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The Dynamics of Two Species of *Megabalanus* (Crustacea: Cirripedia: Balanidae) by a Cellular Automata Model

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M. coccopoma

Megabalanus coccopoma (Darwin, 1854)

Megabalanus coccopoma (Darwin, 1854)

M. tintinnabulum

Megabalanus tintinnabulum (Linnaeus, 1758)

Megabalanus tintinnabulum (Linnaeus, 1758)

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Objectives

1) To develop and to apply the computational model of the Cellular Automata (CA) in the dynamic of the populations of two species of barnacles

2) To determine the parameters of the model that are important in the structure of the populations of two species of *Megabalanus*

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The Logic of the Cellular Automata

- A net in 3 dimensions, where each cell has three possible states, empty space (0), a specimen of the first specie (1) or a specimen of the second specie (2)

- The value taken for a cell in the time t+1 is determined by the values assumed in the time t for its four neighbors, and by the cell itself (height of the column), in accordance with the formula:

$$x\,t{+}1_{ij} = f(x\,t_{ij}\,,\, x\,t_{i-1,\,J}\,,\, x\,t_{i,\,J-1}\,,$$

$$x\,t_{i,\,J+1}\,,\, x\,t_{i+1,\,J})$$

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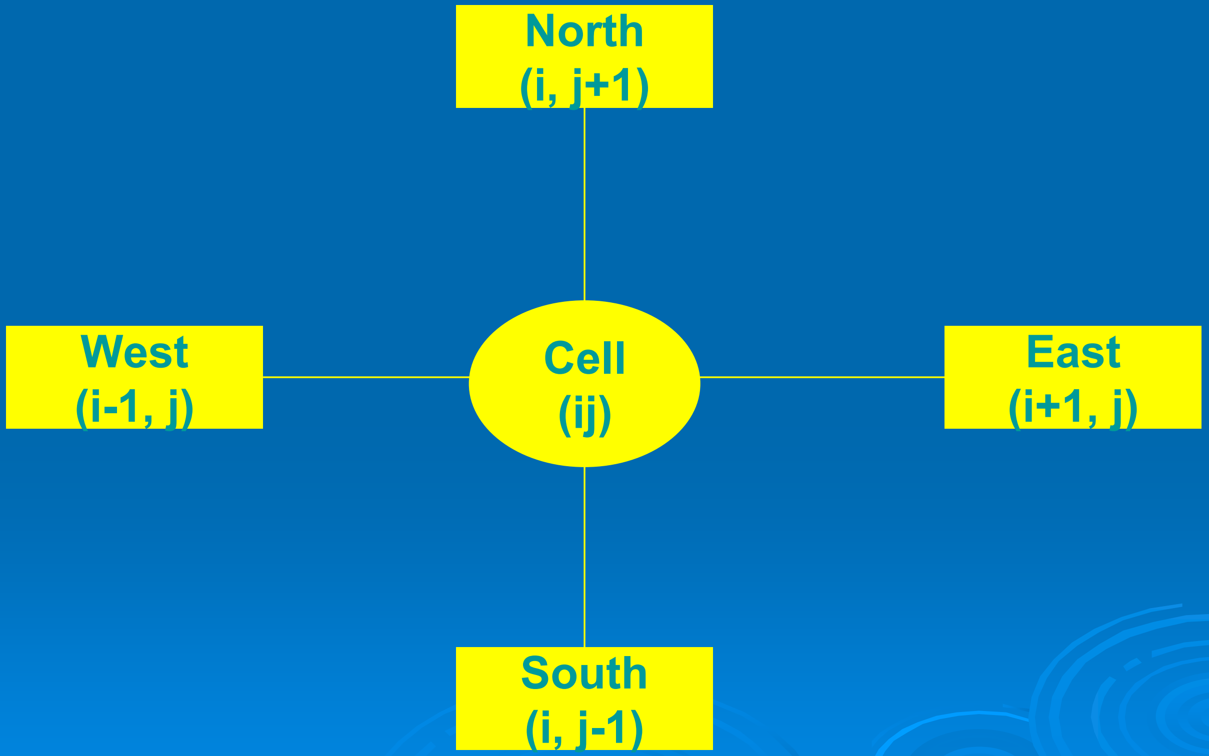
The neighborhood model developed by J. von Neumann



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- When the column reaches a determined height, the whole column comes off of the substrate, forming an empty space (Kill Factor)

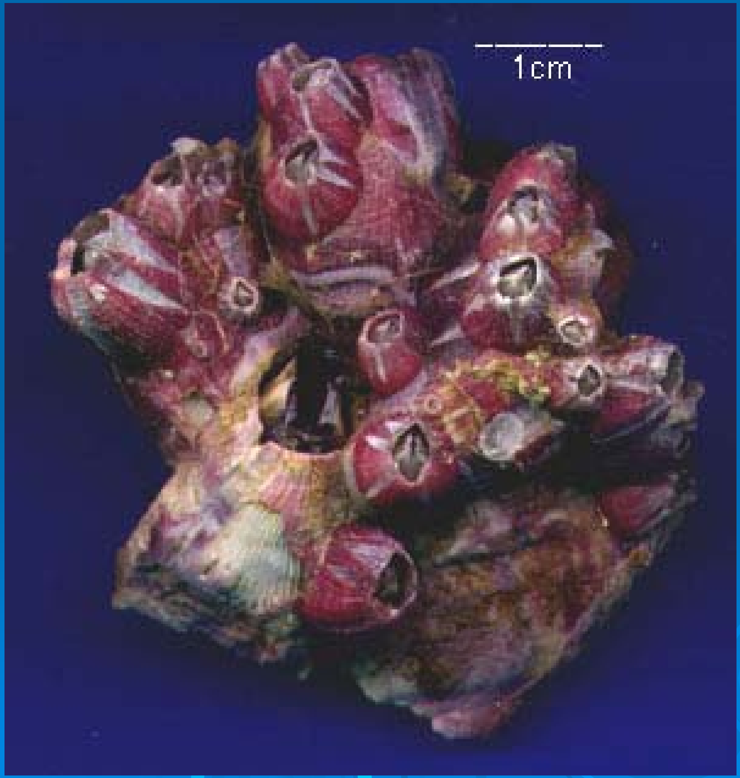
- The simulation begins with an empty net, following a routine of time (Steps of Monte Carlo)

- Initially there are only specimens of *M. tintinnabulum* and in a determined instant it takes place the invasion of *M. coccopoma*, and two species competing for space

Symbols used in the computational simulation, his biological meaning and his use in the model

Simbols	Biological Meaning	Use
0	Empty Space	fixed
1 ou T	Space used by *M. tintinnabulum*	fixed
2 ou C	Space used by *M. coccopoma*	fixed
NxNy	Space of simulation of the model in 50x50 cells	fixed
Passos	Time in Monte Carlo Steps (4 Millions)	fixed
TsobreT	Recruitment of *M. tintinnabulum* over *M. tintinnabulum*	variable
TsobreC	Recruitment of *M. tintinnabulum* over *M. coccopoma*	variable
TsobreV	Recruitment of *M. tintinnabulum* over empty space	variable
CsobreT	Recruitment of *M. coccopoma* over *M. tintinnabulum*	variable
CsobreC	Recruitment of *M. coccopoma* over *M. coccopoma*	variable
CsobreV	Recruitment of *M. coccopoma* over empty space	variable
H	The very height of the column (kill factor)	variable

The complex structure in 3D formed by adults of M. coccopoma, represented in the model by height of the column



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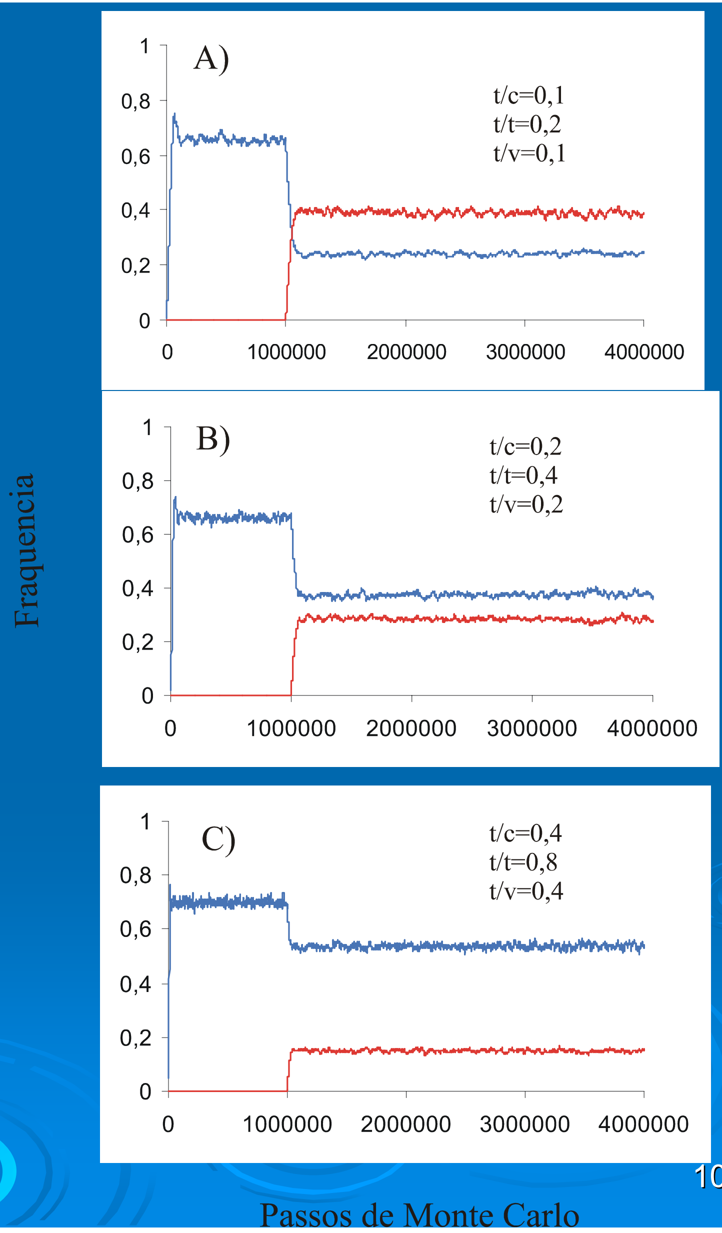
Fixed	Variables		
C/C= 0,4	1	2	3
C/T= 0,2	T/T= 0,2	T/T= 0,4	T/T= 0,8
C/V= 0,1	T/C= 0,1	T/C= 0,2	T/C= 0,4
H= 4	T/V= 0,1	T/V= 0,2	T/V= 0,4



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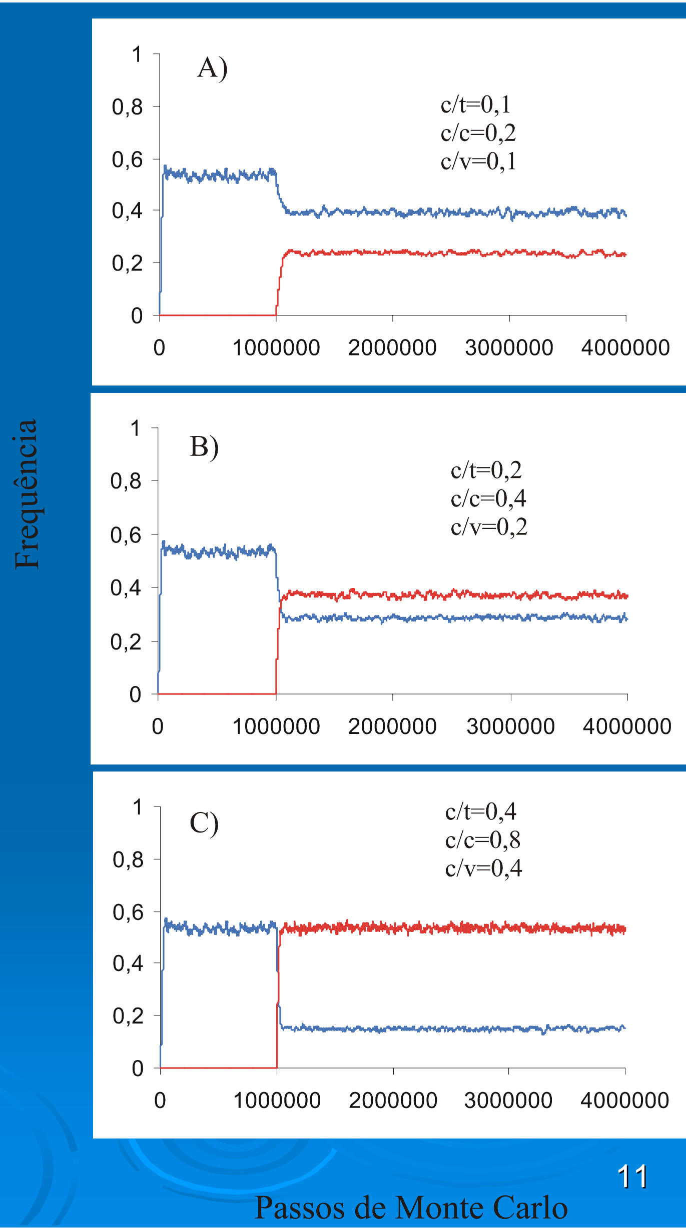
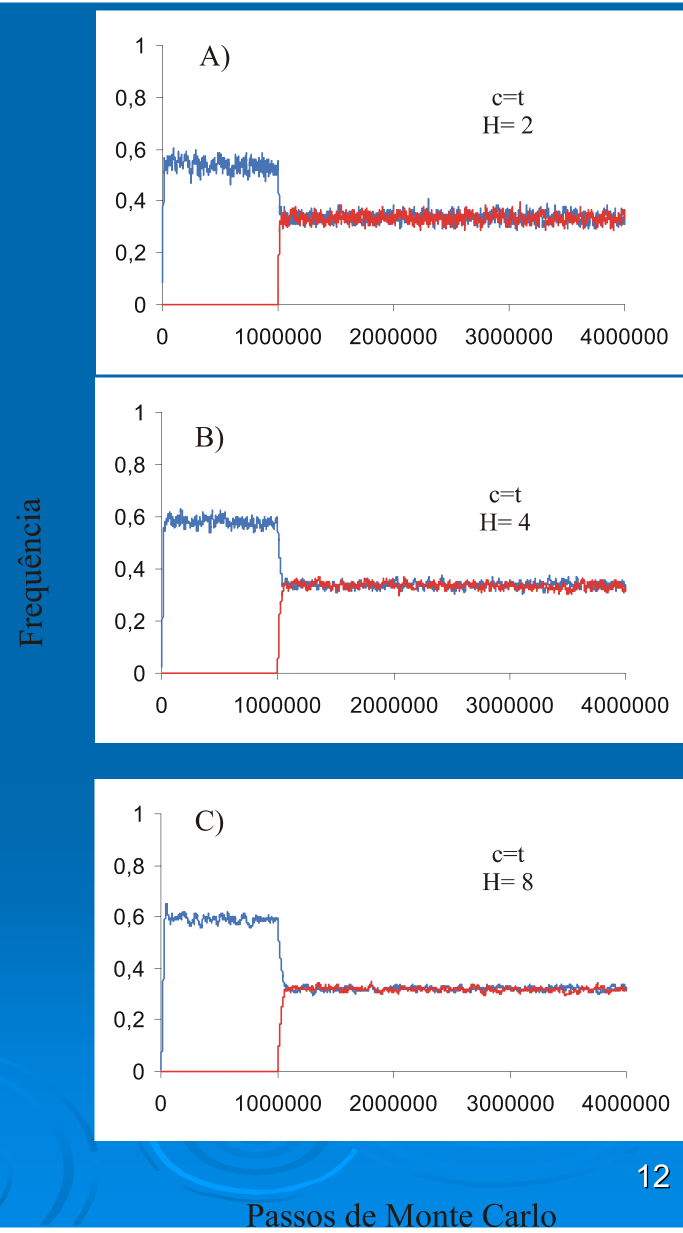
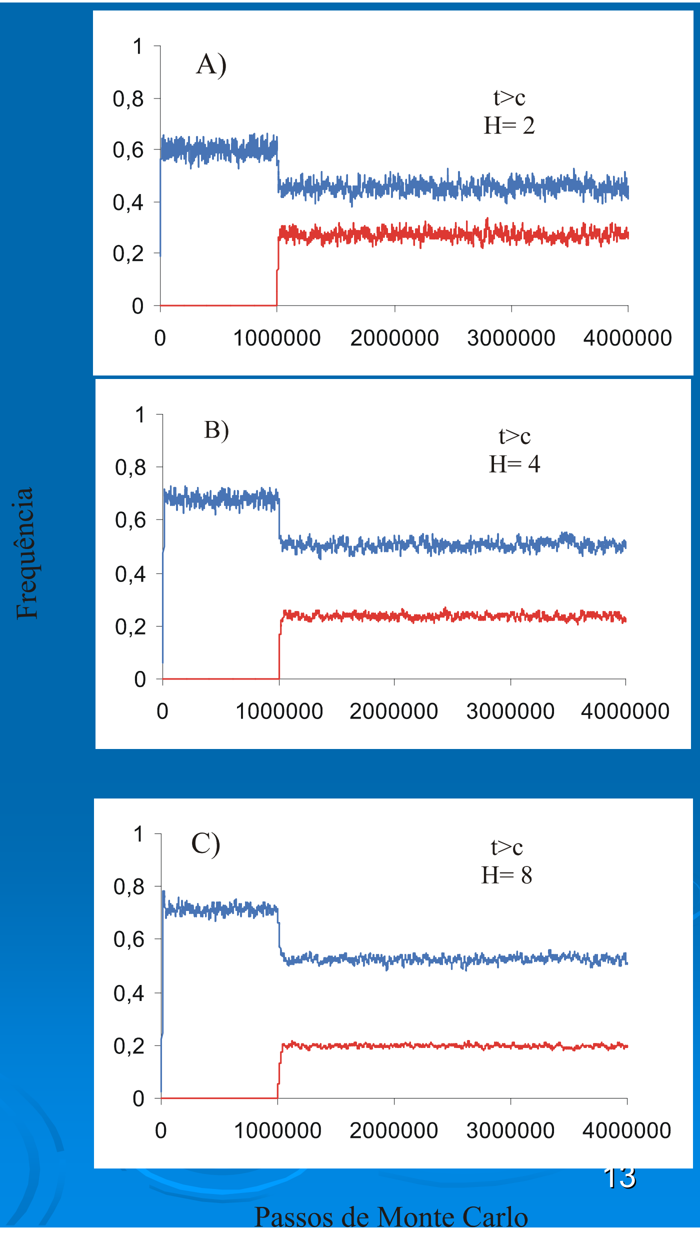
Fixed	Variables		
T/T= 0,4	1	2	3
T/C= 0,2	C/C= 0,2	C/C= 0,4	C/C= 0,8
T/V= 0,1	C/T= 0,1	C/T= 0,2	C/T= 0,4
H= 4	C/V= 0,1	C/V= 0,2	C/V= 0,4



Fixed		Variables		
C/C= 0,4	T/T= 0,4	1	2	3
C/T= 0,2	T/C= 0,2	H= 2	H= 4	H= 8
C/V= 0,1	T/V= 0,1			



Fixed		Variables		
T/T= 0,8	C/C= 0,4	1	2	3
T/C= 0,4	C/T= 0,2	H= 2	H= 4	H= 8
T/V= 0,2	C/V= 0,1			



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C/C= 0,8	T/T= 0,4	1	2	3
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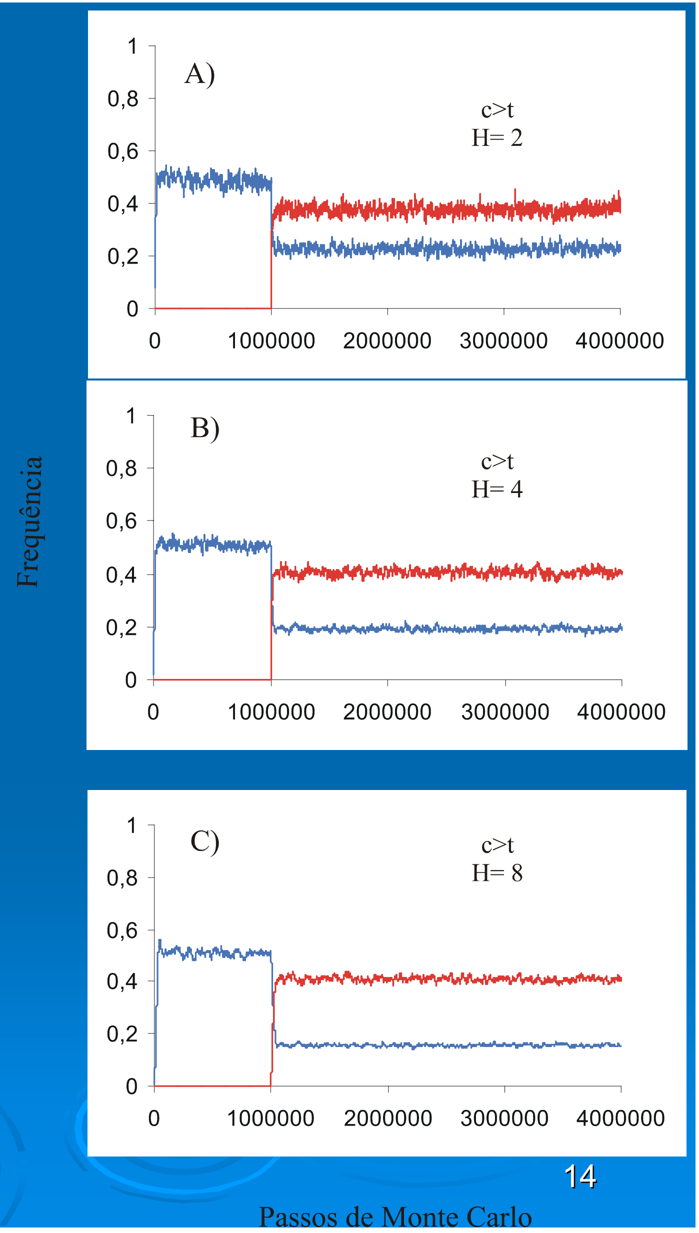

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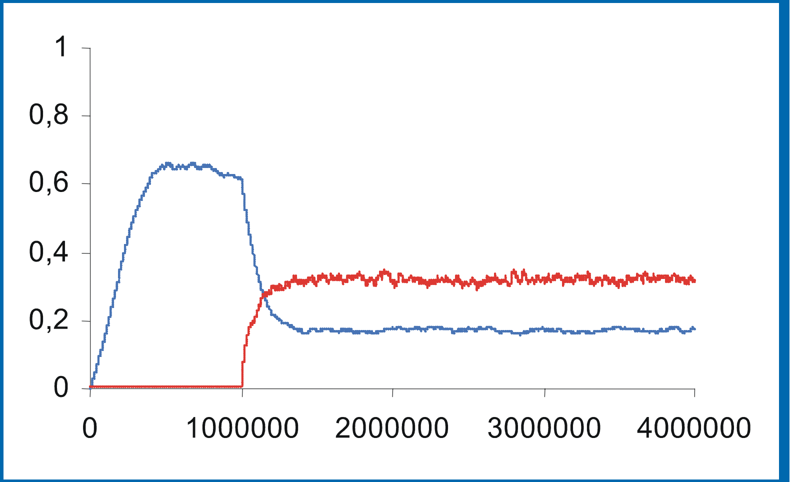
Values of abundance, average, SD and percentage used in the computational simulation with data obtained in the field

	Q1	Q2	Q3	$\bar{X}$	SD	%
M. tintinnabulum (t)	3	3	2	2,67	0,58	9
M. coccopoma (c)	28	26	24	26	2,00	90
t/t	0	0	2	0,67	1,15	2
t/c	3	3	0	2,00	1,73	6
t/v	0	0	0	0	0	1
c/t	2	2	0	1,33	1,15	44
c/c	23	21	22	22	1,00	77
c/v	3	3	2	2,67	0,58	9
H	6	5	4	5	1	4



Passos de Monte Carlo

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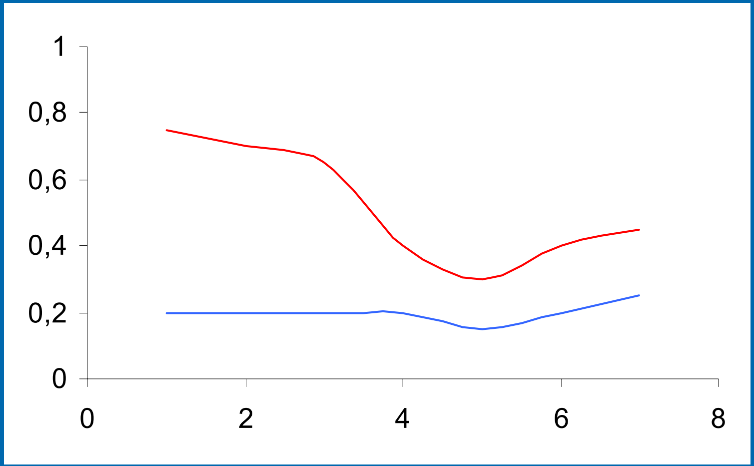
Values of the variation total adults of the two species turned into relative frequency

	M. coccopoma	*M. tintinnabulum*	C/T
T1	0,75	0,20	3,75
T2	0,70	0,20	3,5
T3	0,65	0,20	3,25
T4	0,40	0,20	2
T5	0,30	0,15	2
T6	0,40	0,20	2
T7	0,45	0,25	1,8
T8	0,50	0,20	2,5
$\bar{X}$	**0,52**	**0,20**	**2,6**



Comparison between the results of simulations and field data.

The best simulations of the reality were those of number 1, 13, 14 and 15.

Simulation	Condition	C	T	C/T
1	**T<C, H=4**	**0,35**	**0,2**	**1,75**
2	T=C, H=4	0,3	0,4	0,75
3	T>C, H=4	0,2	0,5	0,40
4	T>C, H=4	0,3	0,5	0,60
5	T=C, H=4	0,4	0,3	1,33
6	T<C, H=4	0,5	0,1	5,00
7	T=C, H=2	0,35	0,35	1,00
8	T=C, H=4	0,35	0,35	1,00
9	T=C, H=8	0,35	0,35	1,00
10	T>C, H=2	0,25	0,45	0,56
11	T>C, H=4	0,25	0,52	0,48
12	T>C, H=8	0,2	0,52	0,38
13	**T<C, H=2**	**0,4**	**0,22**	**1,82**
14	**T<C, H=4**	**0,42**	**0,2**	**2,10**
15	**T<C, H=8**	**0,42**	**0,16**	**2,63**
16	Field Data Simulation	0,35	0,15	2,33
17	Real Data	0,52	0,2	2,60

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Conclusions

1) A useful model was developed for studies of interaction between two species or simulation of the behavior in the time and in the space of a specie alone

2) The recruitment is the most important factor for the domination of the invading specie over the criptogenic one

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Final Conclusions

- *M. tintinnabulum* occurs in Brazilian waters since the beginning of the century XX

- *M. coccopoma* occurs in Brazilian waters since the decade of 1970

- At present, *M. coccopoma* is in bigger abundance of recruits and adults of *M. tintinnabulum*

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Final Conclusions

- It was not predicted by the CA model competitive exclusion of *M. tintinnabulum*

- The recruits' constant arrival (open populations) makes the coexistence possible

- Formation of 3D columns amplifies the differences of abundance caused by the general recruitment of each species