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DISCOVERY

Quantifying the impact of changing the initial data on biodiversity: Its extent and sustainable development scenario

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ABSTRACT

The aim of this study is to quantify the impact of changing the initial data on biodiversity. We have used a numerical method to tackle this challenging scientific problem. We would expect this novel contribution to provide a further insight on some aspect of sustainable development with reference to the sustainability of the ecological resources and the recovering of the loss of ecological resources. The full results of the study are presented and discussed.

Keywords: numerical method, sustainable development, biodiversity, ecological resources

1. INTRODUCTION

The notion of a biological diversity otherwise known as biodiversity has two main components namely the biodiversity gain and biodiversity loss. In this study we are interested in quantifying the impact of changing the initial condition on either the biodiversity loss or biodiversity gain with the expectation of designing a replicative cutting- edge data base. We will expect this novel construction to provide a useful insight that can sustain the production of yeast. The subject of using the concept of numerical mathematics to study the biodiversity is an active area of research that can be seen in works of Ford, *et al.,* (2010) and Ekaka-a (2009).

2. MATHEMATICAL FORMULATION

Following Pielou (1977), we have considered the interaction between two yeast species whose dynamics take the mathematical structure of a non- linear system of first order differential equations

$$\frac{dx_1(t)}{dt} = x_1(t)[\alpha_1 - \beta_1 x_1(t) - r_1 x_2(t)]$$

$$\frac{dx_2(t)}{dt} = x_2(t)[\alpha_2 - \beta_2 x_2(t) - r_2 x_1(t)]$$

Subject to the initial data of interacting yeast species at t=0

$$x_1(0) = x_{10} > 0 \text{ and } x_2(0) = x_{20} > 0$$

x_1(t) represents the biomass of the first yeast species at time (t) whereas x_2(t) represents the second yeast species at the time (t). α_1 Represents the growth rate for the first yeast species while α_2 represents growth rate for the second yeast species. β_1 Represents intra competition coefficient due to the interaction between x_1 (t) and itself while β_2 represents the inter competition coefficient due to the interaction between x_2 (t) and itself. r_1 (t) Represents the intra competition coefficient due to the interaction between x_1 (t) and x_2 (t) whereas r_2 (t) represents the inter competition coefficient due to the interaction between x_1 (t) and x_2 (t). Here, the carrying capacity of the first yeast species is 71.43g per area and the carrying capacity for the second yeast population is 80g per area.

For the purpose of the numerical simulation, we have utilized the parameter value provided by Pielou (1977): α_1 = 0.1, α_2 = 0.008.

Method of analysis

In other to construct a sound simulation method to quantify the impact of changing initial data on biodiversity and study its implication for sustainable development, we have utilized a numerical scheme called the ODE45 Ronge-Kuttea numerical method (Butcher 2005). The method of accessing the impact of initial data biodiversity is stated as follows:

Step1: By using the initial data of (4, 10), we have obtained the biomass of yeast species 1(BYS1) in comparison with the biomass of yeast species 1 due to the indicated initial data hereby denoted as (BYSI$_{ic}$).

Step2: The impact of the initial data on the fixed yeast species is quantified by either biodiversity loss or biodiversity gain.

Step3: By using the initial data of (4, 10), we have obtained the biomass of yeast species 2 (BYS2) and its corresponding biomass of yeast species 2 due to changing initial data (BYS2$_{ic}$)

3. RESULTS AND DISCUSSION

The results that we have obtained upon the implementation of the above method of analysis are fully presented and discussed in this section.

Table 1 Accessing the impact of the initial condition (1, 10) on biodiversity

Example	BYS1	BYS1$_{IC}$	BL(%)	BYS2	BYS2$_{IC}$	BG(%)
1	4.00	1.00	75.00	10.00	10.00	0.00
2	4.34	1.04	76.11	10.68	10.71	0.28
3	4.70	1.07	77.17	11.40	11.46	0.59

4	5.09	1.11	78.17	12.15	12.26	0.93
5	5.50	1.15	79.12	12.93	13.10	1.29
6	5.93	1.19	80.01	13.76	13.99	1.69
7	6.39	1.22	80.86	14.61	14.92	2.11
8	6.88	1.26	81.66	15.50	15.70	2.57
9	7.38	1.30	82.42	16.42	16.92	3.07
10	7.91	1.33	83.14	17.37	17.99	3.60
11	8.46	1.37	83.83	18.34	19.11	4.17
12	9.03	1.40	84.47	19.35	20.27	4.77
13	9.62	1.43	85.08	20.38	21.48	5.41
14	10.22	1.47	85.66	21.42	22.73	6.09
15	10.84	1.49	86.21	22.49	24.02	6.80
16	11.47	1.52	86.73	23.57	25.35	7.56
17	12.12	1.55	87.22	24.66	26.72	8.35
18	12.77	1.57	87.69	25.76	28.13	9.17
19	13.42	1.59	88.14	26.86	29.56	10.03
20	14.08	1.61	88.56	27.97	31.02	10.92

What do we learn from Table 1? For the initial data (4,10), the biomass of yeast species1 and 2 range from 4g to 14.08g increasing monotonically on one hand whereas the biomass of yeast species 2 similarly increase monotonically 10g to 27.96g. In a response of the yeast biomass to changing initial data on biodiversity, we have observed that biodiversity gain can have a positive impact to a sustainable development by creating bigger volume of ecological resources compared to the negative impact of biodiversity loss. The extent of biodiversity can also be determined by the variation of growth rate parameter values, by the variation of intra-competition coefficient and by the variation of the inter-competition which we did not study in this present analysis.

In contrast, introducing a new initial data (1,10) has predicted two types of data denoted here as $BYS1_{ic}$ ranging from 1 to 1.61 where as the biomass for the yeast species 2 due to the initial data (1,10) range from 10g to 31.02. These observations, have predicted both biodiversity loss and biodiversity gain quantified as (BL %) and (BG %).

A similar observation has been made for Table 2-4. However, Tables 5, 6 and 7 show a contribution of biodiversity gain and biodiversity loss in a single variation of initial data such as (5, 10), (6, 10) and (7, 10).

Table 2 Accessing the impact of the initial condition (2,10) on biodiversity

Example	BYS1	$BYS1_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	2.00	50.00	10.00	10.00	0.00
2	4.34	2.07	52.30	10.68	10.70	0.19
3	4.70	2.14	54.47	11.40	11.44	0.41
4	5.09	2.21	56.53	12.15	12.23	0.65
5	5.50	2.28	58.47	12.93	13.05	0.91
6	5.94	2.36	60.32	13.76	13.92	1.21
7	6.39	2.43	62.07	14.61	14.83	1.53
8	6.87	2.49	63.72	15.50	15.79	1.89
9	7.38	2.56	65.28	16.42	16.79	2.28
10	7.91	2.63	66.75	17.37	17.84	2.70
11	8.46	2.69	68.15	18.34	18.92	3.16
12	9.03	2.76	69.47	19.35	20.05	3.65
13	9.62	2.82	70.72	20.38	21.23	4.18
14	10.22	2.87	71.90	21.42	22.44	4.75
15	10.84	2.92	73.02	22.49	23.69	5.35
16	11.47	2.97	74.08	23.57	24.98	5.99
17	12.13	3.02	75.08	24.66	26.31	6.67
18	12.77	3.06	76.04	25.76	27.67	7.39

19	13.42	3.10	76.94	26.86	29.05	8.14
20	14.08	3.13	77.80	27.97	30.46	8.93

Table 3 Accessing the impact of the initial condition (3, 10) on biodiversity

Example	BYS1	$BYS1_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	3.00	25.00	10.00	10.00	0.00
2	4.34	3.10	28.55	10.68	10.69	0.10
3	4.70	3.20	31.90	11.40	11.42	0.22
4	5.09	3.31	35.08	12.15	12.19	0.37
5	5.50	3.41	38.08	12.93	13.00	0.54
6	5.94	3.51	40.92	13.76	13.86	0.73
7	6.39	3.61	43.60	14.61	14.75	0.96
8	6.88	3.70	46.14	15.50	15.69	1.21
9	7.38	3.80	48.54	16.42	16.66	1.50
10	7.91	3.89	50.80	17.37	17.68	1.82
11	8.46	3.98	52.94	18.34	18.74	2.17
12	9.03	4.07	54.97	19.35	19.84	2.56
13	9.62	4.15	56.88	20.38	20.98	2.98
14	10.22	4.22	58.68	21.42	22.16	3.45
15	10.84	4.29	60.39	22.49	23.38	3.95
16	11.47	4.36	62.00	23.57	24.63	4.49
17	12.12	4.42	63.53	24.66	25.91	5.07
18	12.77	4.47	64.98	25.76	27.23	5.68
19	13.42	4.52	66.34	26.86	28.57	6.33
20	14.08	4.56	67.64	27.97	29.93	7.02

Table 4 Accessing the impact of the initial condition (4, 10) on biodiversity

Example	BYS1	$BYS1_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	4.00	0.00	10.00	10.00	0.00
2	4.34	4.13	4.86	10.68	10.68	0.01
3	4.70	4.26	9.46	11.40	11.40	0.04
4	5.09	4.39	13.81	12.15	12.16	0.09
5	5.50	4.52	17.92	12.93	12.96	0.16
6	5.94	4.64	21.80	13.76	13.79	0.26
7	6.39	4.77	25.47	14.61	14.67	0.39
8	6.88	4.89	28.93	15.50	15.58	0.55
9	7.38	5.00	32.19	16.42	16.54	0.73
10	7.91	5.12	35.28	17.37	17.53	0.95
11	8.46	5.23	38.19	18.34	18.57	1.21
12	9.03	5.33	40.94	19.35	19.64	1.50
13	9.62	5.43	43.53	20.38	20.75	1.82
14	10.22	5.52	45.98	21.42	21.89	2.19
15	10.84	5.61	48.28	22.49	23.07	2.59
16	11.47	5.68	50.46	23.57	24.29	3.04
17	12.12	5.75	52.52	24.66	25.53	3.52
18	12.77	5.81	54.47	25.76	26.80	4.04
19	13.42	5.87	56.31	26.86	28.10	4.61
20	14.08	5.91	58.04	27.97	29.42	5.21

Table 5 Accessing the impact of the initial condition (5,10) on biodiversity

Example	BYS1	$BYS1_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	5.00	25.00	10.00	10.00	0.00
2	4.34	5.15	18.75	10.68	10.67	0.08
3	4.70	5.31	12.85	11.40	11.38	0.14
4	5.09	5.46	7.28	12.15	12.13	0.19
5	5.50	5.61	2.01	12.93	12.91	0.21
6	5.94	5.76	2.96	13.76	13.73	0.20
7	6.39	5.91	7.64	14.61	14.59	0.17
8	6.88	6.05	12.06	15.50	15.48	0.11
9	7.38	6.18	16.23	16.42	16.41	0.01
10	7.91	6.31	20.16	17.37	17.39	0.11
11	8.46	6.44	23.87	18.34	18.39	0.27
12	9.03	6.56	27.36	19.35	19.44	0.47
13	9.62	6.67	30.65	20.38	20.52	0.70
14	10.22	6.77	33.75	21.42	21.63	0.97
15	10.84	6.87	36.67	22.49	22.78	1.28
16	11.47	6.95	39.43	23.57	23.96	1.64
17	12.12	7.03	42.02	24.66	25.16	2.03
18	12.77	7.09	44.47	25.76	26.40	2.47
19	13.42	7.14	46.78	26.86	27.66	2.95
20	14.08	7.19	48.96	27.97	28.94	3.47

Table 6 Accessing the impact of the initial condition (6,10) on biodiversity

Example	BYS1	$BYS2_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	6.00	50.00	10.00	10.00	0.00
2	4.34	6.18	42.30	10.68	10.66	0.17
3	4.70	6.35	35.04	11.40	11.36	0.33
4	5.09	6.53	28.18	12.15	12.09	0.46
5	5.50	6.70	21.71	12.93	12.86	0.57
6	5.94	6.86	15.62	13.76	13.66	0.66
7	6.39	7.03	9.87	14.61	14.51	0.72
8	6.88	7.18	4.46	15.50	15.38	0.75
9	7.38	7.33	0.64	16.42	16.29	0.75
10	7.91	7.48	5.44	17.37	17.24	0.72
11	8.46	7.62	9.96	18.34	18.23	0.65
12	9.03	7.74	14.21	19.35	19.24	0.54
13	9.62	7.86	18.21	20.38	20.30	0.40
14	10.22	7.97	21.98	21.42	21.38	0.21
15	10.84	8.07	25.52	22.49	22.49	0.02
16	11.47	8.16	28.85	23.57	23.64	0.29
17	12.12	8.24	31.99	24.66	24.81	0.60
18	12.77	8.31	34.95	25.76	26.01	0.96
19	13.42	8.36	37.73	26.86	27.23	1.36
20	14.08	8.40	40.35	27.97	28.47	1.81

Table 7 Accessing the impact of the initial condition (7, 10) on biodiversity

Example	BYS1	$BYS1_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	7.00	75.00	10.00	10.00	0.00
2	4.34	7.20	65.79	10.68	10.65	0.26
3	4.70	7.39	57.10	11.40	11.34	0.51
4	5.09	7.58	48.91	12.15	12.06	0.73
5	5.50	7.77	41.19	12.93	12.81	0.93
6	5.94	7.95	33.93	13.76	13.60	1.11
7	6.39	8.13	27.09	14.61	14.43	1.26
8	6.88	8.30	20.65	15.50	15.28	1.38
9	7.38	8.46	14.60	16.42	16.18	1.47
10	7.91	8.61	8.90	17.37	17.10	1.52
11	8.46	8.76	3.55	18.34	18.06	1.54
12	9.03	8.89	1.47	19.35	19.05	1.52
13	9.62	9.02	6.20	20.38	20.08	1.46
14	0.22	9.13	10.64	21.42	21.13	1.36
15	0.84	9.24	14.81	22.49	22.22	1.21
16	11.47	9.33	18.72	23.57	23.33	1.02
17	12.12	9.40	22.40	24.66	24.47	0.78
18	12.77	9.47	25.86	25.76	25.63	0.49
19	13.42	9.52	29.11	26.86	26.82	0.16
20	14.08	9.55	32.17	27.97	28.03	0.22

On the other hand Table 8 to Table 10 below shows a contribution of a moderately continuous biodiversity gain in a single variation of initial data such as (8,10), (9,10) and (10,10).

Table 8 Accessing the impact of the initial condition (8, 10) on biodiversity

Example	BYS1	$BYS1_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	8.00	100.00	10.00	10.00	0.00
2	4.34	8.21	89.20	10.68	10.64	0.35
3	4.70	8.42	79.03	11.40	11.32	0.69
4	5.09	8.63	69.46	12.15	12.03	1.00
5	5.50	8.83	60.45	12.93	12.77	1.29
6	5.94	9.02	51.98	13.76	13.54	1.56
7	7.38	9.56	44.01	14.61	14.35	1.80
8	7.91	9.72	36.52	15.50	15.19	2.00
9	8.46	9.87	29.49	16.42	16.06	2.18
10	9.03	10.01	22.89	17.37	16.96	2.31
11	9.62	10.14	16.69	18.34	17.90	2.42
12	9.03	10.01	10.87	19.35	18.87	2.48
13	9.62	10.14	5.42	20.38	19.87	2.49
14	10.22	10.25	0.30	21.42	20.90	2.47
15	10.84	10.35	4.50	22.49	21.95	2.40
16	11.47	10.44	9.00	23.57	23.04	2.28
17	12.12	10.51	13.23	24.66	24.14	2.11
18	12.77	10.57	17.19	25.76	25.27	1.89
19	13.42	10.62	20.91	26.86	26.43	1.63
20	14.08	10.65	24.40	27.97	27.60	1.31

Table 9 Accessing the impact of the initial condition (9, 10) on biodiversity

Example	BYS1	$BYS1_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	9.00	125.00	10.00	10.00	0.00
2	4.34	9.23	112.56	10.68	10.63	0.44
3	4.70	9.45	100.85	11.40	11.30	0.87
4	5.09	9.66	89.84	12.15	11.99	1.27
5	5.50	9.87	79.49	12.93	12.72	1.65
6	5.94	10.08	69.77	13.76	13.48	2.00
7	6.39	10.27	60.65	14.61	4.27	2.32
8	6.88	10.46	52.08	15.50	15.09	2.61
9	7.38	10.63	44.05	16.42	15.95	2.87
10	7.91	10.80	36.52	17.37	16.83	3.09
11	8.46	10.95	29.46	18.34	7.74	3.27
12	9.03	11.09	22.85	19.35	18.69	3.41
13	9.62	1.22	16.65	20.38	19.66	3.50
14	10.22	11.33	10.85	21.42	20.66	3.55
15	10.84	11.43	5.42	22.49	21.69	3.55
16	11.47	11.51	0.33	23.57	22.75	3.49
17	12.12	11.58	4.43	24.66	23.83	3.39
18	12.77	11.63	8.90	25.76	24.93	3.24
19	13.42	11.67	13.08	26.86	26.05	3.03
20	4.08	11.69	17.00	27.97	27.19	2.77

Table 10 Accessing the impact of the initial condition (10, 10) on biodiversity

Example	BYS1	$BYS1_{IC}$	BL (%)	BYS2	$BYS2_{IC}$	BG (%)
1	4.00	10.00	150.00	10.00	10.00	0.00
2	4.34	10.24	135.84	10.68	10.62	0.53
3	4.70	10.47	122.54	11.40	11.28	1.04
4	5.09	10.69	110.05	12.15	11.96	1.53
5	5.09	10.69	98.32	12.93	12.68	2.00
6	5.94	11.12	87.32	13.76	13.42	2.44
7	6.39	11.32	77.01	14.61	14.19	2.84
8	6.88	11.51	67.34	15.50	15.00	3.22
9	7.38	11.68	58.29	16.42	15.83	3.55
10	7.91	11.85	49.82	17.37	16.70	3.85
11	8.46	12.00	41.89	18.34	17.59	4.10
12	9.03	12.14	34.47	19.35	18.51	4.32
13	9.62	12.26	27.53	20.38	19.46	4.48
14	10.22	12.37	21.04	21.42	20.44	4.60
15	10.84	12.46	14.97	22.49	21.44	4.66
16	11.47	12.54	9.30	23.57	22.47	4.67
17	12.12	12.60	3.10	24.66	23.52	4.63
18	12.77	12.64	09.4	25.76	24.59	4.54
19	13.42	12.67	5.60	26.86	25.69	4.39
20	14.08	12.68	9.94	27.97	26.80	4.18

4. CONCLUSION

In this experimental numerical simulation, we have used a computationally efficient ODE45 numerical method to access the impact of the variation of the initial conditions on biodiversity, which on the average indicates sustainable gain.

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