Effects of White-Tailed Deer (Odocoileus virginianus) on Diversity, Distribution, and Height of Tree Species in a Restoration Field in Northfield, Minnesota

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Effects of White-Tailed Deer (*Odocoileus virginianus*) on Diversity, Distribution, and Height of Tree Species in a Reforestation Field in Northfield, Minnesota

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Abstract

To determine proper management techniques for Minnesota's Big Woods restoration, the influence of various biotic factors on vegetation growth should be closely monitored. White-tailed deer (*Odocoileus virginianus*) pose a threat to forest regeneration by browsing on the stems of woody vegetation. This study examined the initial effects of deer browsing on two deer exclosure sites on field reforestation land in Northfield, Minnesota. At sites one and two, the density, spatial distribution and growth of tree species in exclosure area and control area were compared. Site two had a significantly greater mean stem height compared to site one, indicating a greater browsing intensity at site one. I found no significant difference in total density between the exclosure and control areas at site one and two. Site one had a clumped spatial distribution of bur oak (*Quercus macrocarpa)* and red oak (*Quercus rubra*) in the exclosure and control area. The mean height of bur oak and red oak were significantly greater in the control area. Site two, on the other hand, had a random distribution of bur oak and red oak in the exclosure and control area. Mean bur oak height was significantly greater in the exclosure area. Although the effects of deer browsing using exclosures can not yet be determined, this initial data on the distribution, abundance, and height of oak species will be of great importance in future long-term exclosure studies.

Introduction

Following European settlement, cleared forest and increased hunting led to near extirpation of the white-tail deer population in the upper Midwestern United States. Due to the establishment of strict hunting regulations, increased forage, and changes in land-use, the deer population began to increase in the 1930s. Recently, white-tailed deer are the most abundant wild ungulate on the continent and inhabit the majority of the Unites States (Russell et al., 2001).

Large herbivorous mammals, such as deer, play a key role in the modification of their habitat (Anderson, 1994). In the Midwestern part of the United States, white-tailed deer (*Odocoileur virginianus*) are currently so abundant that many observers have suggested that deer are having a significant impact on forest and plant communities. Considerable evidence exists that deer can negatively affect the growth rate of tree seedlings and saplings, alter species composition, and prevent adult recruitment into tree populations (Russell et al., 2001). Additionally, deer can modify successional pathways and alter nutrient cycles (Barret & Stiling, 2006). Ecologists are concerned with the increased and expanded deer population because of the adverse affect browsing has on forest communities (Russell et al., 2001).

The ecological services of forests are of extreme importance to maintaining biodiversity, regulating local and global climate, and protecting soil and watersheds (Secretariat of Convention, 2001). Reforestation projects are essential to restoring key ecological services of the forest. This is done through the dispersal of seedlings and saplings on once existing farmland or forested areas. However, deer may pose a threat to the success of forest regeneration.

Field-forest edges surrounding reforestation sites provide ideal habitat for White-tailed deer (Inouye et al., 1994). During the summer deer inhabit agricultural fields and understory forests. They feed on corn and herbaceous plants and disturbance is low. In the fall deer will forsake food types to concentrate on acorns. Acorns are an important source of protein and easily digested (Rue, 1978). During the winter months there is intensive browsing pressure on reforestation sites. Deer browse the twigs of woody plants and remain in one area due to harsh weather conditions (Shea & Stange, 1998). Many trees that have matured along the field-forest edge are repeatedly browsed by deer (Inouye et al., 1994). Consequently, deer have been found to endanger the regeneration of trees on reforested fields.

In the late 19th century, Southeastern Minnesota's deciduous forest biome was cleared for agriculture use by European settlers with nearly 3,000 square-miles of the Big Woods forest converted to farmland. A number of efforts are underway to restore the ecological services of the Big Woods forest. To determine proper management techniques for hardwood restoration, the influence of various biotic factors, such as deer, on restoration sites should be closely monitored.

Reforestation sites can be found on the natural lands of St. Olaf College located in Northfield, Minnesota. Since 1987, St. Olaf College has made great strides in the restoration of converted farmland to hardwoods forest around its campus. With a combination of methods including direct seeding and planting tree seedlings and saplings, the college's reforestation efforts on more than 90 acres of land have been very successful.

Exclosure studies performed during the late-20th century have revealed that high deer densities result in failure of forest regeneration (Horsley et al., 2003). In the past two decades, southeastern Minnesota's white-tail deer population has significantly increased (Riverbend Nature Center, 2009). In order to assess the impact of deer browsing on tree growth and regeneration, future long-term studies on deer exclosures will be conducted. The purpose of this study was to collect and analyze baseline information on the diversity, distribution, frequency and height of tree species inside and outside of two exclosures located on forest regeneration sites. This study serves as a starting point for future research on deer browsing and forest regeneration on St. Olaf natural lands.

Methods

Study Sites

Since 2001, direct tree seeding has been conducted on approximately 30 acres of St. Olaf land. Using the direct seeding method of planting, four field sites totaling approximately 38 acres were seeded in the years 2001, 2002, 2003, and 2005, respectively. Since then, all four restoration sites have developed into a rudimentary temperate hardwood forest, with primarily tree saplings of red oak (*Quercus rubra*), white oak (*Quercus alba*), black walnut (*Juglans nigra*), box elder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), and several species of elms and poplars. The 2005 field was used for this study. Highway 19 was directly south of the field and the 2003 reforestation site was directly north.

Deer Exlosure Construction

In August 2009, two deer exclosures were constructed on the 2005 field. Enclosure locations were selected on the east and west central parts of the field. Two 10x10m areas were enclosed with wire fencing ten feet high to exclude deer.

Vegetative Sampling

In October 2009, data were collected on the two exclosure sites. Site one was located on the east side and site two on the west side. A 10x10m area located on the east side of each exclosure served as a control. The four areas were each divided into 25 2x2m plots. Plots were labeled as row 1-5 and column A-E starting at the southwest corner of each area. Within each plot, species type and stem height were recorded for each individual. Stem height was defined as the vertical height of the terminal bud.

Data Analysis

Data were analyzed with Stata 9.1 . One-way analysis of variance (ANOVA) was used to analyze the effects of exclosure on variation in density. The number of individuals within each plot were counted and Morrisita's Index and chi-value calculation were used to determine the spatial distribution of the exclosure and control areas of sites one and two. The Shannon and Simpson diversity indices were used to measure species diversity of the exclosure and control of both sites.

One-way (ANOVA) was used to compare the mean stem height of all tree species between site one and two. One-way ANOVA was also used to compare the heights of trees inside and outside the exclosure. Bur oak and red oak height variance was conducted for sites one and two.

Results

Density of tree species

Across both sites, ten tree species were found, although approximately 86% of individuals were either bur or red oak (Table 1). Deer exclosures did not have an effect on tree density; site one and two showed no significant variance in density between exclosures and controls (Table 2). At site one, a mean plot density of 5.96 was found in exclosure and 3.6 in control. At site two, there was a mean plot density of 5.84 in exclosure and 5.76 in control (Table 2).

Species Diversity

There was no significant difference in tree species diversity between site one and two (Table 3). Additionally, there was no significant difference in species diversity between exclosure and control area at site one. However, there was a significant difference in species diversity between exclosure and control area at site two ($p<.05$, $t=2.103$).

Spatial Distribution

Although there was a difference in spatial distribution of oak species between site one and two, exclosures did not have an effect on oak distribution. At site one, bur and red oak species had a clumped distribution. Exclosure area had a bur oak chi-value of 148.8 and a Morrisita's Index of 148.8. Red oak chi-value was 77.5 and a Morrisita's Index of 1.91. Control area had a bur oak chi-value of 43.7 and Morrisita's Index of 1.35. Red oak chi-value was 46.7 and a Morrisita's Index of 2.75 (Table 3). At site two oak species had had a random spatial distribution for exclosure and control areas with a chi-value less than 36.4. By comparing the chi-value, bur oak is more randomly distributed in control area while red oak is more randomly distributed in exclosure area (Table 3).

Height of Tree Species

Site two had a significantly greater tree height compared to site one (P=0.00) (Table 4). At site one exclosure area did not have a greater bur oak and red oak height. Surprisingly, control area had a significantly greater bur oak height (P=.0035) and red oak height (p= .0113) (Table 5 and 6, Fig.1). However, at site two a significantly greater bur oak height (p=.0026) was found in exclosure area while there was no significant difference in red oak height (Table 5 and 6, Fig.1).

Discussion

Exclosure Effects

Exclosure studies can be used with confidence to determine how deer impact changes in the development of vegetative communities. A considerable amount of exclosure studies suggest that deer negatively impact species density and height growth of woody vegetation (Horsley et al. 2003). Conversely, results from my analyses of stem height (Tables 4 & 5) and density (Table 2) between exclosure and control area suggest that deer exclosures had no effect on tree growth and regeneration. However, this is not surprising as deer will browse on woody vegetation only when crops, herbaceous vegetation, and acorns are unavailable due to the winter season (Rue, 1973). Data were collected on the new exclosures in the fall when deer were likely feeding on crops and acorns.

Deer are selective in the tree species they consume (Rue, 1978). During the winter when deer are forced to browse on woody vegetation the preferred tree species is red oak (Shea, 1998). Over time, this selective browsing results in reduced species diversity (Horsley et al., 2003). Although there was a significant difference between species diversity at site two, it is unlikely that this is a result of the newly built exclosure. Additionally, both sites were abundant in oak individuals, suggesting that deer have not yet altered species diversity at site one and two.

Past deer browsing

Deer can influence reforestation by altering the relative density of woody species, and reducing tree growth. Inouye et al. (1994) found that deer significantly reduced proportional rates of increase of red oak seedlings. High oak densities at site one and two (Table 1), make both areas prone to intensive deer browsing in the winter. The difference in mean stem height between site one and two indicates that site one may have had a greater browsing intensity in past winters.

Site one’s clumped spatial distribution (Table 2) of primarily red and bur oak (Table 1) make this area very appealing to deer. Shipley and Spalinger (1995) intake rate based on the mechanics of cropping, chewing, and encountering bites to describe white-tailed deer browse patterns. With decrease in density and patch size, deer walked faster between patches, cropped larger bites, and cropped more bites per stem. As the bit size and number of bites increased, potential digestible energy declined (Shipley & Spalinger, 1995). This negative correlation between patch size and digestible energy may explain site ones greater browsing intensity due to the clumped distribution.

Furthermore, the greater browsing intensity at site one may be due proximity of forest-field edge. Southern Minnesota's abundance of agricultural field and forest edges provides ideal habitat for successful reproduction in the summer and suitable cover in the winter. Site one corners a 2003 reforestation field and understory forest. As deer tend to browse woody-vegetation at forest edges (Inouye et al., 1994), there may be a selective browsing pressure on oak species in site one.

Future studies

Department of Natural Resources concluded that the white-tailed deer population has increased significantly in the last two decades (River Bend Nature Center, 2009). Lack of natural predators and ability to act quickly to favorable conditions have allowed the white-tailed deer population to continue to grow. Additionally, the mild winters in recent years have aggravated high densities of white-tailed deer in Rice County and Northfield areas. It is likely that the white-tailed deer population will continue to increase if mild winters persist and forest-field edges remain abundant. Therefore, I expect future exclosure studies to reveal significant differences in growth and density of woody-species, specifically red oaks, at site one and two. Additionally, selective browsing on red oaks may result in a shift in species diversity and richness. To properly determine the progress of St. Olaf reforestation sites, browsing pressure of white-tailed deer must be closely monitored. The influence of biotic factors, such as whit-tailed deer, on tree species must be properly managed in efforts to restore Minnesota's Big Woods.

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Table 1. The relative density of tree species on the east (site one) and west (site two) end of reforestation field in Northfield, MN.

Site One

Species	**Number of Individuals**	**Relative Denisty**
Black Cherry	3	0.012
Black Walnut	2	0.008
Boxelder	8	0.032
Bur Oak	140	0.571
Cotton Wood	4	0.016
Elm	3	0.012
Maple	2	0.008
Green Ash	1	0.004
Prickly Ash	8	0.032.
Red Oak	74	0.302
Total	245	

Site Two

Species	**Number of Individuals**	**Relative Density**
Black Cherry	0	0.000
Black Walnut	3	0 .010
Boxelder	22	0.080
Bur Oak	145	0.531
Cotton Wood	2	0.007
Elm	1	0.003
Maple	1	0.003
Green Ash	3	0.010
Prickly Ash	0	0.000
Red Oak	96	0.35
Total	273	

Table 2. Results of a one-way ANOVA on plot density of trees in exclosure area and control areas on the east (site one) and west (site two) sides of reforestation field in Northfield, MN.

Site One

Plot	Mean	Std. Dev.	Freq.	P-Value= .0803
Exclosure	5.96	5.71	25	
Control	3.60	1.70	25	
Total	4.72	4.25	50	

Site Two

Plot	Mean	Std. Dev.	Freq.	P-Value= .9138
Exclosure	5.84	2.44	25	
Control	5.76	2.74	25	
Total	5.78	2.57	50	

Table 3. Morrisita's Index of spatial distribution of bur oak and red oak on the east (site one) and west (site two) sides of reforestation field in Northfield, MN.

Site One

	Exclosure		**Control**	
Species	**X (chi-value)**	**Morrisita's Index**	**X (chi-value)**	**Morrisita's Index**
Bur Oak	148.8	2.83	43.7	1.35
Red Oak	77.5	1.91	46.7	2.75

Site Two

	Excosure		**Control**	
Species	**X (chi-value)**	**Morrisita's Index**	**X (chi-value)**	**Morrisita's Index**
Bur Oak	36.1	1.14	32.8	1.18
Red Oak	31.2	1.20	32.3	1.15

Table 4. Results of a one-way ANOVA on mean stem height of trees on the east (site one) and west (site two) sides of reforestation field in Northfield, MN.

Site	Freq.	Mean Height(cm)	Std. Dev	P-Value=0.00
One	240	38	25.8	
Two	290	49.4	27.9	
Total	530	44.2	27.5	

Table 5. Results of a one-way ANOVA comparing mean stem height of bur oak individuals on the east (site one) and west (site two) sides of a reforestation field in Northfield, MN.

Site One

Plot	Mean	Std. Dev.	Freq.	P-Value= .0035
Exclosure	28.0	11.10	70	
Control	38.63	27.42	60	
Total	32.90	20.93	130	

Site Two

Plot	Mean	Std. Dev.	Freq.	P-Value= .0026
Exclosure	44.17	15.42	96	
Control	36.08	16.89	59	
Total	41.09	16.43	155	

Table 6. Results of a one-way ANOVA comparing mean stem height of red oak individuals on the east (site one) and west(site two) sides of a reforestation field in Northfield, MN.

Site One

Plot	Mean	Std. Dev.	Freq.	P-Value= .0113
Exclosure	28.61	8.85	60	
Control	36.5	17.03	14	
Total	30.10	11.16	74	

Site Two

Plot	Mean	Std. Dev.	Freq.	P-Value=.4897
Exclosure	47.23	19.68	38	
Control	44.60	18.22	68	
Total	45.54	18.71	106	

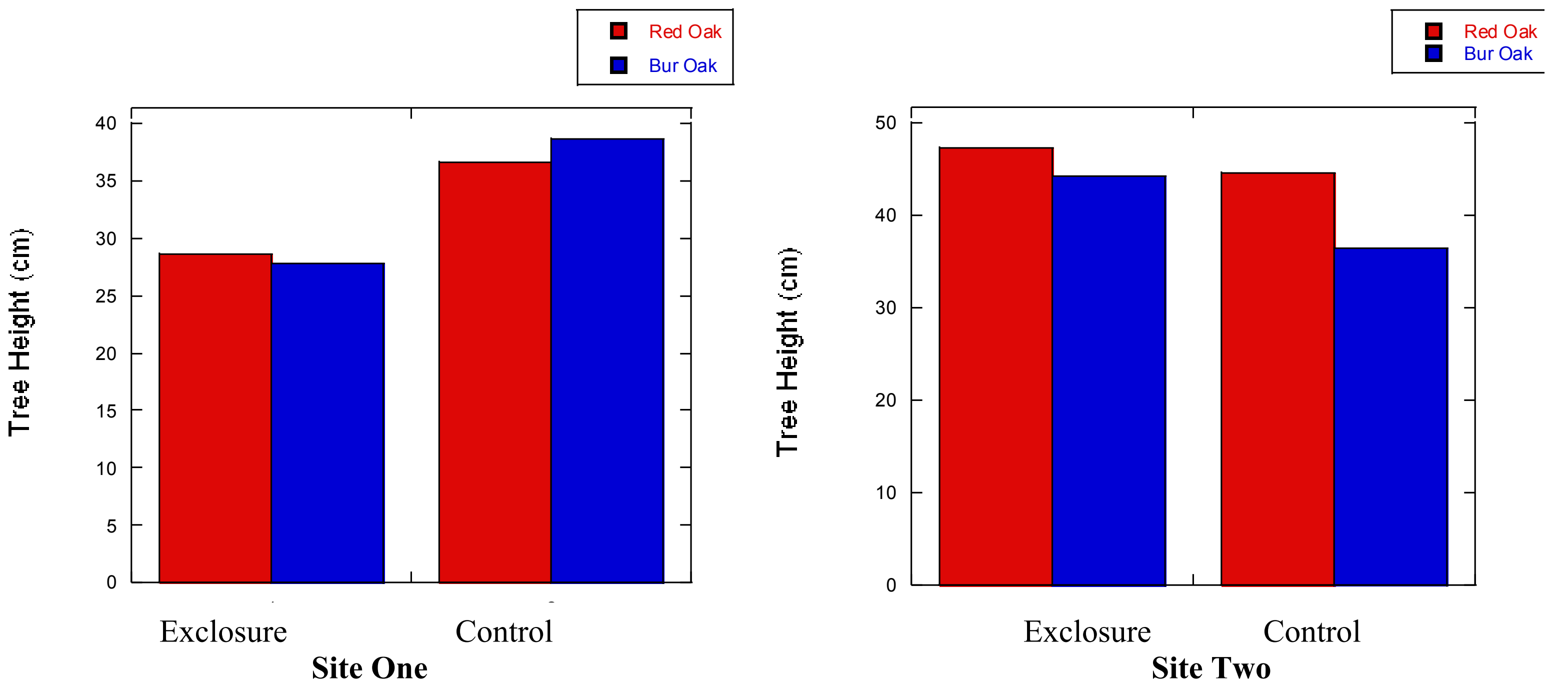

Figure 1. Mean stem height of bur oak and red oak in exclosure and control areas on the east side (site one) and west side (site two) of reforestation field in Northfield, MN.

Bur Oak site one		Red oak	
33	1	29	1
23	1	19	1
13	1	40	1
18	1	22	1
30	1	32	1
28	1	28	1
14	1	22	1
19	1	29	1
21	1	29	1
30	1	10	1
21	1	36	1
36	1	32	1
19	1	17	1
12	1	18	1
13	1	25	1
20	1	45	1
19	1	19	1
36	1	31	1
32	1	21	1
35	1	31	1
18	1	18	1
31	1	13	1
27	1	31	1
21	1	19	1
13	1	17	1
25	1	12	1
31	1	40	1
25	1	32	1
26	1	24	1
21	1	29	1
31	1	21	1
24	1	16	1
25	1	24	1
38	1	38	1
11	1	37	1
35	1	16	1
19	1	35	1
30	1	31	1
32	1	45	1
61	1	22	1
47	1	37	1
35	1	42	1
17	1	24	1
34	1	36	1
27	1	40	1
23	1	27	1
25	1	26	1
54	1	41	1
14	1	38	1
44	1	45	1
29	1	23	1
37	1	32	1

24	1	36	1
21	1	27	1
40	1	32	1
43	1	37	1
4	1	35	1
32	1	30	1
25	1	32	1
17	1	22	1
50	1	36	2
53	1	37	2
39	1	35	2
42	1	24	2
12	1	18	2
24	1	34	2
27	1	41	2
37	1	48	2
32	1	33	2
26	1	28	2
32	2	50	2
30	2	59	2
31	2	28	2
45	2	41	2
14	2		
20	2		
82	2		
52	2		
23	2		
81	2		
36	2		
25	2		
29	2		
30	2		
28	2		
10	2		
22	2		
31	2		
32	2		
24	2		
18	2		
20	2		
17	2		
40	2		
175	2		
137	2		
20	2		
31	2		
23	2		
37	2		
43	2		
37	2		
35	2		
66	2		
28	2		

37	2
35	2
28	2
27	2
23	2
17	2
20	2
23	2
43	2
44	2
49	2
45	2
55	2
30	2
18	2
40	2
22	2
19	2
40	2
46	2
66	2
41	2
45	2
44	2
55	2
38.6	

Site	Ex12	Bur Oak Height2
2	1	93
2	1	57
2	1	47
2	1	89
2	1	20
2	1	35
2	1	28
2	1	37
2	1	44
2	1	39
2	1	48
2	1	30
2	1	36
2	1	65
2	1	58
2	1	60
2	1	68
2	1	44
2	1	50
2	1	52
2	1	30
2	1	33
2	1	24
2	1	32
2	1	36
2	1	57
2	1	23
2	1	48
2	1	30
2	1	28
2	1	43
2	1	33
2	1	43
2	1	31
2	1	53
2	1	47
2	1	79
2	1	44
2	1	35
2	1	42
2	1	48
2	1	65
2	1	47
2	1	36
2	1	50
2	1	66
2	1	43
2	1	44
2	1	40
2	1	60
2	1	39
2	1	40

2	1	51
2	1	74
2	1	50
2	1	40
2	1	45
2	1	49
2	1	32
2	1	43
2	1	33
2	1	54
2	1	36
2	1	43
2	1	43
2	1	34
2	1	37
2	1	54
2	1	20
2	1	40
2	1	41
2	1	52
2	1	19
2	1	34
2	1	57
2	1	42
2	1	20
2	1	27
2	1	39
2	1	73
2	1	40
2	1	21
2	1	39
2	1	36
2	1	30
2	1	38
2	1	48
2	1	45
2	1	39
2	1	61
2	1	23
2	1	34
2	1	80
2	1	64
2	1	75
2	1	17
2	2	33
2	2	46
2	2	68
2	2	30
2	2	7
2	2	28
2	2	35
2	2	24
2	2	60

2	2	42
2	2	49
2	2	45
2	2	101
2	2	40
2	2	17
2	2	25
2	2	33
2	2	12
2	2	61
2	2	28
2	2	24
2	2	38
2	2	56
2	2	18
2	2	68
2	2	40
2	2	45
2	2	39
2	2	52
2	2	35
2	2	50
2	2	30
2	2	42
2	2	48
2	2	25
2	2	43
2	2	50
2	2	36
2	2	27
2	2	22
2	2	28
2	2	28
2	2	32
2	2	19
2	2	12
2	2	29
2	2	20
2	2	35
2	2	12
2	2	38
2	2	38
2	2	32
2	2	18
2	2	35
2	2	39
2	2	54
2	2	56
2	2	30
2	2	27

EXC!	Total Density1	EXC2	Total Density
1	16	1	7
1	20		
1	23	1	2
1	10	1	4
1	2	1	10
1	17	1	8
1	6	1	5
1	4	1	5
1	1	1	3
1	1	1	7
1	4	1	2
1	4	1	6
1	7	1	5
1	2	1	11
1	1	1	7
1	1	1	9
1	6	1	4
1	3	1	4
1	2	1	5
1	0	1	8
1	2	1	6
1	2	1	2
1	3	1	5
1	4	1	6
1	8	1	9
2	0	1	6
2	1	2	3
2	4	2	5
2	4	2	3
2	5	2	7
2	5	2	5
2	4	2	4
2	4	2	6
2	5	2	3
2	5	2	5
2	4	2	11
2	6	2	7
2	4	2	2
2	6	2	6
2	4	2	5
2	2	2	14
2	3	2	3
2	6	2	6
2	1	2	9
2	2	2	8
2	2	2	4
2	4	2	4
2	3	2	5
2	5	2	8
2	1	2	7
		2	4

Exclosure2	RED Oak Heght
1	9
1	20
1	57
1	54
1	32
1	42
1	59
1	52
1	23
1	104
1	47
1	65
1	20
1	80
1	48
1	27
1	60
1	67
1	36
1	46
1	69
1	43
1	65
1	55
1	53
1	17
1	57
1	48
1	36
1	65
1	21
1	30
1	64
1	56
1	45
1	39
1	61
1	23
2	55
2	37
2	40
2	21
2	75
2	58
2	30
2	39
2	52
2	40
2	34
2	43
2	46
2	40

2	33
2	18
2	20
2	48
2	53
2	71
2	63
2	78
2	19
2	37
2	52
2	60
2	18
2	62
2	50
2	30
2	25
2	35
2	65
2	62
2	88
2	36
2	77
2	60
2	15
2	43
2	41
2	31
2	92
2	41
2	18
2	13
2	53
2	67
2	45
2	29
2	48
2	59
2	70
2	74
2	35
2	39
2	22
2	60
2	25
2	40
2	42
2	26
2	37
2	36
2	32
2	45
2	48

2	37
0	0

Exclosure-F	Control-RO	Exclosure-E	Control-BO	1	9
9	55	93	33	1	20
20	37	57	46	1	57
57	40	47	68	1	54
54	21	89	30	1	32
32	75	20	7	1	42
42	58	35	28	1	59
59	30	28	35	1	52
52	39	37	24	1	23
23	52	44	60	1	104
104	40	39	42	1	47
47	34	48	49	1	65
65	43	30	45	1	20
20	46	36	101	1	80
80	40	65	40	1	48
48	33	58	17	1	27
27	18	60	25	1	60
60	20	68	33	1	67
67	48	44	12	1	36
36	53	50	61	1	46
46	71	52	28	1	69
69	63	30	24	1	43
43	78	33	38	1	65
65	19	24	56	1	55
55	37	32	18	1	53
53	52	36	68	1	17
17	60	57	40	1	57
57	18	23	45	1	48
48	62	48	39	1	36
36	50	30	52	1	65
65	30	28	35	1	21
21	25	43	50	1	30
30	35	33	30	1	64
64	65	43	42	1	56
56	62	31	48	1	45
45	88	53	25	1	39
39	36	47	43	1	61
61	77	79	50	1	23
23	60	44	36	2	55
	15	35	27	2	37
	43	42	22	2	40
	41	48	28	2	21
	31	65	28	2	75
	92	47	32	2	58
	41	36	19	2	30
	18	50	12	2	39
	13	66	29	2	52
	53	43	20	2	40
	67	44	35	2	34
	45	40	12	2	43
	29	60	38	2	46
	48	39	38	2	40
	59	40	32	2	33

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