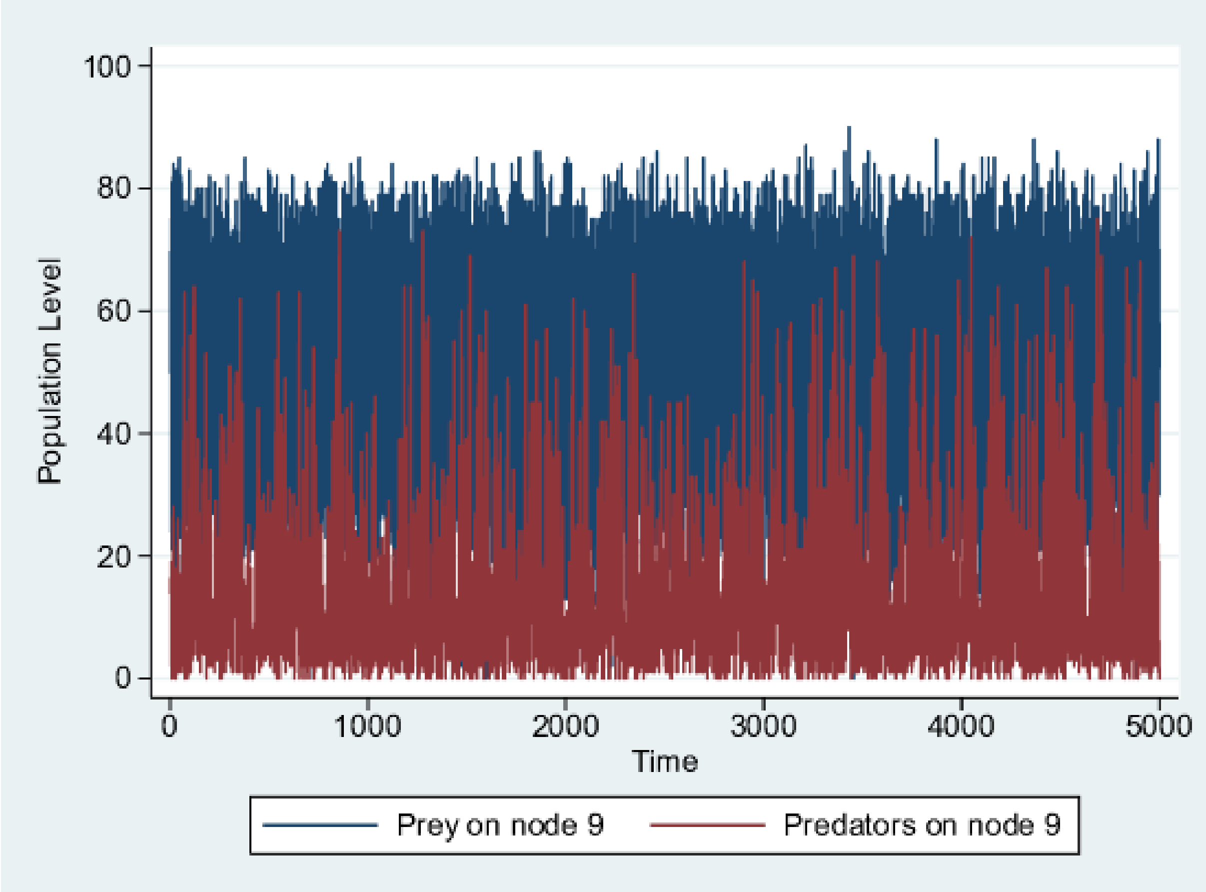
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 7
Predators on node 7

2



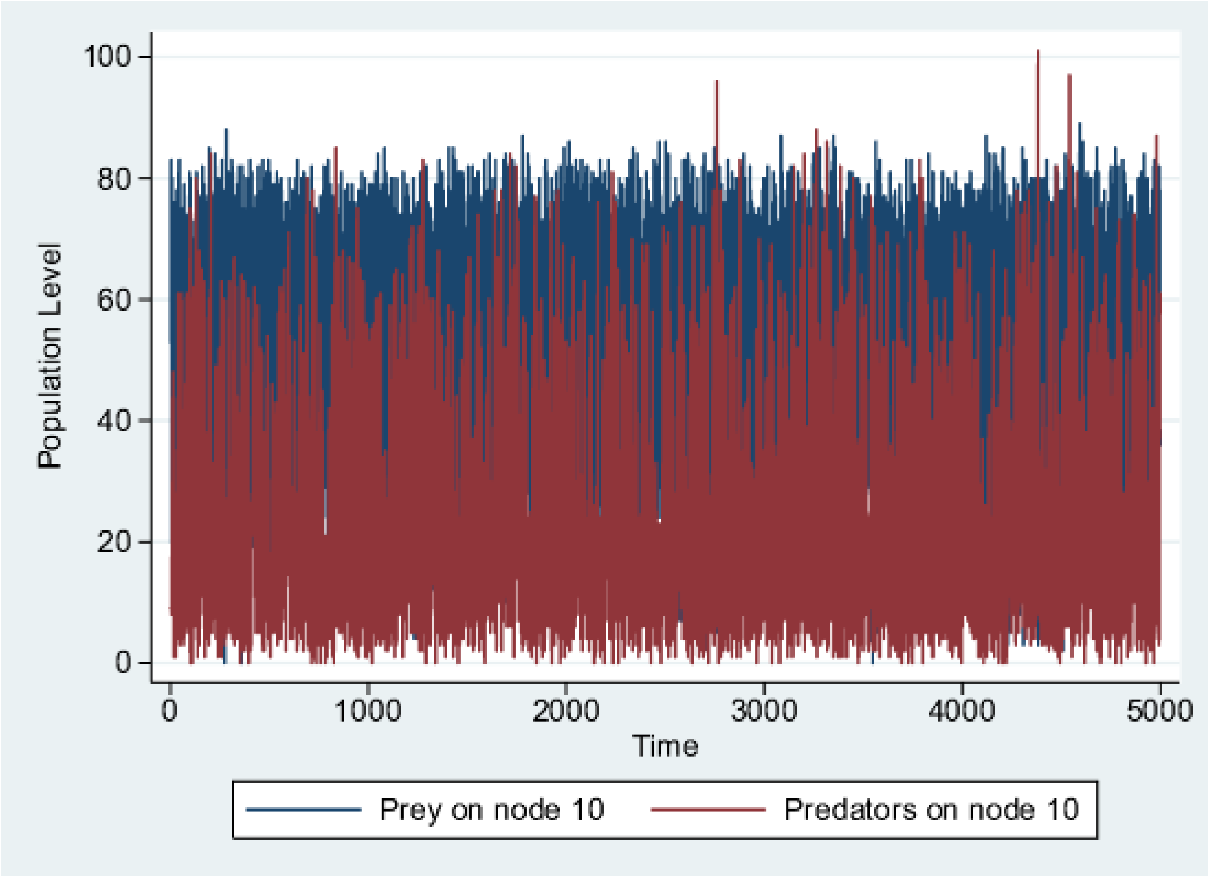
100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 8
Predators on node 8

1



100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 9
Predators on node 9

2


100
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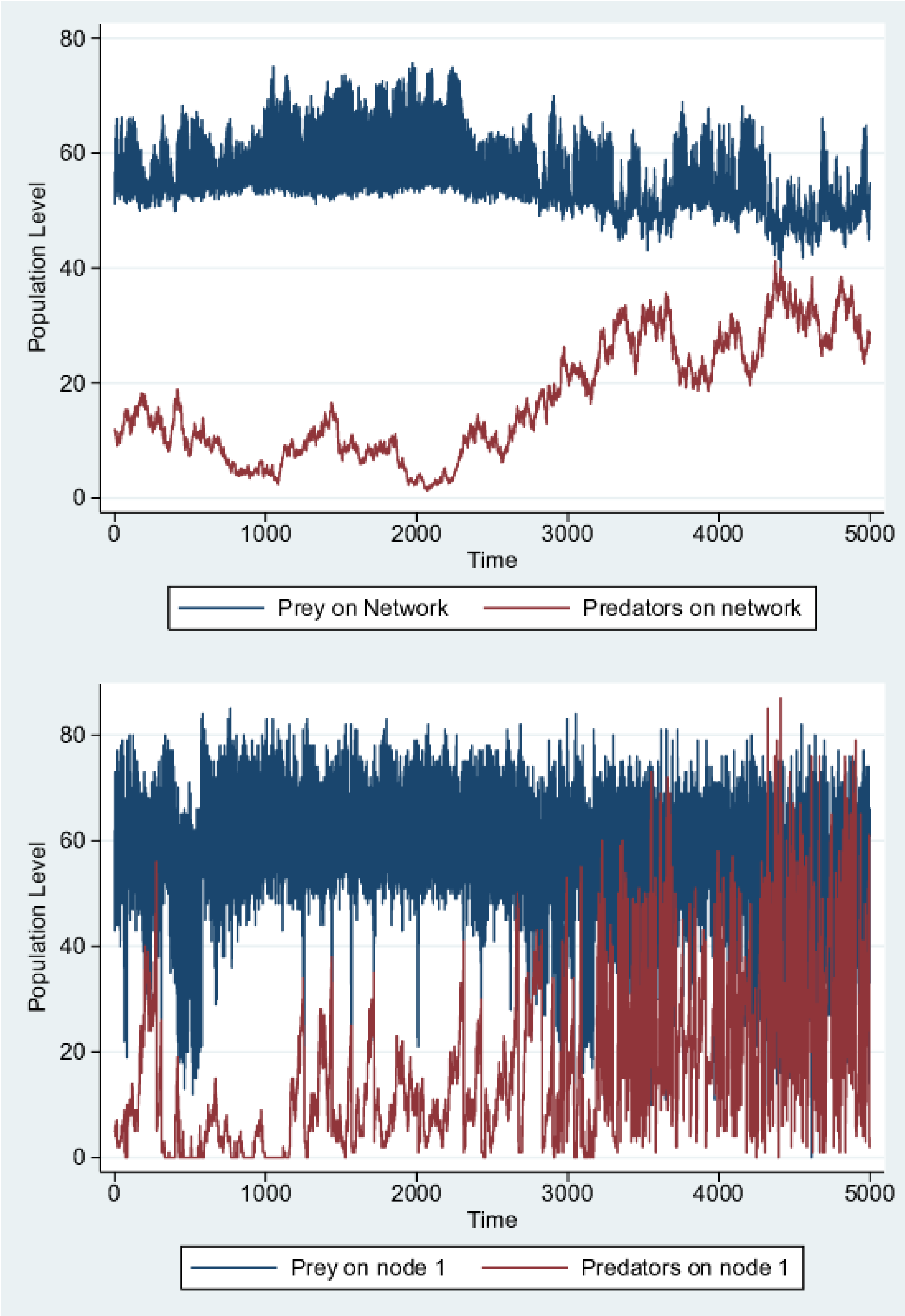
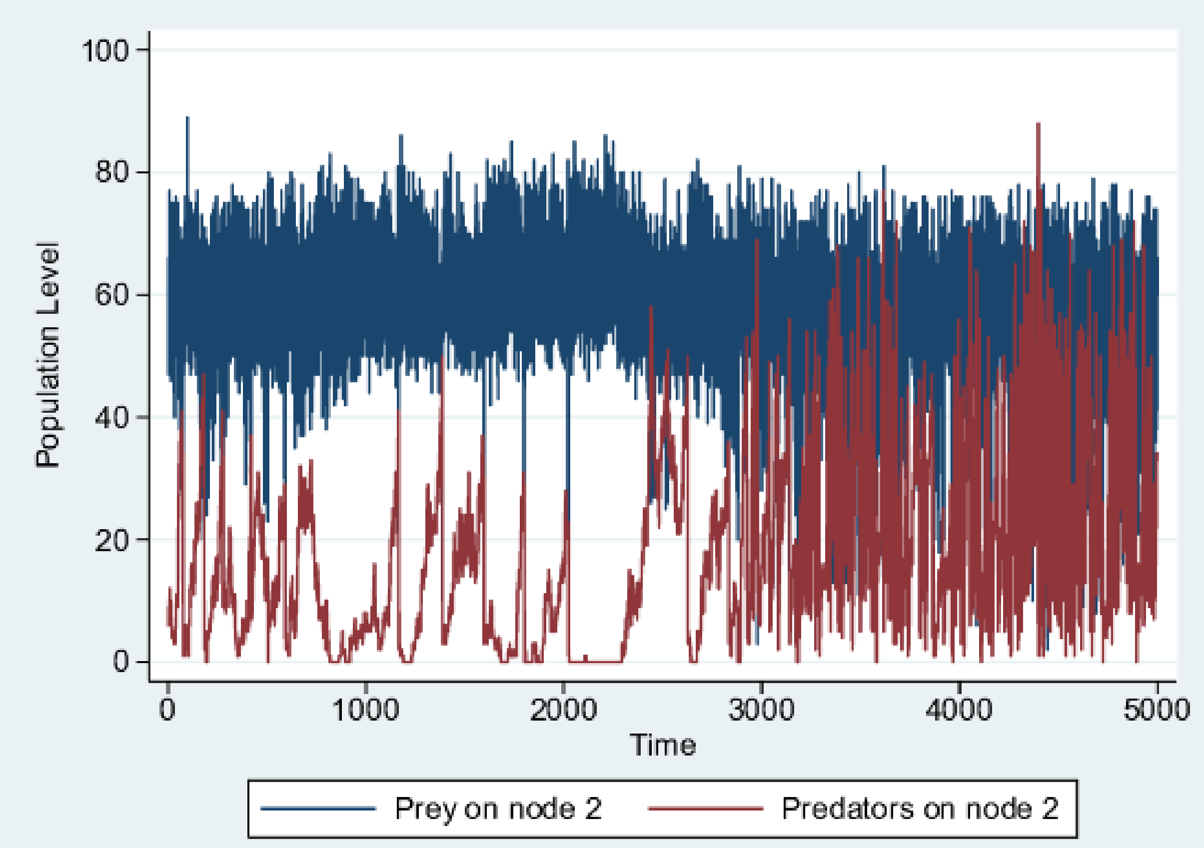
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 10
Predators on node 10

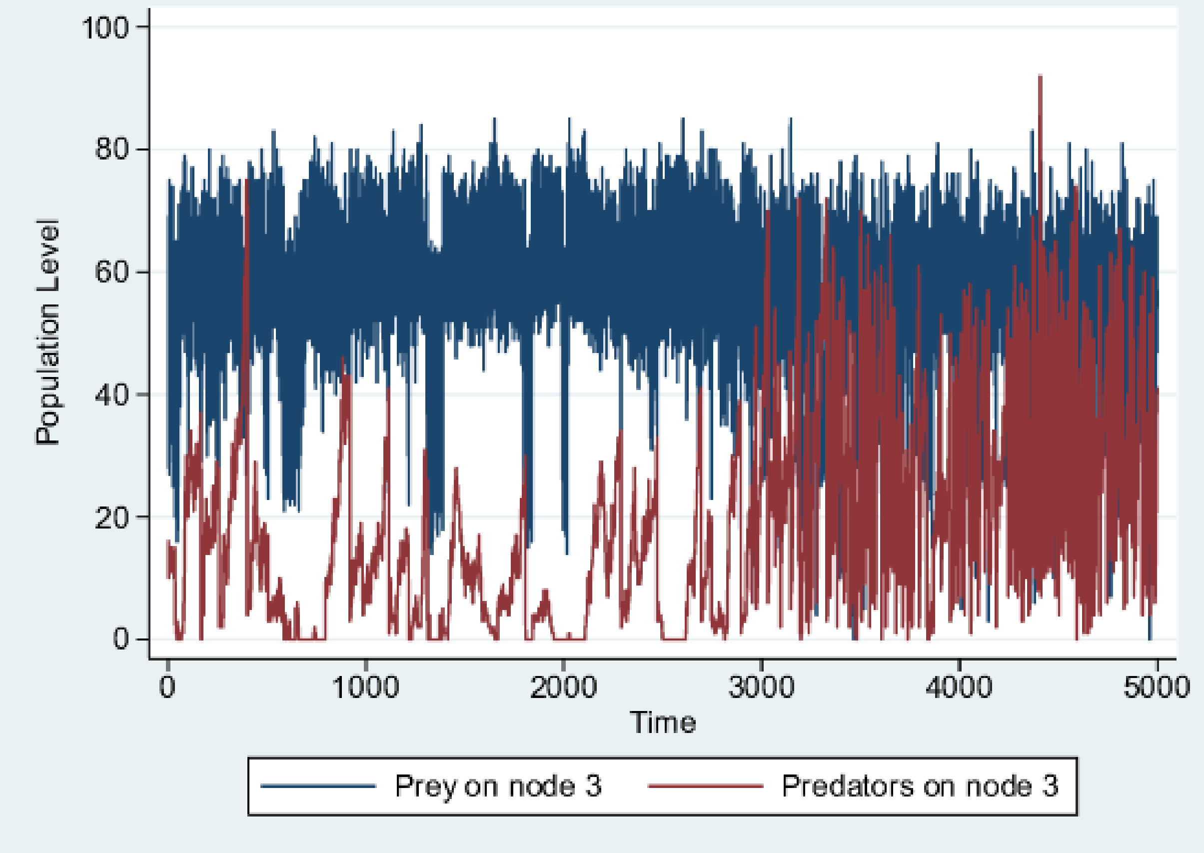
1

RUN 8

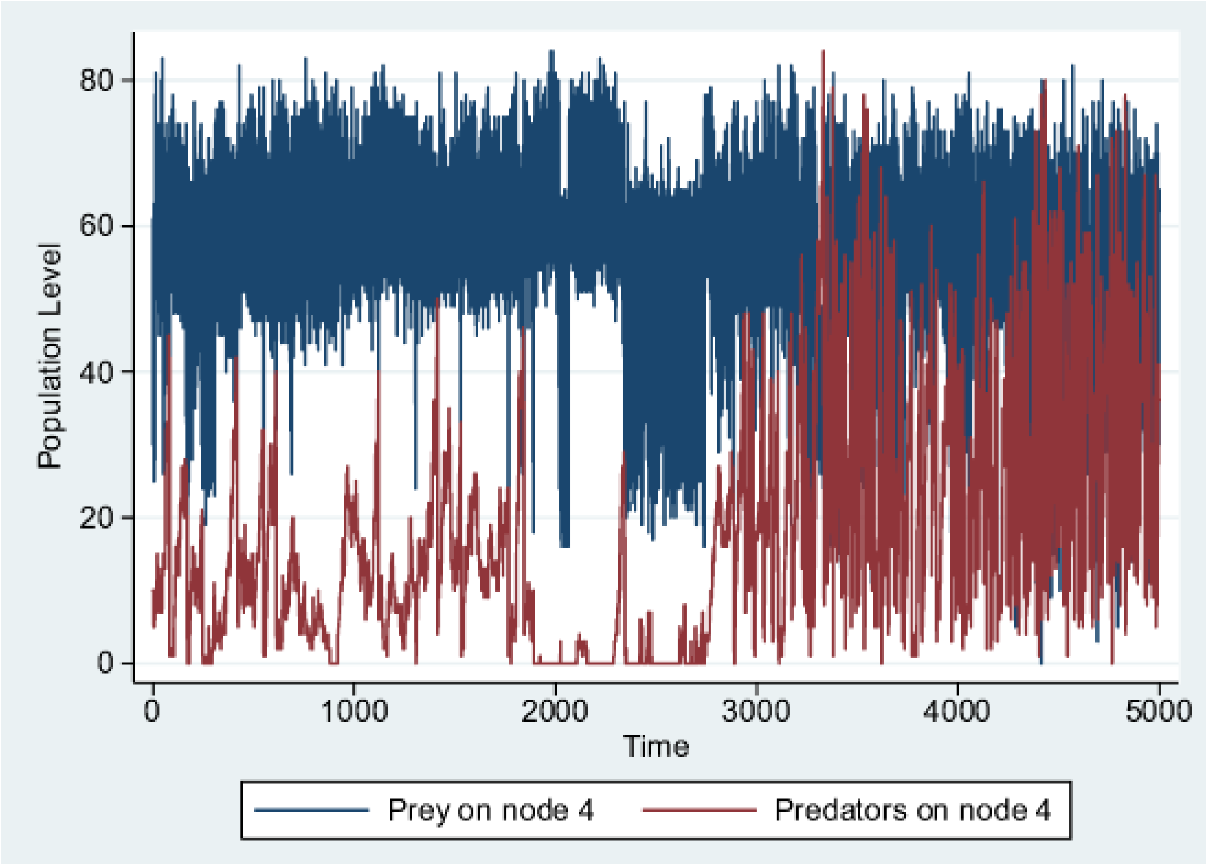

Population Level
Time
Prey on Network
Predators on network
Population Level
Time
Prey on node 1
Predators on node 1


100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 2
Predators on node 2

1

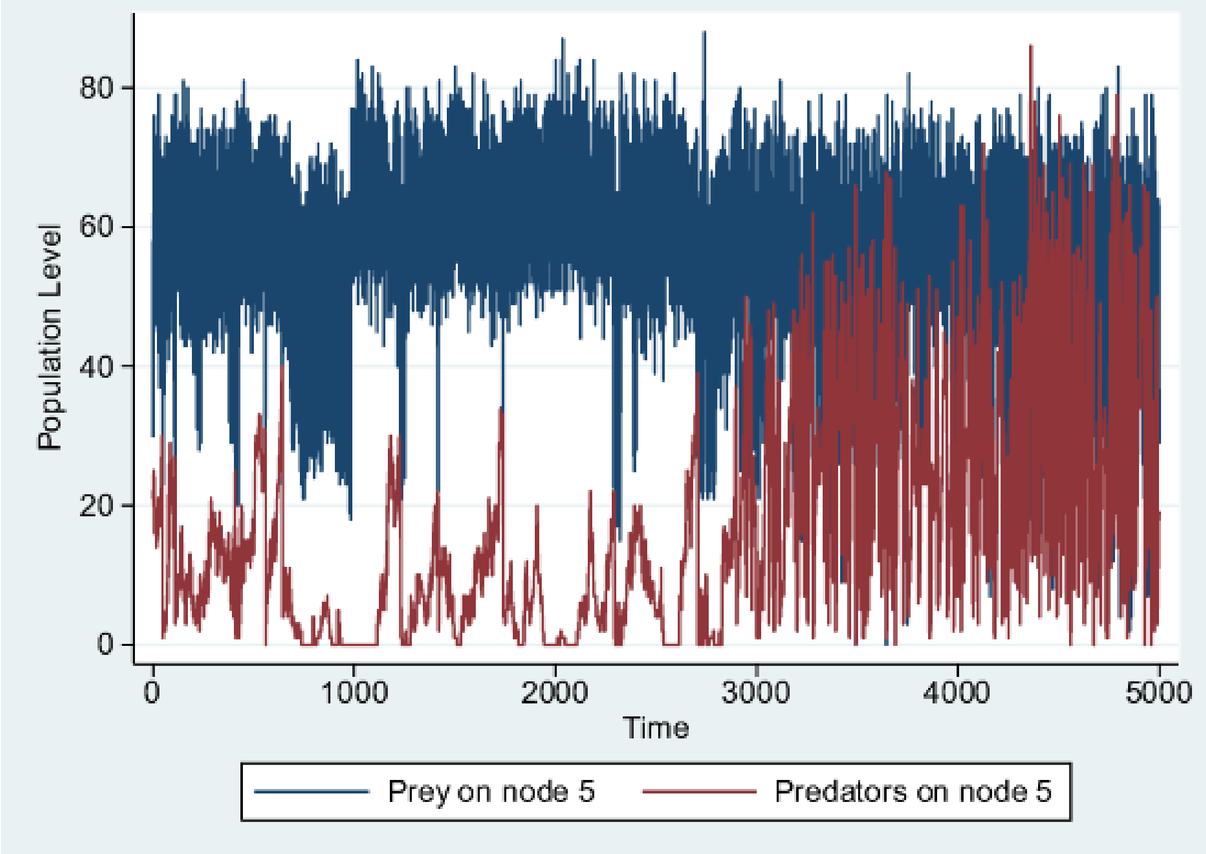

100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 3
Predators on node 3

2



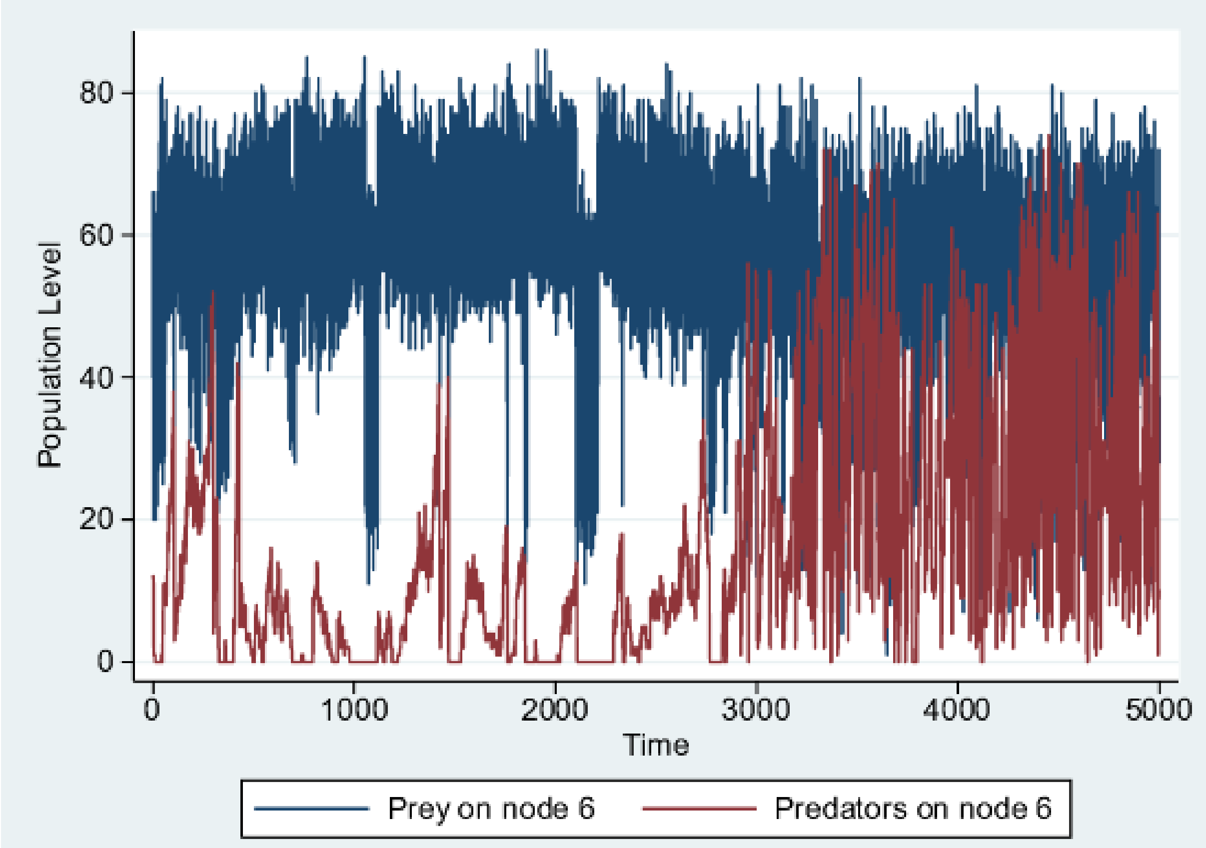
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 4
Predators on node 4

1

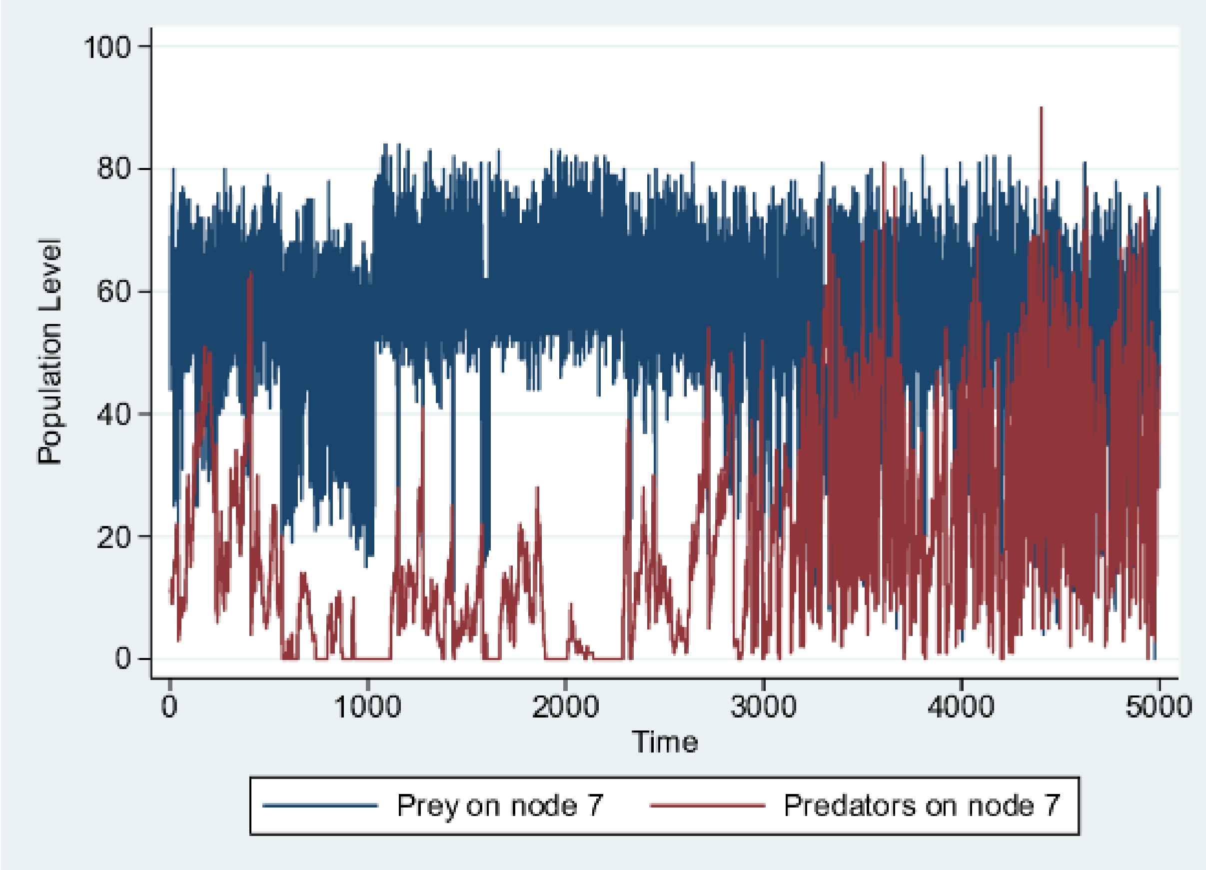


80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 5
Predators on node 5

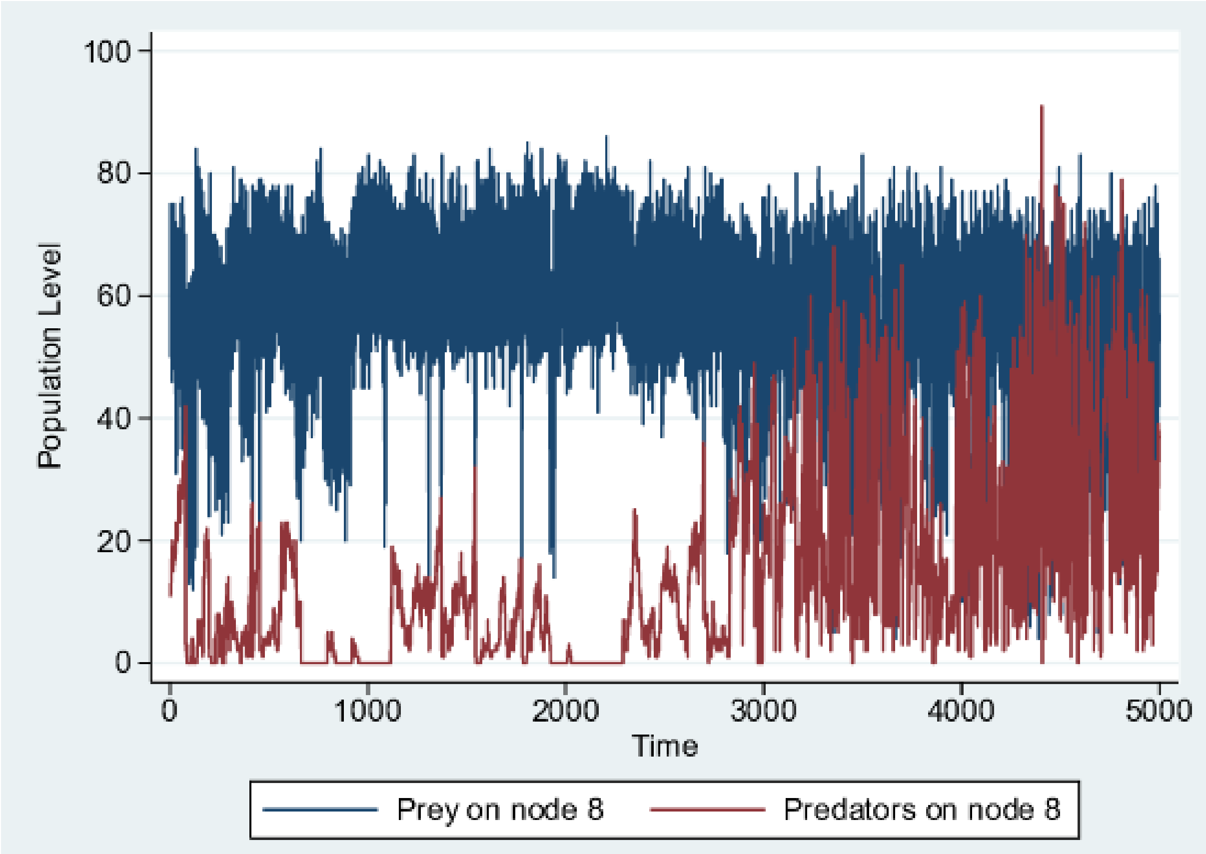
2


Population Level
Time
Prey on node 6
Predators on node 6

1

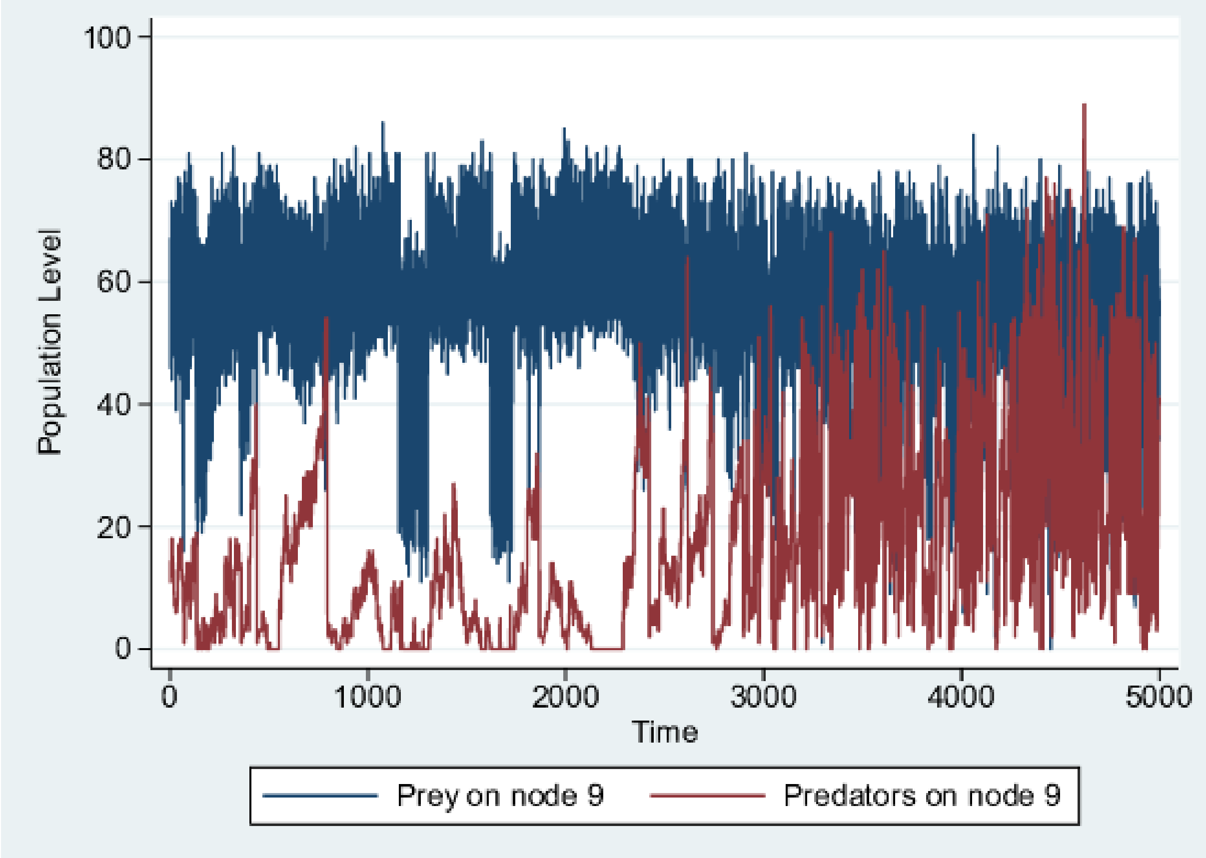

Population Level
Time
Prey on node 7
Predators on node 7

2



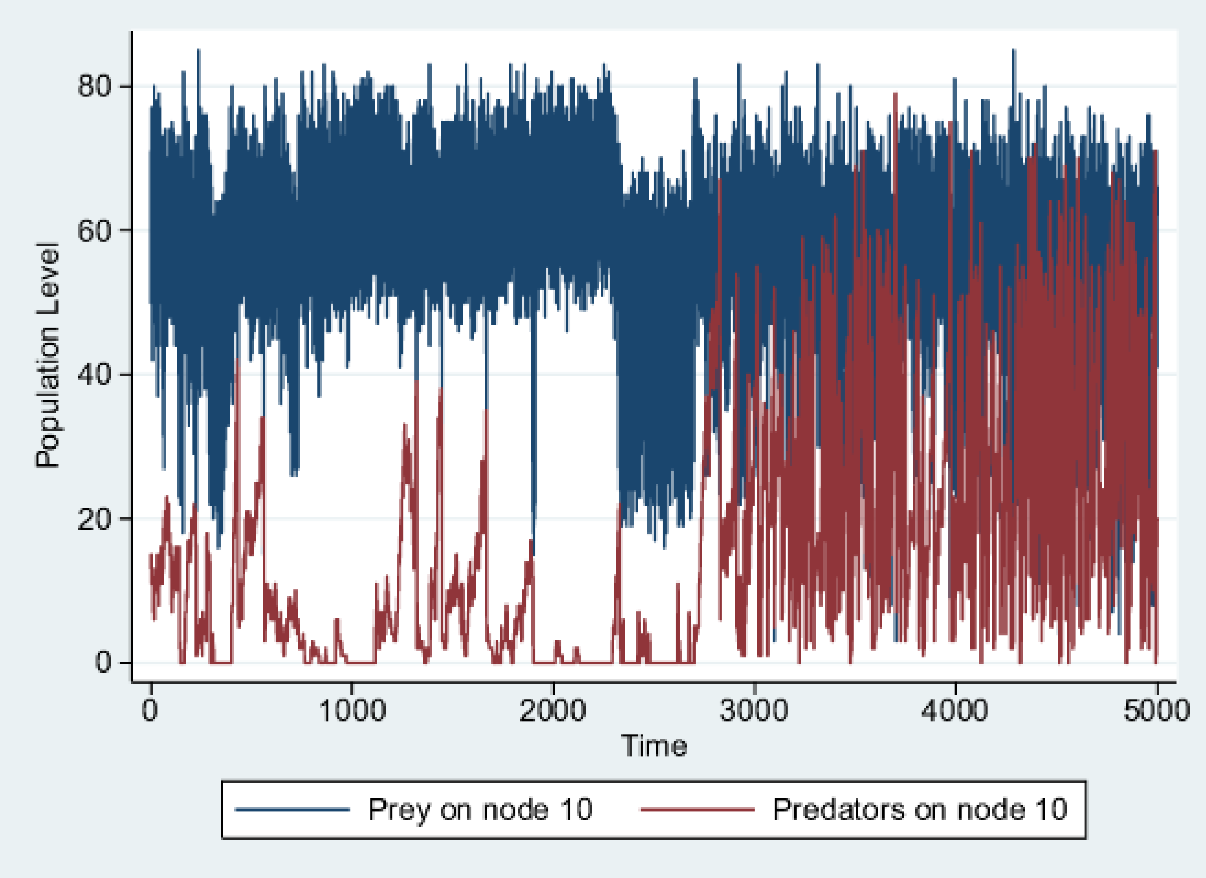
100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 8
Predators on node 8

1



100
80
60
40
20
0
Population Level
0
1000
2000
3000
4000
5000
Time
Prey on node 9
Predators on node 9

2


Population Level
80
60
40
20
0
0
1000
2000
3000
4000
5000
Time
Prey on node 10
Predators on node 10

1