NB 64087

The Impacts of Hurricane Gloria, Deer & Trails

The Sunken Forest

Fire Island National Seashore

Fire Island, NY

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ABSTRACT

This report is part of the continuing study of changes in the vegetation communities on Fire Island in general and the Sunken Forest in particular. Data collected in the summer of 1987 indicate that there continues to be a low level of mortality related to the September,1985 hurricane. Several partially uprooted Sassafras albidum and Amelanchier canadensis trees died between August, 1986 and August, 1987. In most areas within the Sunken Forest the shrub layer continues to show a vigorous response to the opening up of the canopy above. The decline of the herbaceous perennial related to deer grazing continues eventhough the woody seedling populations continue to flourish.

Dramatic changes have occurred in the herb layer after the first year of the deer exclosure study, with cover increasing from 7.1% to 10.6% in exclosed forest plots and seedling density nearly doubling. Control plots remained essentially constant.

In the assessment of the impacts of the Sunken Forest boardwalk and associated "dirt" trails on the herbaceous layer, it was found that the boardwalk itself had little negative impact compared to the considerable negative influence of the dirt paths. Smilax rotundifolia appears to be giving protection to the herb layer and herbaceous cover is related to Smilax abundance.

Results & Discussion

100 m^2 Plots. The overall density of trees in the Sunken Forest plots remained essentially unchanged between 1986 and 1987 (Figure 1, Table 1, Appendix A). There were some significant changes in the densities of species, however, during this period. Nyssa sylvatica and tree-sized Vaccinium corymbosum increased in density while Sassafras albidum and Amelanchier canadensis both decreased. The mortality of the latter two species is related to the demise of hurricane-weakened trees. As noted in Art (1987), there were a substantial number of Sassafras and Amelanchier individuals that were only partially uprooted in September, 1985 by Hurricane Gloria. Some of these trees survived through the 1986 growing season but succumbed during the 1987 growing season.

Table 1. F.I.N.S. SUNKEN FOREST - TREES PLOT POPULATION 1985
100 SQ. METER PLOTS- DATA COLLECTED IN 1987

SPECIES	DENSITY (100M-2)	S.D.	S.E.	R.S.E.
Ilex opaca	7.05	6.03	1.03	0.15
Sassafras albidum	3.32	3.35	0.57	0.17
Amelanchier canadensis	9.11	9.14	1.57	0.17
Nyssa sylvatica	1.32	2.19	0.38	0.29
Quercus velutina	0.16	0.37	0.06	0.41
Vaccinium corymbosum	3.42	5.75	0.99	0.29
Pinus rigida	0.11	0.46	0.08	0.75
Prunus serotina	0.42	1.12	0.19	0.46
Rhus copallina	0.11	0.32	0.05	0.51
Pyrus arbutifolia	0.37	1.38	0.24	0.64
Rhododendron viscosum	0.16	0.69	0.12	0.75
Acer rubrum	0.74	3.21	0.55	0.75
MEAN TOTAL	26.26	12.91	2.21	0.08

The increase in Vaccinium trees also appears to be related to the disturbances wrought by Hurricane Gloria. Large blueberry shrubs growing in the vicinity of gaps created by branch breaking and tree

Figure 1.

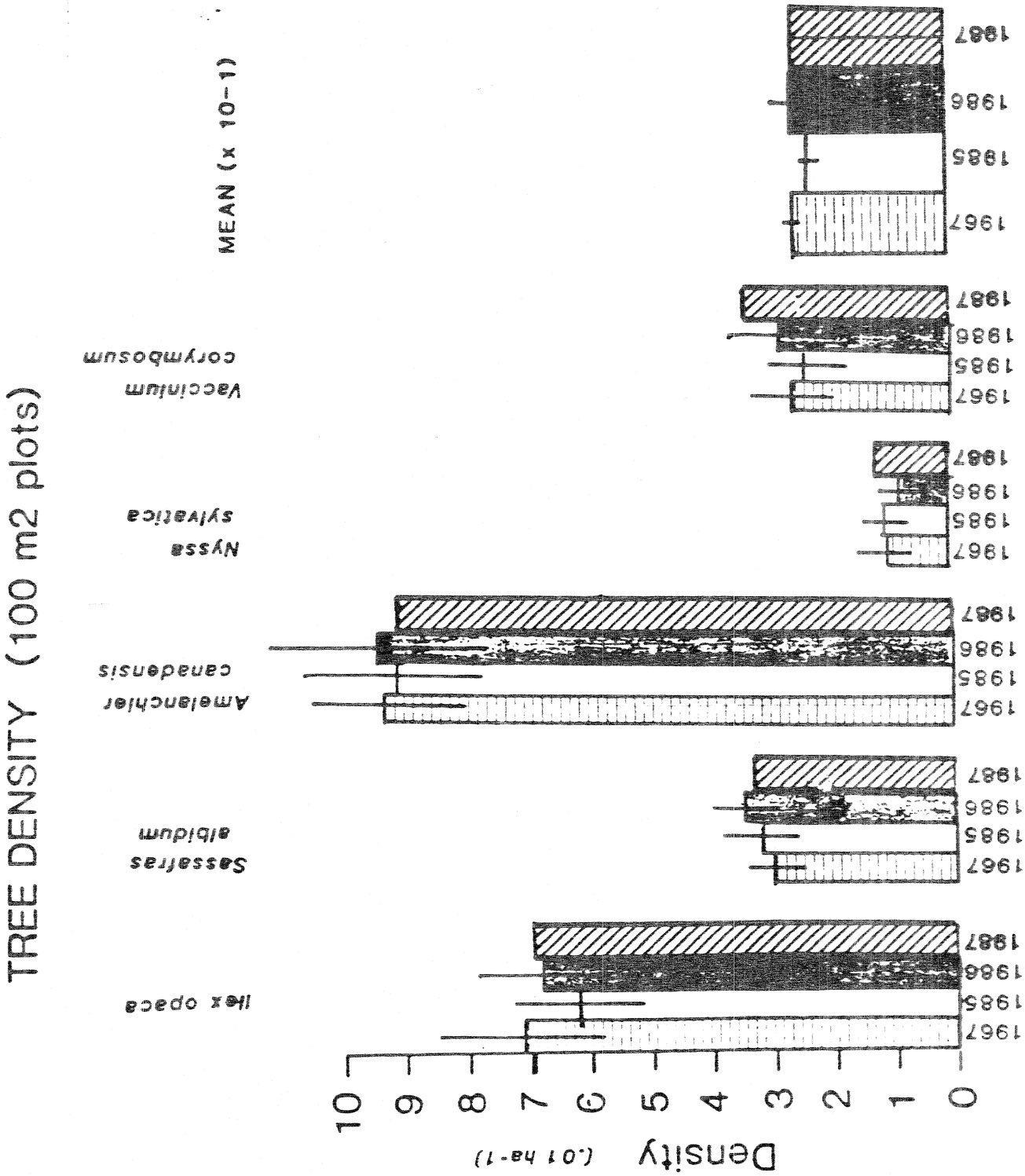
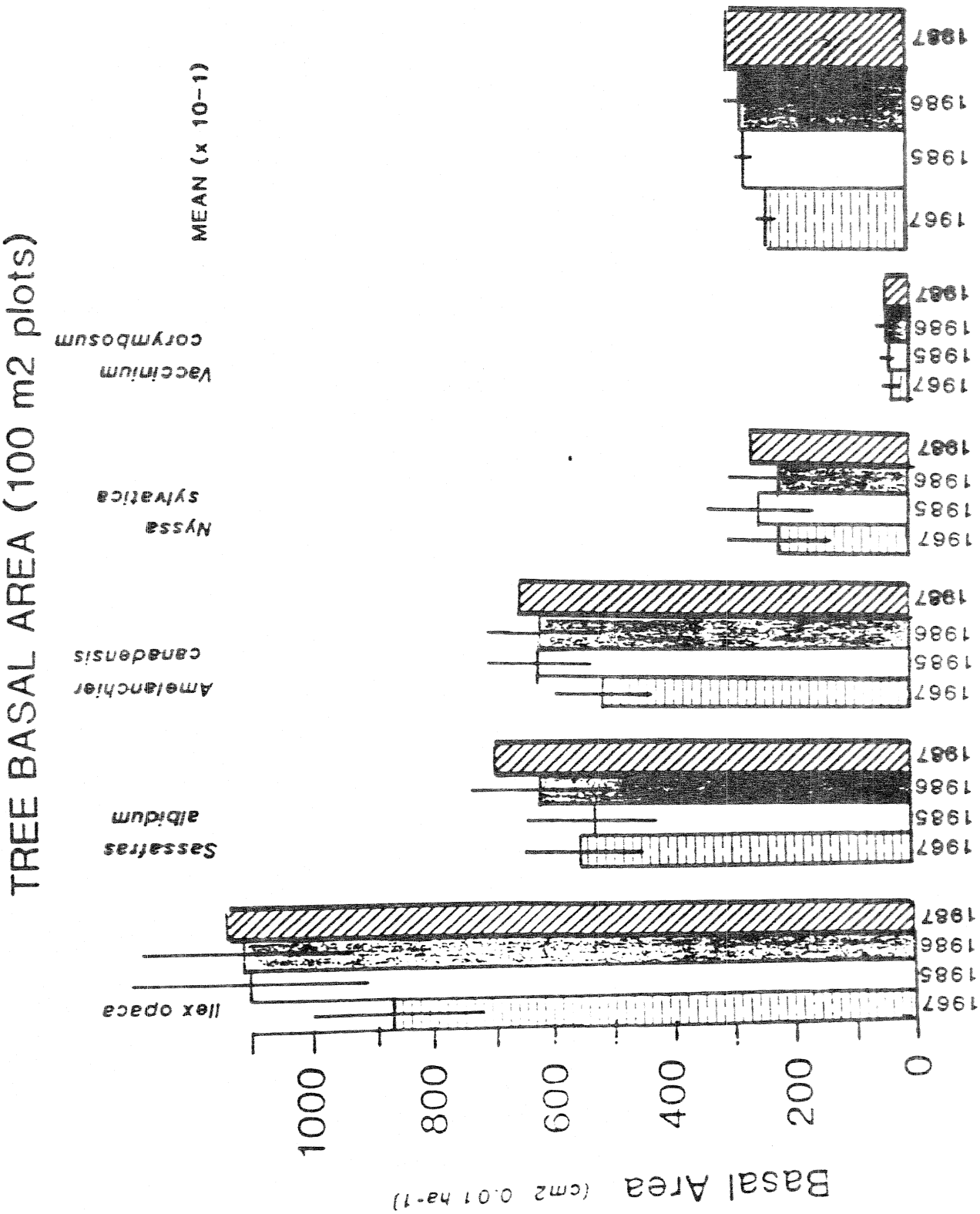

TREE DENSITY (100 m2 plots)
MEAN (x 10-1)
Density (.01 ha-1)
0 1 2 3 4 5 6 7 8 9 10
Ilex opaca
Sassafras albidum
Amelanchier canadensis
Nyssa sylvatica
Vaccinium corymbosum
1967
1985
1986
1987

Figure 2.


TREE BASAL AREA (100 m2 plots)
MEAN (x 10-1)
Basal Area (cm2 0.01 ha-1)
0
200
400
600
800
1000
Ilex opaca
Sassafras albidum
Amelanchier canadensis
Nyssa sylvatica
Vaccinium corymbosum
1967
1985
1986
1987

uprooting during the hurricane have now been recruited into the tree layer.

Eventhough the densities of Sassafras and amelanchier decreased, their basal areas along with those of Ilex and Nyssa, the four dominant tree species, all increased from 1986 to 1987. For Nyssa this increase marked a return to pre-hurricane levels, while for the other tree species the trend was a continuation of post-hurricane growth seen in 1986 (Figure 2 & Table 2, Appendix A).

Table 2.
F.I.N.S. SUNKEN FOREST - TREES PLOT POPULATION 1985
100 SQ. METER PLOTS- DATA COLLECTED IN 1987

SPECIES	BASAL AREA (cm2 100m-2)	S.D.	S.E.	R.S.E.
Ilex opaca	1155.9	972.77	166.83	0.14
Sassafras albidum	693.8	692.38	118.74	0.17
Amelanchier canadensis	655.1	552.91	94.82	0.14
Nyssa sylvatica	269.1	530.88	91.04	0.34
Quercus velutina	146.4	567.27	97.28	0.66
Vaccinium corymbosum	47.6	74.65	12.80	0.27
Pinus rigida	36.7	159.83	27.41	0.75
Prunus serotina	13.4	37.38	6.41	0.48
Rhus copallina	1.0	3.10	0.53	0.52
Pyrus arbutifolia	4.2	16.12	2.77	0.66
Rhododendron viscosum	2.0	8.79	1.51	0.75
Acer rubrum	36.0	157.10	26.94	0.75
MEAN TOTAL	3061.2	990.90	169.93	0.06

Between 1986 and 1987, the shrub layer also showed continued positive responses to the 1985 hurricane. The densities of all species represented in the shrub layer increased, and the mean density increased significantly (Table 3, Figure 3, Appendix A). Although the basal areas of Sassafras, Amelanchier and Gaylussacia bacata decreased, they were more than compensated for by increased basal areas of Ilex opaca, I. glabra, and Vaccinium (Table 3, Figure 3, Appendix A).

Table 3. F.I.N.S. SUNKEN FOREST - SHRUB PLOT POPULATION 1985
100 SQ. METER PLOTS- DATA COLLECTED IN 1987

SPECIES	DENSITY (100 m-2)	S.D.	S.E.	R.S.E.
Ilex opaca	0.21	0.92	0.16	2.99
Sassafras albidum	0.42	1.26	0.22	2.05
Amelanchier canadensis	1.68	2.77	0.48	1.13
Nyssa sylvatica	0.21	0.92	0.16	2.99
Vaccinium corymbosum	5.89	8.68	1.49	1.01
Pyrus arbutifolia	2.32	6.44	1.10	1.91
Rhus radicans	0.21	0.92	0.16	2.99
Ilex glabra	0.63	2.75	0.47	2.99
Gaylussacia baccata	2.32	7.22	1.24	2.14
Myrica pensylvanica	0.63	2.75	0.47	2.99
MEAN TOTAL	3.63	5.66	0.97	0.27

Table 4. F.I.N.S. SUNKEN FOREST - SHRUB PLOT POPULATION 1985
100 SQ. METER PLOTS- DATA COLLECTED IN 1987

SPECIES	BASAL AREA (cm2 100m-2)	S.D.	S.E.	R.S.E.
Ilex opaca	1.03	4.50	0.77	2.99
Sassafras albidum	3.86	14.09	2.42	2.50
Amelanchier canadensis	20.80	32.01	5.49	1.06
Nyssa sylvatica	1.69	7.38	1.27	2.99
Vaccinium corymbosum	118.77	176.55	30.28	1.02
Pyrus arbutifolia	15.94	41.93	7.19	1.80
Rhus radicans	2.65	11.53	1.98	2.99
Ilex glabra	5.58	24.32	4.17	2.99
Gaylussacia baccata	2.92	8.79	1.51	2.07
Myrica pensylvanica	2.41	10.50	1.80	2.99
MEAN TOTAL	43.91	60.09	10.31	0.27

have died since 1986 and have been replaced by smaller shrubs recruited from the herb layer. If normal growth and thinning occurs over the next several years, the density of shrubs may decrease as the basal area of the shrub layer increases.

Perhaps the most dramatic and significant change in the Sunken Forest during the period 1967 - 1987 has been the reduction in the cover of the herb layer, especially in the dominance of herbaceous perennials such as Aralia nudicaulis, Smilacina stellata, Melanthecum

canadense, Trientalis borealis, and Gaultheria procumbens. As noted by Art (1987), the main refugia of these herbaceous perennials is under dense tangles of Smilax rotundifolia that provide protection from deer grazing. In Chapter 3 of this report data is presented showing that Smilax plays the identical role of protecting perennial herbs in the vicinity of trails. Therefore, unless there is a dramatic increase in Smilax tangles it is unlikely that there will be a substantial increase in perennial herbs.

While the total cover in the herb layer increased by about 1/3 from 1985 to 1987 (Table 5, Figure 5, Appendix A) the populations of most herbaceous perennials have continued to decline. Even with the construction of deer exclosures around three of the 19 plots, the populations of Aralia, Maianthemum, Smilacina, Trientalis, and Osmunda cinnamomea are approaching extripation in the permanent plots. The seedlings of woody species such as Ilex opaca, Nyssa, Vaccinium, Prunus serotina, Rhus radicans, Gaylussacia bacata, and Parthenocissus quinquefolia, however, dramatically increased in cover between 1986 and 1987. The net result was greater cover in the herb layer, but a reduction in species diversity because of the decline in herbaceous perennials.

The density of woody seedlings changed considerably between 1986 and 1987 as well (Table 6, Appendix A). Substantial increases in population densities of woody seedlings were concomitant with increases in woody seedling cover. Ilex opaca had nearly a 5-fold increase in seedling density and Smilax rotundifolia seedlings increased by about 350%. It is likely that these increases in seedling densities are the result of delayed germination of burried seeds in the soil seed bank.

Figure 3.

SHRUB DENSITY (100 m2 plots)
MEAN (x 10-1)
Density (.01 ha-1)
0
5
10
15
20
1967
1985
1986
1987
Ilex opaca
Sassafras albidum
Amelanchier canadensis
Vaccinium corymbosum
Ilex glabra
28±20
Gaylussacia baccata

Figure 5.

HERB COVER & LIANA DENSITY (100 m2 plots)
% Cover
0
1
2
3
4
5
6
7
8
9
10
Aralia nudicaulis
Smilacina stellata
Ilex opaca
Sassafras albidum
Amelanchier canadensis
Ilex glabra
TOTAL (x 10-1)
Smilax rotundifolia
Density (m-2)
1967
1985
1986
1987

Figure 4.

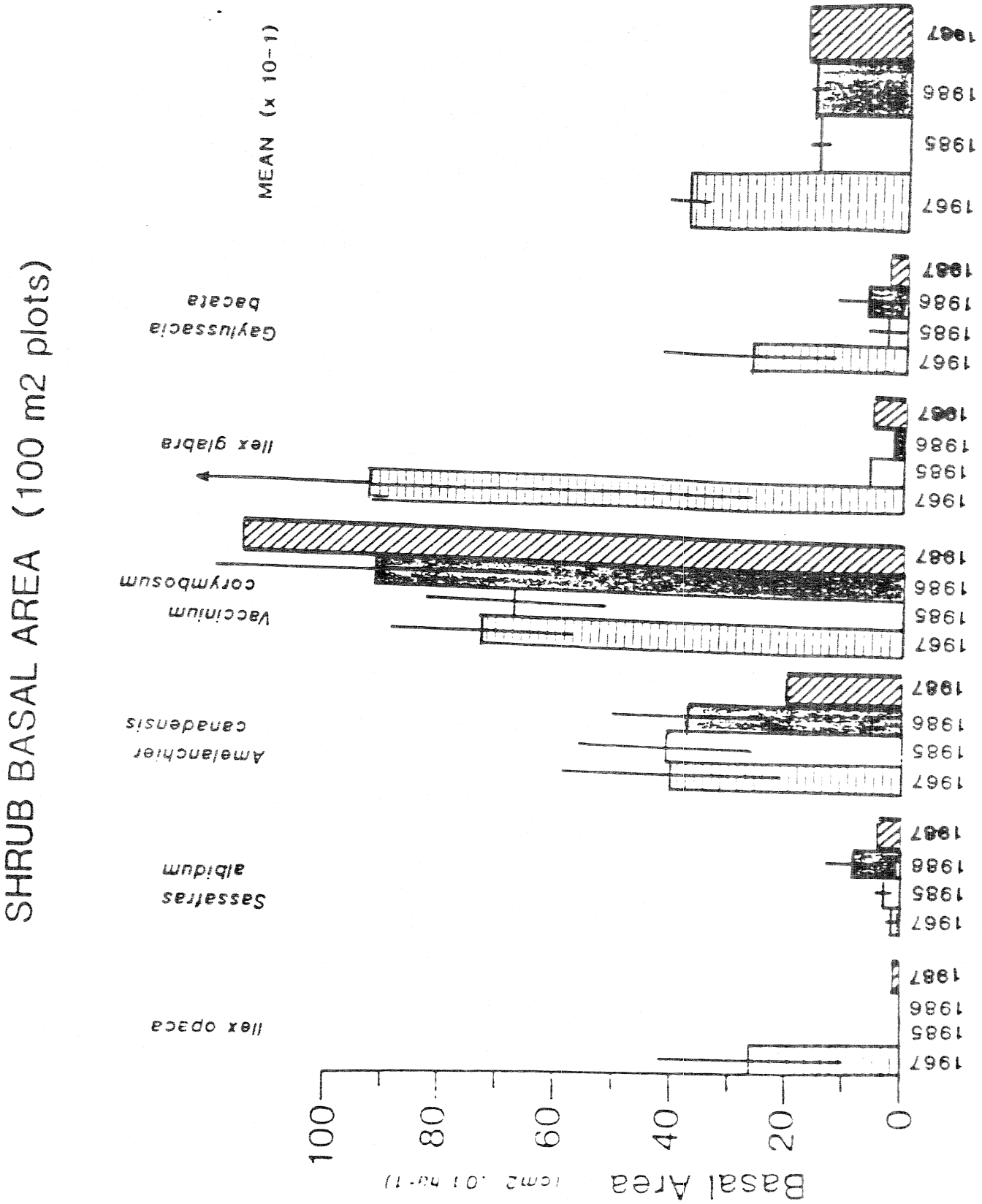

SHRUB BASAL AREA (100 m2 plots)
MEAN (x 10-1)
Basal Area (cm2 .01 ha-1)
0
20
40
60
80
100
1967
1985
1986
1987
Ilex opaca
Sassafras albidum
Amelanchier canadensis
Vaccinium corymbosum
Ilex glabra
Gaylussacia baccata

Table 5. F.I. SUNKEN FOREST - HERB PLOT POPULATION 1985
100 SQ. METER PLOTS- DATA COLLECTED IN 1987

SPECIES	1986 COVER (%)	1987 COVER	S.D.	S.E.	R.S.E.
Ilex opaca	0.203	0.326	0.581	0.099	0.31
Sassafras albidum	2.559	2.032	2.307	0.395	0.19
Amelanchier canadensis	0.409	0.445	0.278	0.047	0.11
Nyssa sylvatica	0.150	0.305	0.610	0.104	0.34
Vaccinium corymbosum	0.013	0.041	0.125	0.021	0.51
Pinus rigida	0.001	0.000			
Juniperus virginiana	0.000	0.001	0.005	0.001	0.75
Prunus serotina	0.813	1.396	2.485	0.426	0.31
Rhus copallina	0.042	0.043	0.127	0.021	0.50
Pyrus arbutifolia	0.161	0.101	0.148	0.025	0.25
Baccharis halimifolia	0.000	0.014	0.057	0.009	0.68
Rhododendron viscosum	0.001	0.000			
Rhus radicans	0.583	0.907	1.938	0.332	0.37
Ilex glabra	0.092	0.146	0.630	0.108	0.74
Gaylussacia baccata	3.487	4.053	9.996	1.714	0.42
Viburnum dentatum	0.028	0.001	0.005	0.001	0.75
Pteridium aquilinum	0.026	0.197	0.490	0.084	0.43
Aralia nudicaulis	0.133	0.028	0.114	0.019	0.71
Hypericum virginicum	0.133	0.395	1.446	0.248	0.63
Maianthemum canadense	0.158	0.009	0.025	0.004	0.47
Myrica pensylvanica	0.211	0.804	3.438	0.589	0.73
Osmunda cinnamomea	0.105	0.092	0.401	0.068	0.75
Parthenocissus quinquefolia	0.109	1.389	1.463	0.250	0.18
Phragmities communis	0.592	0.329	1.433	0.245	0.75
Pluchea purpurascens	0.000	0.133	0.573	0.098	0.74
Smilacina stellata	0.029	0.004	0.012	0.002	0.54
Solidago sempervirens	0.000	0.001	0.005	0.001	0.75
Teucrium canadense	0.053	0.001	0.005	0.001	0.75
Trientalis borealis	0.201	0.162	0.465	0.079	0.49
Vaccinium macrocarpon	0.329	0.132	0.573	0.098	0.75
Vitis labrusca	0.000	0.004	0.009	0.001	0.41
Smilax glauca	0.030	0.013	0.057	0.009	0.75
Smilax rotundifolia	0.092	0.272	0.257	0.044	0.16
Carex sp.	0.001	0.014	0.057	0.009	0.68
Polygonum hydropiperoides	1.079	0.605	2.578	0.442	0.73
Erectities heracifolia	0.000	0.001	0.005	0.001	0.75
Scirpus americana	0.197	0.000			
Rubus hispidus	0.026	0.066	0.286	0.049	0.75
Sphagnum spp.	0.132	0.026	0.114	0.019	0.75
Phytolacca americana	0.000	0.197	0.860	0.147	0.75
Carex swanii	0.000	0.014	0.057	0.009	0.68
Ammophila breviligulata	0.000	0.026	0.114	0.019	0.75
Panicum lanuginosum	0.000	0.001	0.005	0.001	0.75
Crataegus spp.	0.000	0.001	0.005	0.001	0.75
Spartina alterniflora	0.066	0.000			
I. opaca 1 yr old	0.000	0.016	0.019	0.003	0.21
MEAN TOTAL	12.245	16.555	12.6170	2.0643	0.21

Table 5. F.I. SUNKEN FOREST - HERB PLOT POPULATION 1985
100 SQ. METER PLOTS- DATA COLLECTED IN 1987

SPECIES	1986 DENSITY (M-2)	1987 DENSITY	S.D.	S.E.	R.S.E.
Ilex opaca	1.33	6.62	10.00	1.71	0.26
Sassafras albidum	3.13	3.60	2.97	0.50	0.14
Amelanchier canadensis	4.00	7.16	4.98	0.85	0.12
Nyssa sylvatica	0.73	0.62	1.17	0.20	0.33
Vaccinium corymbosum	0.06	0.10	0.34	0.05	0.56
Juniperus virginiana	0.00	0.01	0.05	0.01	0.75
Prunus serotina	2.58	2.64	2.28	0.39	0.15
Rhus copallina	0.05	0.08	0.16	0.05	0.36
Pyrus arbutifolia	0.33	0.39	0.64	0.11	0.28
Baccharis halimifolia	0.00	0.09	0.34	0.05	0.64
Rhus radicans	0.93	0.88	1.59	0.27	0.31
Ilex glabra	0.03	0.13	0.42	0.07	0.56
Gaylussacia baccata	1.09	1.53	3.68	0.63	0.41
Viburnum dentatum	0.05	0.01	0.05	0.01	0.75
Myrica pensylvanica	0.13	0.17	0.58	0.10	0.59
Parthenocissus quinquefolia	0.63	1.50	1.43	0.24	0.16
Vitis labrusca	0.00	0.05	0.13	0.02	0.44
Smilax glauca	0.58	0.04	0.17	0.02	0.75
Smilax rotundifolia	1.90	6.83	5.37	0.92	0.14
Rubus hispidus	0.07	0.07	0.28	0.04	0.75
Crataegus spp.	0.00	0.01	0.05	0.09	0.75
I. opaca >1 yr old	-.--	0.25	0.28	0.04	0.20
MEAN TOTAL	17.69	33.09	12.71	2.08	0.06

Another major change that was noted in the herb layer of the 100m2 plots was the survival of a small, but probably significant, number of Ilex opaca seedlings that were two years old (Table 6). The vast majority of holly seedlings (96%) were from newly germinated seeds, however the summer of 1987 marked the first time in two decades that a substantial number (0.25 m-2) of greater than year-old holly seedlings have been seen in the Sunken Forest. They undoubtedly owe their presence to the opening up of the canopy following Hurricane Gloria and the subsequent enhancement of holly germination during the 1986 growing season (Art, 1987). It is possible that the disturbances associated with Hurricane Gloria will eventually lead to increased regeneration of Ilex opaca

Ecosystem Study Plot (E.S.P.). The E.S.P., perhaps more than any other area in the Sunken Forest, has been hard hit by the impacts of both deer browsing and Hurricane Gloria (Art, 1987). However, there are clear signs of recovery from the hurricane disturbances so evident in the 1986 data collected in the plot. Mean tree heights of Ilex opaca and Sassafras albidum have returned to pre-September, 1985 levels and only Amelanchier canadensis showed a decline between 1986 and 1987 (Figure 6, Table 7). Over all, the mean canopy height increased by 15 cm between 1986 and 1987.

The basal area of the E.S.P. was remarkably constant from 1986 to 1987 (3649 to 3623 cm2 100 m-2) with the gains in Ilex opaca and Sassafras toward pre-hurricane levels being balanced by mortality of hurricane stressed Amelanchier individuals that died during the period (Figures 7 & 8). The death of 6 shadbush trees accounts for the entire decline in total tree density between 1986 and 1987. All 6 of

Figure 6.

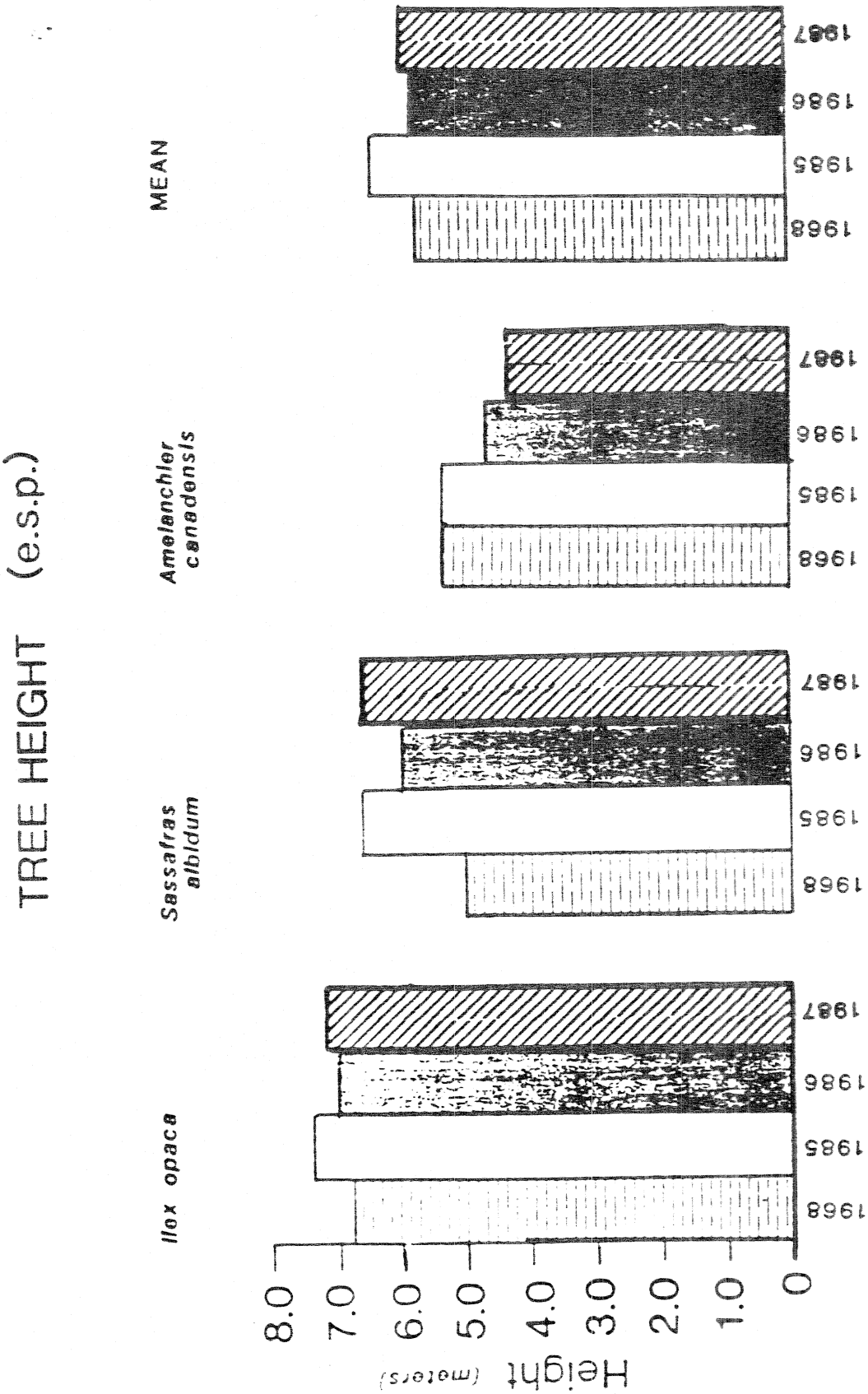

TREE HEIGHT (e.s.p.)
Ilex opaca
Sassafras albidum
Amelanchier canadensis
MEAN
1988
1985
1986
1987
Height (meters)
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

Figure 7.

TREE BASAL AREA (e.s.p.)
Species Basal Area (cm2 0.01 ha-1)
2000
1500
1000
500
0
Ilex opaca
Sassafras albidum
Amelanchier canadensis
TOTAL
1968
1985
1986
1987
Total Basal Area
4000
3000
2000
1000
0

Figure 8

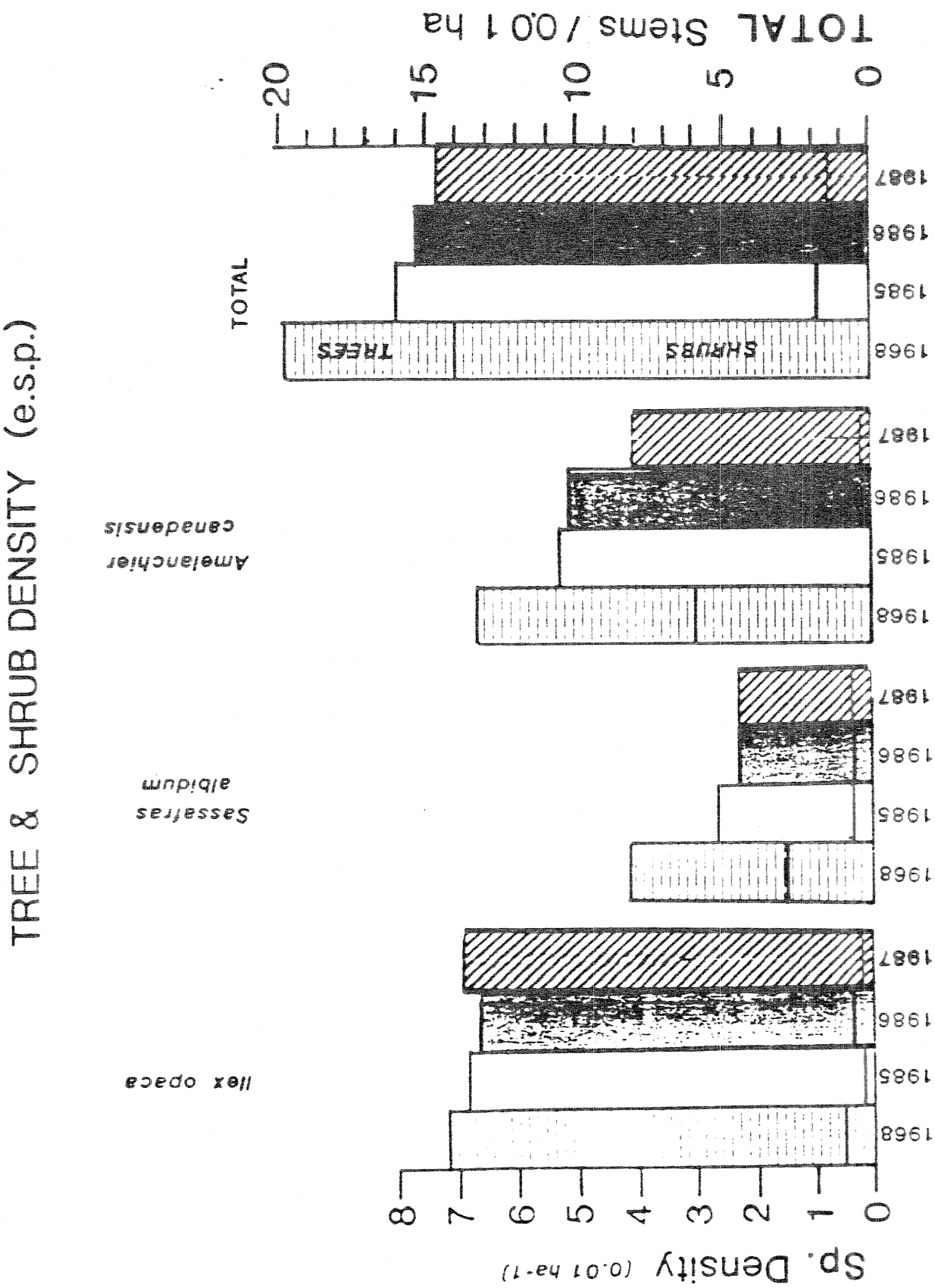

TREE & SHRUB DENSITY (e.s.p.)
Sp. Density (0.01 ha-1)
0 1 2 3 4 5 6 7 8
1988
1985
1986
1987
Ilex opaca
Sassafras albidum
Amelanchier canadensis
TOTAL Stems /0.01 ha
0 5 10 15 20
TOTAL
TREES
SHRUBS

Table 7. SUNKEN FOREST ECOSYSTEM STUDY PLOT 1987

TREES

SPECIES	Basal Area Cm2,100m-2	Density 100m-2	Mean Height meters
Ilex opaca	2219.23	7.00	7.09
Sassafras albidum	830.91	2.33	6.59
Amelanchier canadensis	362.22	4.17	4.33
Nyssa sylvatica	171.90	0.33	3.90
Prunus serotina	31.67	0.33	4.75
Rhus radicans	4.40	0.17	6.23
Parthenocissus quinquefolia	3.23	0.33	6.38
TOTAL	3622.85	14.67	6.08

SHRUBS

Ilex opaca	1.43	0.17	1.20
Sassafras albidum	6.54	0.33	2.25
Amelanchier canadens	0.75	0.17	2.50
Vaccinium corymbosum	5.62	0.33	2.35
Viburnum dentatum	4.65	0.33	2.90
TOTAL	18.99	1.33	2.34

LIANAS

Parthenocissus quinquefolia	20.37	5.50	0.00

HERB SPECIES	% COVER	+/- ERROR	DENSITY	+/- ERROR
Ilex opaca	0.75	0.92	6.19	2.91
Sassafras albidum	3.19	1.93	6.25	2.49
Amelanchier canadensis	0.17	0.13	2.94	1.84
Nyssa sylvatica	0.03	0.06	0.11	0.26
Pinus rigida	0.00	0.00	0.03	0.06
Prunus serotina	1.25	0.48	3.03	1.23
Baccharis halimifolia	0.06	0.09	0.36	0.42
Rhus radicans	0.06	0.08	0.22	0.28
Parthenocissus quinquefolia	1.58	0.68	2.75	0.83
Vitis labrusca	0.00	0.00	0.03	0.06
Smilax rotundifolia	0.83	0.37	18.50	7.14
Dryopteris spinulosa	0.56	1.20	0.00	0.03
TOTAL	8.48		40.41	

Figure 9

HERB LAYER COVER & SEEDLING DENSITY (e.s.p.)
% Cover
0
10
20
30
40
50
Aralia nudicaulis
Smilacina stellata
Maianthemum canadense
TOTAL
Ilex opaca
Sassafras albidum
Amelanchier canadensis
Smilax rotundifolia
Density (m-2)
0
1
2
3
4
5
6
7
23.5
18.6
1968
1985
1986
1987

these trees had been either partially uprooted by the hurricane or had massive crown damage caused by larger adjacent trees falling onto them.

The overall canopy, however, is well on its way to recovery from the initial hurricane damage. The expression of the percent of the canopy that was disrupted by the hurricane, using the sum of the basal areas times canopy damage of individual trees (Art, 1987) showed initial destruction of 28% of the canopy in the E.S.F. One year later about half of that damage had been repaired, largely through growth extension of crowns adjacent to gaps caused by broken limbs and uprooted trees. In 1987 hurrican disruption of the canopy amounted to only 15% (Figure 7).

The shrub layer in the E.S.F. continues to be poorly developed, a situation that dates from prior to the hurricane. The slight increases in shrub density in 1986 were reversed by 1987, when densities fell to pre-hurricane levels (Figure 8). The herb layer, however continues to show a vigorous response to the hurricane disruption of the tree and shrub layers (Table 7, Figure 9). As in the 100 m2 plots, woody tree seedlings generally have increased in cover and density between 1986 and 1987, with the exception of Smilax rotundifolia which has showed a slight decline in density while its cover increased. There are even fewer herbaceous perennials in the E.S.F. than the Sunken Forest as a whole, and annuals such as Erictities heracifolia and Phytolacca americana have disappeared since 1986.

Conclusions. The second growing season following Hurricane Gloria is marked by low levels of delayed, storm related mortality to

Amelanchier and Sassafras. These mortality features are most clearly seen in those permanent plots with trees that were partially uprooted in 1985 and in an obviously stressed condition during the 1986 growing season. The losses in density of trees have in general been compensated for by the increased diameter and crown growth of the remaining trees, the basal area of the Sunken Forest being at least as high as it was in 1986.

Apart from the E.S.P., the shrub layer appears to be responding postively to the opening up of the tree canopy above. There is vigorous recruitment of young individuals into the shrub layers, especially for species such as Vaccinium corymbosum and Gaylussacia baccata.

The woody component of the herb layer is continuing to flourish after the hurricane, with increased vigor of Ilex, Sassafras, Amelanchier, Rhus radicans, Parthenocissus quinquefolia, Prunus serotina, and Gaylussacia. The herbaceous perennials, such as Aralia nudicaulis, Melanthemum canadense, Smilacina stellata, and Trientalis borealis have unfortunately declined greatly over the past year. The dominace of herbaceous perennial species in the herb layer plots has declined from 12 species with 14.4% cover in 1967, to 12 species with 2.75% cover in 1986, to 12 species with 2% cover in 1987.

CHAPTER 2

DEER EXCLOSURE STUDY

Undoubtedly the most significant biological event in the past two decades has been the increase in the population of eastern white-tail deer from zero in 1967 to over several hundred by 1986 (see Art, 1987). Field evidence collected in 1985 and 1986 strongly suggests that the deer are directly responsible for the dramatic decline in the dominance of the herb layer in general and herbaceous perennials in particular in the Sunken Forest over the past 20 years. While the deer may have little impact on most well established, mature trees, they undoubtedly are having an effect on the regeneration of the Forest by differential browsing of species in the herb and shrub layers. It is probable that the decline of shrub species such as *Ilex glabra* and *Gaylussacia bacata* are in large part a result of deer browsing.

Clearly deer are not the only biological agent changing the plant populations in the Sunken Forest and other parts of Fire Island. Rabbits have long been present and grey squirrels were also introduced onto the island since 1967 (Art, 1987). It is difficult to separate the impacts of deer from other herbivores or even the successional processes of canopy closure by simply examining permanent plots in the Forest.

For this reason, in addition to need for data relevant to the prudent management of the National Seashore's natural resources, a deer exclosure experiment was initiated in summer of 1986.

Methods

In order to assess the impacts of deer on as wide a diversity of plant community types as possible, three sites, the Sunken Forest, the Wilderness Area between Watch Hill and Smith Point, and the Lighthouse area west of Kismet, were used. These sites represent a series of successional phases in the development of barrier island vegetation from open swale-dune scrub, to pitch pine savannah, to holly-sassafras- shadbush maritime forest. Maritime forest variation ranging from sites on the lee of the secondary dune to the margins of forest swamps were also sampled.

A total of 14 10x10m plots were used in this study: 6 were selected from the existing permanent plots in the western portion of the Sunken Forest, 4 newly constructed 100m2 plots each in the lighthouse and wilderness areas. In each of the locations, plots were selected in matched pairs to represent similar composition, structure, apparent browsing intensity, and site conditions so that one of the pair could serve as the experimental exclosed plot and the other plot as the control (Table 8). The designation of exclosed or control status was made by random draw.

The initial vegetational inventories were conducted in early August, 1986. The corners of each 10x10m plot was marked in the field using 2.5' lengths of iron bar which was painted orange. The corners were numbered 1 to 4 in a counter clockwise fashion from corner 1 in the southeast corner of the plot. The post in corner 1 was fitted with a yellow plastic cap with the plot number engraved.

Table 8. Deer Study Plot Characteristics

Control	Exclosure	Location	Conditions
Plot 50 [W3]	Plot 51 [W4]	Wilderness Area	Young swale-dune scrub
Plot 44 [L1]	Plot 45 [L2]	Lighthouse (100 m NE)	Young swale scrub
Plot 46 [L3]	Plot 47 [L4]	Lighthouse (650 m E)	Mature swale scrub
Plot 48 [W1]	Plot 49 [W2]	Wilderness Area	Pitch pine savannah
Plot 3	Plot 19	Sunken Forest	Forest lee of the 2° dune
Plot 22	Plot 20	Sunken Forest	Damp maritime forest
Plot 24	Plot 21	Sunken Forest	Mature maritime forest

The census of vegetation generally followed the methods of Art (1976). The tree layer was inventoried by measuring diameters at brest height of every woody stem. The entire shrub layer was censused by measuring basal diameters and heights of each individual. A total of 7 1x1m herb plots were used to estimate the cover of all plants <1.0m high and determine the density of woody seedlings and lianas. Four of these plots (1,2,3, & 4) were located in the corners of the 100m2 plot and 3 additional plots (plots 5,6,7) for sampling the herb layer were located by random draw. The herb plots were marked with yellow plastic tent pegs placed in the SE corner of the plot. The row and column locations of herb plots 5 - 7 for each of the study plots are given in Appendix C.

Immediately after the vegetation was sampled in 1986, deer exclosures were carefully constructed around each designated experimental plot. These exclosures were approximately 13x13 meters

providing a buffer of 1.5 meters around the 10x10m plot inside. The exclosures were constructed using 8 pressure-treated 4x4" posts that were trimmed to 8' high after they had been set into the ground. An 8' high fence was attached to the posts using galvanized steel fencing with 3"x6" mesh. The bottom of the fence was set as close to the ground as possible, but 6x6" entry holes were cut to allow rabbits access to the exclosure. Locking doors were cut into the fencing to allow easier research acess in the future.

Each plot was photographed from each of the 4 corners, using a 35mm camera with a 35mm lens. The orientation of the photograph was diagonally across the plot, e.g. from corner 1 toward corner 3, with the camera held at approximately 5.5' above the ground. The set of photographs from 1987 is contained in Appendix D.

The vegetation in both the exclosures and the control plots was inventoried and photographed again in late July to early August, 1987 using the same techniques with the addition that all of the shrubs were tagged using oval aluminum tags affixed with plastic lock-strips and the crown diameters were measured to the nearest centimeter.

Results & Discussion

Full data from 1986 and 1987 inventories of exprimental and control plots are contained in Appendix C. Summary data for trees, shrubs and herbs are contained in Tables 9 - 16. The first year changes are most easily seen in the summary Table 17 which aggregates the data by various strata, contrasting plots in the Sunken Forest with those of open swale habitats.

Table 9 F.I.N.S. DEER STUDY - TREE DENSITY (100m-2)

SPECIES	DENSITY	S.D.	S.E.	R.S.E.
1986 DATA -CONTROLS				
Ilex opaca	5.71	7.27	1.25	0.22
Sassafras albidum	1.29	1.70	0.29	0.23
Amelanchier canadensis	6.14	10.14	1.74	0.28
Quercus velutina	0.14	0.38	0.06	0.45
Vaccinium corymbosum	2.43	6.43	1.10	0.45
Pinus rigida	0.86	2.27	0.39	0.45
Juniperus virginiana	0.14	0.38	0.06	0.45
Rhus copallina	0.14	0.38	0.06	0.45
Pyrus arbutifolia	0.14	0.38	0.06	0.45
Rhododendron viscosum	1.00	2.65	0.45	0.45
TOTAL MEAN	18.00	24.46	4.19	0.23
1987 DATA - CONTROLS				
Ilex opaca	5.71	7.27	1.25	0.22
Sassafras albidum	1.29	1.70	0.29	0.23
Amelanchier canadensis	5.43	7.91	1.36	0.25
Quercus velutina	0.14	0.38	0.06	0.45
Vaccinium corymbosum	1.71	4.54	0.78	0.45
Pinus rigida	0.86	2.27	0.39	0.45
Juniperus virginiana	1.29	3.40	0.58	0.45
Prunus serotina	0.14	0.38	0.06	0.45
MEAN TOTAL	15.57	17.50	3.00	0.18
1986 DATA - EXCLOSURES				
Ilex opaca	3.57	8.58	1.47	0.41
Sassafras albidum	1.71	2.36	0.40	0.24
Amelanchier canadensis	7.00	12.12	2.08	0.30
Nyssa sylvatica	0.86	1.86	0.32	0.37
Vaccinium corymbosum	2.00	3.61	0.62	0.31
Pinus rigida	0.71	1.50	0.26	0.36
Juniperus virginiana	0.14	0.38	0.06	0.45
Prunus serotina	0.43	1.13	0.19	0.45
Pyrus arbutifolia	0.29	0.76	0.13	0.45
Acer rubrum	2.00	5.29	0.91	0.45
MEAN TOTAL	18.71	23.65	4.06	0.22
1987 DATA - EXCLOSURES				
Ilex opaca	3.29	8.26	1.42	0.43
Sassafras albidum	1.57	1.99	0.34	0.22
Amelanchier canadensis	7.86	13.13	2.25	0.29
Nyssa sylvatica	0.86	1.86	0.32	0.37
Vaccinium corymbosum	1.86	4.10	0.70	0.38
Pinus rigida	0.71	1.50	0.26	0.36
Juniperus virginiana	0.14	0.38	0.06	0.45
Prunus serotina	0.43	1.13	0.19	0.45
Pyrus arbutifolia	0.14	0.38	0.06	0.45
Acer rubrum	2.00	5.29	0.91	0.45
MEAN TOTAL	18.85	23.31	4.00	0.21

Table 10. F.I.N.S. DEER STUDY - TREE BASAL AREA (cm2 100m-2)

SPECIES	BASAL AREA	S.D.	S.E.	R.S.E.
1986 DATA - CONTROLS				
Ilex opaca	802.0	1025.75	175.91	0.22
Sassafras albidum	209.4	311.46	53.41	0.26
Amelanchier canadensis	452.7	663.97	113.87	0.25
Quercus velutina	24.6	65.02	11.15	0.45
Vaccinium corymbosum	35.4	93.54	16.04	0.45
Pinus rigida	187.4	495.88	85.04	0.45
Juniperus virginiana	1.1	2.85	0.49	0.45
Rhus copallina	11.7	30.88	5.30	0.45
Pyrus arbutifolia	1.7	4.52	0.77	0.45
Rhododendron viscosum	11.6	30.75	5.27	0.45
MEAN TOTAL	1737.5	1869.67	320.64	0.18
1987 DATA - CONTROLS				
Ilex opaca	770.2	979.12	167.92	0.22
Sassafras albidum	213.6	319.86	54.86	0.26
Amelanchier canadensis	589.0	761.58	130.61	0.22
Quercus velutina	23.9	63.28	10.85	0.45
Vaccinium corymbosum	27.3	72.19	12.38	0.45
Pinus rigida	202.3	535.26	91.80	0.45
Juniperus virginiana	20.4	53.96	9.25	0.45
Prunus serotina	2.3	6.01	1.03	0.45
MEAN TOTAL	1849.0	1904.18	326.56	0.18
1986 DATA -EXCLOSURES				
Ilex opaca	398.6	953.31	163.49	0.41
Sassafras albidum	233.5	357.38	61.29	0.26
Amelanchier canadensis	300.0	502.67	86.21	0.29
Nyssa sylvatica	195.3	413.60	70.93	0.36
Vaccinium corymbosum	21.9	37.87	6.49	0.30
Pinus rigida	145.9	381.35	65.40	0.45
Juniperus virginiana	1.1	2.85	0.49	0.45
Prunus serotina	15.3	40.54	6.95	0.45
Pyrus arbutifolia	2.7	7.07	1.21	0.45
Acer rubrum	109.8	290.53	49.83	0.45
MEAN TOTAL	1424.0	1498.11	256.92	0.18
1987 DATA - EXCLOSURES				
Ilex opaca	397.8	961.60	164.91	0.41
Sassafras albidum	215.0	325.21	55.77	0.26
Amelanchier canadensis	326.2	536.21	91.96	0.28
Nyssa sylvatica	204.9	420.12	72.05	0.35
Vaccinium corymbosum	19.5	38.58	6.62	0.34
Pinus rigida	146.3	381.24	65.38	0.45
Juniperus virginiana	1.5	3.85	0.66	0.45
Prunus serotina	17.1	45.31	7.77	0.45
Pyrus arbutifolia	1.3	3.43	0.59	0.45
Acer rubrum	97.8	258.82	44.39	0.45
MEAN TOTAL	1427.4	1504.95	258.09	0.18

Table 11. F.I.N.S. DEER STUDY - SHRUB DENSITY per 100m2 (.01ha)

SPECIES	DENSITY	S.D.	S.E.	R.S.E.
1986 DATA - CONTROLS				
Ilex opaca	0.29	0.49	0.08	0.29
Amelanchier canadensis	0.57	1.51	0.26	0.45
Vaccinium corymbosum	19.14	44.16	7.57	0.40
Juniperus virginiana	1.86	4.10	0.70	0.38
Prunus serotina	0.14	0.38	0.06	0.45
Rhus copallina	0.14	0.38	0.06	0.45
Pyrus arbutifolia	4.43	11.28	1.93	0.44
Rhododendron viscosum	1.14	3.02	0.52	0.45
Ilex glabra	14.14	36.11	6.19	0.44
Myrica pensylvanica	0.14	0.38	0.06	0.45
MEAN TOTAL	42.00	95.68	16.41	0.39
1987 DATA - CONTROLS				
Ilex opaca	0.14	0.38	0.06	0.45
Amelanchier canadensis	0.57	1.51	0.26	0.45
Vaccinium corymbosum	16.71	39.46	6.77	0.40
Juniperus virginiana	2.14	4.41	0.76	0.35
Rhus copallina	0.14	0.38	0.06	0.45
Pyrus arbutifolia	3.86	9.77	1.68	0.43
Rhododendron viscosum	1.29	3.40	0.58	0.45
Rhus radicans	0.43	0.79	0.13	0.31
Ilex glabra	9.71	24.40	4.19	0.43
Quercus coccinea	0.14	0.38	0.06	0.45
Myrica pensylvanica	0.29	0.49	0.08	0.29
MEAN TOTAL	35.57	79.50	13.63	0.38
1986 DATA - EXCLOSURES				
Ilex opaca	0.14	0.38	0.06	0.45
Amelanchier canadensis	2.57	4.72	0.81	0.31
Vaccinium corymbosum	17.29	33.68	5.78	0.33
Juniperus virginiana	0.29	0.76	0.13	0.45
Pyrus arbutifolia	3.00	4.73	0.81	0.27
Rhus radicans	0.57	1.51	0.26	0.45
Ilex glabra	0.43	1.13	0.19	0.45
Myrica pensylvanica	0.71	1.89	0.32	0.45
Acer rubrum	0.14	0.38	0.06	0.45
Lyonia mariana	0.14	0.38	0.06	0.45
MEAN TOTAL	25.29	39.39	6.75	0.27
1987 DATA - EXCLOSURES				
Amelanchier canadensis	1.86	3.18	0.55	0.29
Vaccinium corymbosum	16.86	37.37	6.41	0.38
Pinus rigida	0.14	0.38	0.06	0.45
Juniperus virginiana	0.71	0.95	0.16	0.23
Rhus copallina	0.14	0.38	0.06	0.45
Pyrus arbutifolia	3.43	5.47	0.94	0.27
Rhododendron viscosum	0.43	1.13	0.19	0.45
Rhus radicans	1.43	3.36	0.58	0.40
Ilex glabra	0.43	1.13	0.19	0.45
Myrica pensylvanica	0.71	1.89	0.32	0.45
Lyonia mariana	0.29	0.76	0.13	0.45
MEAN TOTAL	26.43	45.65	7.83	0.30

Table 12. F.I.N.S. DEER STUDY - SHRUB BASAL AREA cm2 per 100m2 (.01ha)

SPECIES	BASAL AREA	S.D.	S.E.	R.S.E.
1986 DATA - CONTROLS				
Ilex opaca	4.42	8.68	1.49	0.34
Amelanchier canadensis	5.57	14.74	2.53	0.45
Vaccinium corymbosum	88.45	198.22	33.99	0.38
Juniperus virginiana	22.08	48.02	8.24	0.37
Prunus serotina	3.03	8.03	1.38	0.45
Rhus copallina	0.36	0.96	0.16	0.45
Pyrus arbutifolia	7.95	17.74	3.04	0.38
Rhododendron viscosum	8.60	22.76	3.90	0.45
Ilex glabra	64.00	158.17	27.13	0.42
Myrica pensylvanica	2.48	6.56	1.12	0.45
MEAN TOTAL	206.95	425.37	72.90	0.35
1987 DATA - CONTROLS				
Ilex opaca	4.60	12.16	2.09	0.45
Amelanchier canadensis	4.12	10.91	1.87	0.45
Vaccinium corymbosum	137.89	324.84	55.71	0.40
Juniperus virginiana	28.18	59.51	10.21	0.36
Rhus copallina	0.36	0.96	0.16	0.45
Pyrus arbutifolia	7.48	16.34	2.80	0.37
Rhododendron viscosum	14.51	38.38	6.58	0.45
Rhus radicans	0.49	0.95	0.16	0.33
Ilex glabra	56.79	138.91	23.82	0.42
Quercus coccinea	0.36	0.96	0.16	0.45
Myrica pensylvanica	1.07	2.16	0.37	0.35
MEAN TOTAL	255.84	551.29	94.54	0.37
1986 DATA - EXCLOSURES				
Ilex opaca	2.69	7.13	1.22	0.45
Amelanchier canadensis	23.17	44.26	7.59	0.33
Vaccinium corymbosum	105.13	148.19	25.41	0.24
Juniperus virginiana	3.92	10.37	1.78	0.45
Pyrus arbutifolia	14.13	24.36	4.18	0.30
Rhus radicans	0.65	1.72	0.29	0.45
Ilex glabra	1.49	3.94	0.68	0.45
Myrica pensylvanica	4.81	12.73	2.18	0.45
Acer rubrum	1.01	2.67	0.46	0.45
Lyonia mariana	0.25	0.67	0.11	0.45
MEAN TOTAL	157.25	163.71	28.07	0.18
1987 DATA - EXCLOSURES				
Amelanchier canadensis	18.53	31.64	5.43	0.29
Vaccinium corymbosum	152.69	282.02	48.37	0.32
Pinus rigida	1.71	4.52	0.77	0.45
Juniperus virginiana	4.84	8.05	1.38	0.28
Rhus copallina	0.16	0.43	0.07	0.45
Pyrus arbutifolia	13.55	23.91	4.10	0.30
Rhododendron viscosum	8.35	22.09	3.79	0.45
Rhus radicans	0.99	2.36	0.40	0.41
Ilex glabra	1.69	4.47	0.77	0.45
Myrica pensylvanica	4.36	11.54	1.98	0.45
Lyonia mariana	0.38	1.01	0.17	0.45
MEAN TOTAL	207.26	288.57	49.49	0.24

Table 13 F.I.N.S. DEER STUDY - SHRUB HEIGHT (meters)

SPECIES	HEIGHT	S.D.	S.E.	R.S.E.
1986 DATA - CONTROLS				
Ilex opaca	1.85	2.28	0.39	0.42
Amelanchier canadensis	4.40	2.20	0.38	0.34
Vaccinium corymbosum	1.41	0.30	0.05	4.84
Juniperus virginiana	1.54	0.61	0.10	0.88
Prunus serotina	3.20	0.00	0.00	0.00
Rhus copallina	1.50	0.00	0.00	0.00
Pyrus arbutifolia	1.51	1.12	0.19	3.95
Rhododendron viscosum	4.49	1.59	0.27	0.49
Ilex glabra	1.69	0.23	0.04	2.36
Myrica pensylvanica	1.20	0.00	0.00	0.00
MEAN TOTAL	1.65	1.63	0.28	0.00
1987 DATA - CONTROLS				
Ilex opaca	1.90	0.00	0.00	0.00
Amelanchier canadensis	4.15	2.07	0.36	0.34
Vaccinium corymbosum	1.41	0.29	0.05	4.06
Juniperus virginiana	1.51	0.64	0.11	1.09
Rhus copallina	0.10	0.00	0.00	0.00
Pyrus arbutifolia	1.47	1.11	0.19	3.49
Rhododendron viscosum	4.22	1.41	0.24	0.51
Rhus radicans	1.20	1.10	0.19	0.47
Ilex glabra	1.44	0.29	0.05	2.32
Quercus coccinea	1.70	0.00	0.00	0.00
Myrica pensylvanica	1.05	1.29	0.22	0.42
MEAN	1.56	1.54	0.26	0.00
1986 DATA - EXCLOSURES				
Ilex opaca	1.70	0.00	0.00	0.00
Amelanchier canadensis	3.97	1.32	0.23	1.03
Vaccinium corymbosum	1.66	0.38	0.06	4.74
Juniperus virginiana	1.55	1.10	0.19	0.24
Pyrus arbutifolia	2.44	1.22	0.21	1.80
Rhus radicans	1.10	0.55	0.09	0.34
Ilex glabra	2.07	1.19	0.20	0.30
Myrica pensylvanica	1.14	0.51	0.09	0.38
Acer rubrum	6.00	0.00	0.00	0.00
Lyonia mariana	1.10	0.00	0.00	0.00
MEAN	1.99	1.94	0.33	0.01
1987 DATA - EXCLOSURES				
Amelanchier canadensis	3.83	1.53	0.26	0.89
Vaccinium corymbosum	1.50	0.35	0.06	4.70
Pinus rigida	1.40	0.00	0.00	0.00
Juniperus virginiana	1.34	1.10	0.19	0.70
Rhus copallina	1.00	0.00	0.00	0.00
Pyrus arbutifolia	1.99	1.06	0.18	2.18
Rhododendron viscosum	4.00	2.31	0.40	0.30
Rhus radicans	1.17	0.50	0.09	0.74
Ilex glabra	2.20	1.27	0.22	0.30
Myrica pensylvanica	1.16	0.52	0.09	0.36
Lyonia mariana	1.05	0.74	0.13	0.24
MEAN	1.74	1.69	0.29	0.01

Table 14. F.I.N.S. DEER STUDY - HERB LAYER DENSITY per meter

SPECIES	DENSITY	S.D.	S.E.	R.S.E.
1986 DATA - CONTROLS				
Ilex opaca	1.000	1.3628	0.2337	0.23
Sassafras albidum	1.245	2.1487	0.3685	0.30
Amelanchier canadensis	4.612	5.9879	1.0269	0.22
Vaccinium corymbosum	0.571	1.4498	0.2486	0.44
Prunus serotina	0.980	1.5981	0.2741	0.28
Rhus copallina	0.184	0.2435	0.0418	0.23
Pyrus arbutifolia	0.776	1.1184	0.1918	0.25
Rhododendron viscosum	0.020	0.0540	0.0093	0.45
Rhus radicans	8.837	13.3109	2.2828	0.26
Ilex glabra	0.327	0.5637	0.0967	0.30
Gaylussacia baccata	0.429	0.7868	0.1349	0.31
Rosa carolina	1.429	2.7118	0.4651	0.33
Viburnum dentatum	0.041	0.1080	0.0185	0.45
Myrica pensylvanica	2.388	2.8136	0.4825	0.20
Parthenocissus quinquefolia	0.449	0.3443	0.0591	0.13
Trientalis borealis	0.041	0.1080	0.0185	0.45
Smilax glauca	0.694	1.5917	0.2730	0.39
Smilax rotundifolia	1.694	2.3012	0.3946	0.23
Rubus hispidus	2.673	4.7956	0.8224	0.31
Lyonia mariana	0.061	0.1620	0.0278	0.45
Rubus allegheniensis	0.490	1.1747	0.2015	0.41
Prunus maritima	0.408	1.0799	0.1852	0.45
MEAN	29.347	6.4580	1.1075	0.04
1987 DATA -CONTROLS				
Ilex opaca	1.694	2.4306	0.4168	0.25
Sassafras albidum	1.204	1.9827	0.3400	0.28
Amelanchier canadensis	4.653	6.2694	1.0752	0.23
Vaccinium corymbosum	0.816	2.0975	0.3597	0.44
Juniperus virginiana	0.041	0.1080	0.0185	0.45
Prunus serotina	1.102	1.6998	0.2915	0.26
Rhus copallina	0.143	0.1844	0.0316	0.22
Pyrus arbutifolia	0.918	1.8878	0.3237	0.35
Rhododendron viscosum	0.020	0.0540	0.0093	0.45
Rhus radicans	8.918	15.3888	2.6391	0.30
Ilex glabra	0.408	0.7163	0.1228	0.30
Gaylussacia baccata	0.388	0.7591	0.1302	0.34
Rosa carolina	1.224	2.4548	0.4210	0.34
Myrica pensylvanica	1.837	2.0277	0.3478	0.19
Parthenocissus quinquefolia	0.592	0.8388	0.1439	0.24
Vitis labrusca	0.020	0.0540	0.0093	0.45
Smilax glauca	0.041	0.0697	0.0120	0.29
Smilax rotundifolia	2.551	3.1530	0.5407	0.21
Rubus hispidus	2.673	4.3171	0.7404	0.28
Rubus allegheniensis	0.449	0.8976	0.1539	0.34
Prunus maritima	0.490	1.2959	0.2222	0.45
MEAN TOTAL	30.184	8.8120	1.5112	0.05

Table 14. F.I.N.S. DEER STUDY - HERB LAYER DENSITY per meter [Continued]

SPECIES	DENSITY	S.D.	S.E.	R.S.E.
1986 DATA - EXCLOSURES				
Ilex opaca	0.163	0.2788	0.0478	0.29
Sassafras albidum	0.347	0.7462	0.1280	0.37
Amelanchier canadensis	2.633	3.6718	0.6297	0.24
Nyssa sylvatica	0.490	0.9719	0.1667	0.34
Vaccinium corymbosum	0.020	0.0540	0.0093	0.45
Juniperus virginiana	0.020	0.0540	0.0093	0.45
Prunus serotina	0.245	0.3754	0.0644	0.26
Rhus copallina	0.041	0.1080	0.0185	0.45
Pyrus arbutifolia	0.551	0.7258	0.1245	0.23
Baccharis halimifolia	0.061	0.1620	0.0278	0.45
Rhus radicans	9.122	10.9341	1.8752	0.21
Gaylussacia baccata	0.367	0.6274	0.1076	0.29
Rosa carolina	0.347	0.6794	0.1165	0.34
Viburnum dentatum	0.082	0.2160	0.0370	0.45
Myrica pensylvanica	2.163	2.4515	0.4204	0.19
Parthenocissus quinquefolia	0.143	0.3194	0.0548	0.38
Smilax glauca	0.204	0.5399	0.0926	0.45
Smilax rotundifolia	1.204	2.1058	0.3611	0.30
Rubus hispidus	0.776	1.3347	0.2289	0.30
Rubus allegheniensis	0.163	0.4320	0.0741	0.45
Rosa rugosa	0.020	0.0540	0.0093	0.45
Prunus maritima	0.388	0.8027	0.1377	0.36
MEAN TOTAL	19.551	9.5737	1.6419	0.08
1987 DATA - EXCLOSURES				
Ilex opaca	0.633	0.9507	0.1630	0.26
Sassafras albidum	0.673	0.9784	0.1678	0.25
Amelanchier canadensis	4.816	7.1112	1.2196	0.25
Nyssa sylvatica	0.510	0.9824	0.1685	0.33
Vaccinium corymbosum	0.163	0.2908	0.0499	0.31
Juniperus virginiana	0.020	0.0540	0.0093	0.45
Prunus serotina	0.653	0.7905	0.1356	0.21
Rhus copallina	0.041	0.1080	0.0185	0.45
Pyrus arbutifolia	0.449	0.5620	0.0964	0.21
Rhus radicans	6.367	6.7637	1.1600	0.18
Gaylussacia baccata	0.327	0.6101	0.1046	0.32
Rosa carolina	0.347	0.9179	0.1574	0.45
Gaultheria procumbens	0.020	0.0540	0.0093	0.45
Myrica pensylvanica	1.367	1.6860	0.2891	0.21
Parthenocissus quinquefolia	0.490	0.5399	0.0926	0.19
Smilax glauca	0.306	0.5620	0.0964	0.31
Smilax rotundifolia	3.388	4.0091	0.6875	0.20
Rubus hispidus	0.571	1.0135	0.1738	0.30
Rubus allegheniensis	0.510	1.3499	0.2315	0.45
Rosa rugosa	0.204	0.5399	0.0926	0.45
Prunus maritima	0.143	0.3194	0.0548	0.38
MEAN TOTAL	22.000	10.5621	1.8114	0.08

Table 15. F.I.N.S. DEER STUDY - HERB COVER (%)

SPECIES	COVER	S.D.	S.E.	R.S.E.
1986 DATA - CONTROLS				
Ilex opaca	0.057	0.115	0.019	0.35
Sassafras albidum	0.433	0.743	0.127	0.29
Amelanchier canadensis	0.382	0.379	0.065	0.17
Vaccinium corymbosum	4.796	11.771	2.018	0.42
Prunus serotina	0.373	0.654	0.112	0.30
Rhus copallina	0.618	1.313	0.225	0.36
Pyrus arbutifolia	0.776	1.074	0.184	0.24
Rhododendron viscosum	0.002	0.005	0.000	0.45
Rhus radicans	11.608	17.897	3.069	0.26
Ilex glabra	0.186	0.339	0.058	0.31
Gaylussacia baccata	2.449	5.129	0.879	0.36
Rosa carolina	2.490	4.263	0.731	0.29
Viburnum dentatum	0.041	0.108	0.018	0.45
Pteridium aquilinum	0.020	0.054	0.009	0.45
Myrica pensylvanica	9.061	9.153	1.569	0.17
Parthenocissus quinquefolia	0.506	0.930	0.159	0.32
Smilacina stellata	0.022	0.059	0.010	0.45
Trientalis borealis	0.022	0.053	0.009	0.41
Smilax glauca	0.027	0.058	0.009	0.37
Smilax rotundifolia	0.067	0.078	0.013	0.20
Carex sp.	0.024	0.058	0.010	0.41
Vaccinium oxycoccus	0.390	0.698	0.119	0.31
Solidago odora	0.002	0.005	0.000	0.45
Rubus hispidus	6.939	12.280	2.106	0.30
Andropogon virginicus	0.614	1.625	0.278	0.45
Agrostis hyemalis	0.061	0.162	0.027	0.45
Carex swanii	0.510	1.349	0.231	0.45
Juncus canadensis	0.020	0.054	0.009	0.45
Lyonia mariana	0.041	0.108	0.018	0.45
Panicum virgatum	0.286	0.638	0.109	0.38
Juncus gerardii	0.061	0.112	0.019	0.31
Ammophila breviligulata	1.020	1.420	0.243	0.24
Panicum lanuginosum	0.841	2.212	0.379	0.45
Solidago tenuifolia	0.535	0.847	0.145	0.27
Rumex acetosella	0.184	0.337	0.057	0.31
Rubus allegheniensis	2.449	6.170	1.058	0.43
Achellia millefolia	0.104	0.275	0.047	0.45
Polygonella arctulata	0.027	0.070	0.012	0.45
Cyperus rotundus	0.124	0.329	0.056	0.45
Leechia maritima	0.163	0.372	0.063	0.39
Eupatorium hyssopifolium	0.020	0.054	0.009	0.45
Spartina patens	0.331	0.868	0.148	0.45
Prunus maritima	3.980	10.529	1.805	0.45
Hudsonia tomentosa	0.429	1.133	0.194	0.45
MEAN	53.092	41.558	7.127	0.13

Table 15. F.I.N.S. DEER STUDY - HERB COVER (%)
[Continued]

SPECIES	COVER	S.D.	S.E.	R.S.E.
1987 DATA -CONTROLS				
Ilex opaca	0.086	0.130	0.022	0.26
Sassafras albidum	0.280	0.486	0.083	0.30
Amelanchier canadensis	0.384	0.392	0.067	0.18
Vaccinium corymbosum	3.641	9.607	1.647	0.45
Juniperus virginiana	0.041	0.108	0.018	0.45
Prunus serotina	0.643	1.282	0.219	0.34
Rhus copallina	0.496	0.840	0.144	0.29
Pyrus arbutifolia	2.267	5.804	0.995	0.44
Rhododendron viscosum	0.002	0.005	0.000	0.45
Rhus radicans	12.271	21.031	3.606	0.29
Ilex glabra	0.227	0.480	0.082	0.36
Gaylussacia baccata	1.571	3.087	0.529	0.34
Rosa carolina	1.571	3.184	0.546	0.35
Pteridium aquilinum	0.061	0.162	0.027	0.45
Myrica pensylvanica	6.857	7.057	1.210	0.18
Parthenocissus quinquefolia	0.598	0.620	0.106	0.18
Smilacina stellata	0.002	0.005	0.000	0.45
Trientalis borealis	0.122	0.324	0.055	0.45
Vaccinium macrocarpon	0.371	0.638	0.109	0.29
Vitis labrusca	0.002	0.005	0.000	0.45
Smilax glauca	0.004	0.007	0.001	0.29
Smilax rotundifolia	0.990	2.213	0.379	0.38
Solidago odora	0.002	0.005	0.000	0.45
Rubus hispidus	7.490	12.682	2.175	0.29
Cyperus esculentus	0.102	0.270	0.046	0.45
Andropogon virginicus	0.367	0.971	0.166	0.45
Agrostis hyemalis	0.002	0.005	0.000	0.45
Carex swanii	1.655	4.310	0.739	0.45
Panicum virgatum	0.592	1.386	0.237	0.40
Juncus gerardii	1.020	1.699	0.291	0.29
Ammophila breviligulata	0.514	0.658	0.112	0.22
Panicum lanuginosum	0.371	0.970	0.166	0.45
Solidago tenuifolia	0.616	1.010	0.173	0.28
Rumex acetosella	0.102	0.270	0.046	0.45
Rubus alleghaniensis	2.000	4.230	0.725	0.36
Achellia millefolia	0.143	0.378	0.064	0.45
Polygonella arctulata	0.027	0.058	0.009	0.37
Leechia maritima	0.247	0.451	0.077	0.31
Carex silicea	0.020	0.054	0.009	0.45
Drosera rotundifolia	0.020	0.054	0.009	0.45
Eupatorium hyssopifolium	0.041	0.108	0.018	0.45
Panicum sp.	0.020	0.054	0.009	0.45
Prunus maritima	3.612	9.557	1.639	0.45
Hudsonia tomentosa	0.776	2.051	0.351	0.45
Cladonia rangerifera	0.002	0.005	0.000	0.45
MEAN	52.231	42.584	7.303	0.14

Table 15. F.I.N.S. DEER STUDY - HERB COVER (%)
[Continued]

SPECIES	COVER	S.D.	S.E.	R.S.E.
1986 DATA -EXCLOSURES				
Ilex opaca	0.010	0.017	0.003	0.30
Sassafras albidum	0.088	0.219	0.037	0.43
Amelanchier canadensis	0.320	0.490	0.084	0.26
Nyssa sylvatica	0.086	0.168	0.028	0.34
Vaccinium corymbosum	0.143	0.378	0.064	0.45
Juniperus virginiana	0.041	0.108	0.018	0.45
Prunus serotina	0.033	0.063	0.010	0.33
Rhus copallina	0.102	0.270	0.046	0.45
Pyrus arbutifolia	0.316	0.519	0.089	0.28
Baccharis halimifolia	0.020	0.054	0.009	0.45
Rhus radicans	10.047	12.120	2.078	0.21
Gaylussacia baccata	0.306	0.524	0.089	0.29
Rosa carolina	0.429	0.742	0.127	0.30
Viburnum dentatum	0.102	0.270	0.046	0.45
Hypericum virginicum	0.002	0.005	0.000	0.45
Myrica pensylvanica	6.714	6.549	1.123	0.17
Osmunda cinnamomea	0.163	0.432	0.074	0.45
Parthenocissus quinquefolia	0.306	0.692	0.118	0.39
Trientalis borealis	0.433	0.758	0.130	0.30
Smilax glauca	0.020	0.054	0.009	0.45
Smilax rotundifolia	0.041	0.085	0.014	0.36
Polygonum hydropiperoides	1.531	4.049	0.694	0.45
Vaccinium oxycoccus	0.592	1.565	0.268	0.45
Rubus hispidus	2.102	3.900	0.669	0.32
Cyperus esculentus	0.041	0.108	0.018	0.45
Andropogon virginicus	2.408	4.133	0.708	0.29
Carex swanii	0.922	2.142	0.367	0.40
Juncus canadensis	0.408	1.079	0.185	0.45
Lyonia mariana	0.041	0.108	0.018	0.45
Panicum virgatum	2.469	6.533	1.120	0.45
Rhynchospora capitellata	0.020	0.054	0.009	0.45
Juncus gerardii	0.204	0.307	0.052	0.26
Ammophila breviligulata	1.571	2.736	0.469	0.30
Panicum lanuginosum	0.124	0.223	0.038	0.31
Solidago tenuifolia	0.884	1.296	0.222	0.25
Rumex acetosella	0.267	0.523	0.089	0.34
Rubus allegheniensis	1.837	4.859	0.833	0.45
Rosa rugosa	0.082	0.216	0.037	0.45
Polygonella arctulata	0.004	0.007	0.001	0.29
Cyperus rotundus	0.124	0.323	0.055	0.45
Leechia maritima	0.002	0.005	0.000	0.45
Mentha?	0.002	0.005	0.000	0.45
Spartina patens	0.837	1.762	0.302	0.36
Panicum sp.	0.061	0.162	0.027	0.45
Prunus maritima	3.267	8.032	1.377	0.42
Hudsonia tomentosa	1.306	3.455	0.592	0.45
MEAN	40.831	32.437	5.563	0.14

Table 15. F.I.N.S. DEER STUDY - HERB COVER (%)
[Continued]

SPECIES	COVER	S.D.	S.E.	R.S.E.
1987 DATA -EXCLOSURES				
Ilex opaca	0.022	0.032	0.005	0.25
Sassafras albidum	0.478	0.722	0.124	0.26
Amelanchier canadensis	0.245	0.345	0.059	0.24
Nyssa sylvatica	0.306	0.597	0.102	0.33
Vaccinium corymbosum	1.127	2.967	0.509	0.45
Juniperus virginiana	0.408	1.079	0.185	0.45
Prunus serotina	0.084	0.127	0.021	0.26
Rhus copallina	0.102	0.270	0.046	0.45
Pyrus arbutifolia	0.353	0.626	0.107	0.30
Rhus radicans	10.457	12.392	2.125	0.20
Gaylussacia baccata	0.449	0.834	0.143	0.32
Rosa carolina	0.327	0.863	0.148	0.45
Viburnum dentatum	0.306	0.809	0.138	0.45
Pteridium aquilinum	0.041	0.108	0.018	0.45
Gaultheria procumbens	0.102	0.270	0.046	0.45
Hypericum virginicum	0.102	0.270	0.046	0.45
Myrica pensylvanica	5.594	5.499	0.943	0.17
Osmunda cinnamomea	0.143	0.378	0.064	0.45
Parthenocissus quinquefolia	0.592	0.788	0.135	0.23
Trientalis borealis	0.612	1.102	0.189	0.31
Smilax glauca	0.694	1.356	0.232	0.34
Smilax rotundifolia	1.886	4.713	0.808	0.43
Carex sp.	0.002	0.005	0.000	0.45
Polygonum hydropiperoides	1.633	4.319	0.740	0.45
Vaccinium oxycoccus	0.084	0.221	0.038	0.45
Scirpus americana	0.002	0.005	0.000	0.45
Solidago odora	0.020	0.054	0.009	0.45
Rubus hispidus	1.041	1.798	0.308	0.30
Cyperus esculentus	0.122	0.266	0.045	0.37
Sphagnum spp.	0.041	0.108	0.018	0.45
Andropogon virginicus	2.347	4.055	0.695	0.30
Agrostis hyemalis	0.082	0.216	0.037	0.45
Carex swanii	1.510	3.749	0.643	0.43
Panicum virgatum	2.347	6.022	1.032	0.44
Rhynchospora capitellata	0.408	1.079	0.185	0.45
Juncus gerardii	0.490	0.708	0.121	0.25
Ammophila breviligulata	4.859	11.639	1.996	0.41
Panicum lanuginosum	0.410	0.740	0.126	0.31
Solidago tenuifolia	1.571	1.916	0.328	0.21
Rumex acetosella	0.429	0.947	0.162	0.38
Rubus allegheniensis	2.345	6.204	1.064	0.45
Rosa rugosa	0.082	0.216	0.037	0.45
Polygonella arctulata	0.027	0.053	0.009	0.35
Cyperus rotundus	0.022	0.059	0.010	0.45
Leechia maritima	0.167	0.269	0.046	0.28
Mentha?	0.020	0.054	0.009	0.45
Eupatorium hyssopifolium	0.041	0.108	0.018	0.45

Spartina patens	0.084	0.221	0.038	0.45
Panicum sp.	0.531	1.403	0.240	0.45
Prunus maritima	3.878	9.348	1.603	0.41
Hudsonia tomentosa	1.041	2.753	0.472	0.45
MEAN TOTAL	50.063	39.890	6.841	0.14

Table 16. F.I.N.S. DEER STUDY - LIANA DENSITY (m-2)

SPECIES	DENSITY	S.D.	S.E.	R.S.E.
1986 DATA - CONTROLS				
Rhus radicans	0.041	0.1080	0.0185	0.45
Parthenocissus quinquefolia	0.122	0.3240	0.0556	0.45
Smilax glauca	0.184	0.3754	0.0644	0.35
Smilax rotundifolia	0.959	1.5773	0.2705	0.28
TOTAL MEAN	1.306	1.7813	0.3055	0.23
1987 DATA - CONTROLS				
Rhus radicans	0.020	0.0540	0.0093	0.45
Smilax glauca	0.041	0.1080	0.0185	0.45
Smilax rotundifolia	0.551	0.9419	0.1615	0.29
MEAN TOTAL	0.612	1.0489	0.1700	0.29
1986 DATA - EXCLOSURES				
Rhus radicans	0.020	0.0540	0.0093	0.45
Parthenocissus quinquefolia	0.020	0.0540	0.0093	0.45
Smilax glauca	0.306	0.5972	0.1024	0.33
Smilax rotundifolia	1.388	2.7979	0.4798	0.35
MEAN TOTAL	1.735	3.3324	0.5715	0.33
1987 DATA - EXCLOSURES				
Smilax glauca	0.102	0.1590	0.0273	0.27
Smilax rotundifolia	0.367	0.6487	0.1112	0.30
MEAN TOTAL 0.469	0.7410	0.1271	0.27	

Table 17

FIRE ISLAND DEER IMPACTS

	CONTROL (Deer)		EXCLOSURES (No Deer)	
	1986	1987	1986	1987
TREES				
DENSITY				
FOREST	39.7 →	33.7	41.7 →	42.0
OPEN	1.8 →	3.8	1.5 →	1.5
MEAN	18.0 →	16.6	18.7 →	18.8
BASAL AREA				
FOREST	3614 →	3795	2980 →	2986
OPEN	330 →	390	257 →	259
MEAN	1737 →	1849	1424 →	1427
SHRUBS				
DENSITY				
FOREST	9.3 →	7.6	20.0 →	15.0
OPEN	66.5 →	56.5	29.2 →	35.0
MEAN	42.0 →	35.6	25.3 →	26.4
BASAL AREA				
FOREST	76 →	78	206 →	196
OPEN	294 →	391	120 →	215
MEAN	207 →	256	157 →	207
HEIGHT				
FOREST	3.24 →	3.55	3.28 →	3.12
OPEN	1.50 →	1.38	1.31 →	1.29
MEAN	1.65 →	1.56	2.00 →	1.74
HERBS				
DENSITY				
FOREST	27.2 →	28.5	14.2 →	25.9
OPEN	30.8 →	31.4	23.6 →	19.1
MEAN	29.3 →	30.2	19.6 →	22.0
COVER				
FOREST	9.7 →	8.2	7.1 →	10.6
Trientalis	0.003 →	0.000	0.43 →	1.14
OPEN	85.6 →	85.2	66.2 →	79.7
MEAN	53.1 →	52.7	40.8 →	50.1

As was expected, there is relatively little evidence for differences in the changes in the tree layer between the control and the exclosure plots in a period as short as 12 months(Tables 9, 10, 17). The reduction of tree density in the control plots in the Sunken Forest are undoubtedly related to residual hurricane mortality rather than in impact of deer. All of the habitats and treatments showed increases in basal area between 1986 and 1987, indicating net growth, regardless of the presence or absence of deer browsing.

There were some unexpected changes in the shrub layer over the first season of the experiment (Tables 11, 12, 13, 17). The density of shrubs in the control plots and those in the Sunken Forest decreased, while shrub density in exclosed plots in open habitats increased. There were increases in the basal areas of all groups of shrubs except for the exclosed plots in the Sunken Forest. Most striking is the decrease in shrub height in all the plots except the Forest controls. The decreases in height do not appear to be simply an artifact of the recruitment of younger, small shrubs from the herb layer since they are coupled with decreases in shrub density. Now that individual shrubs have been given identification numbers, we will be able to follow the changes in height of individual stems to determine the nature of these fluctions in height if they continue in the future.

Photographic evidence clearly indicates that the shrubs in exclosed plots in the Forest are responding positively to being free from deer browsing pressures. Amelanchier, Sassafras and Pyrus arbutifolia have vigorous new inside exclosures in contrast to woody seedlings not so protected from deer (Figures 10 -13).

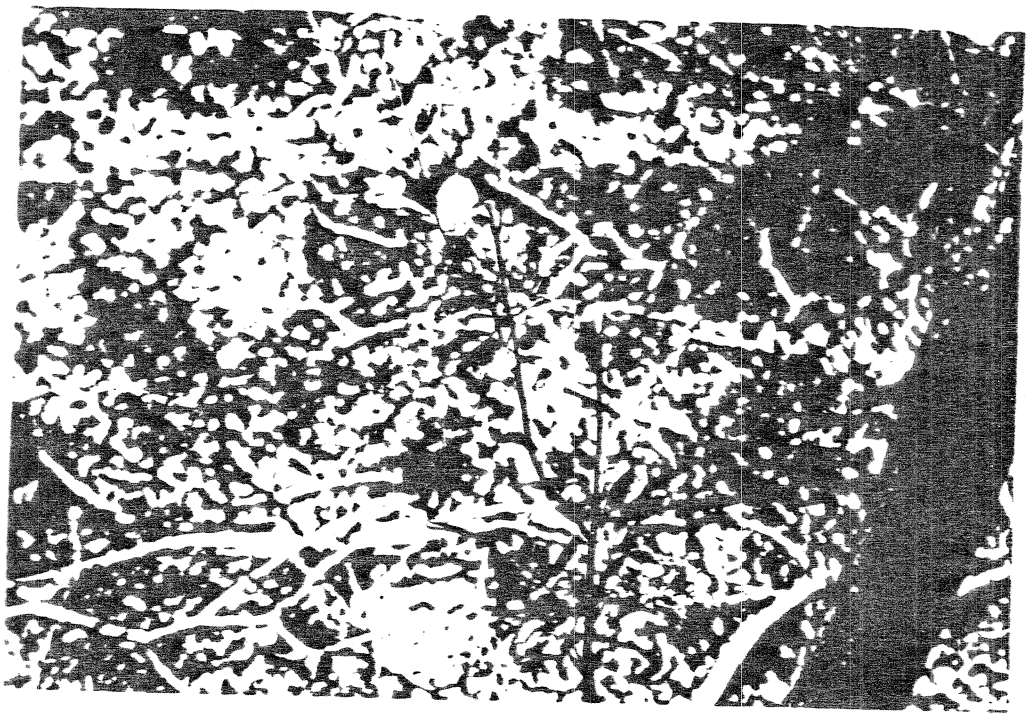


Figure 11a. Nearly 30cm extension growth of Amelanchier in the Plot 20 exclosure. Note the past browsing injury on the twig.

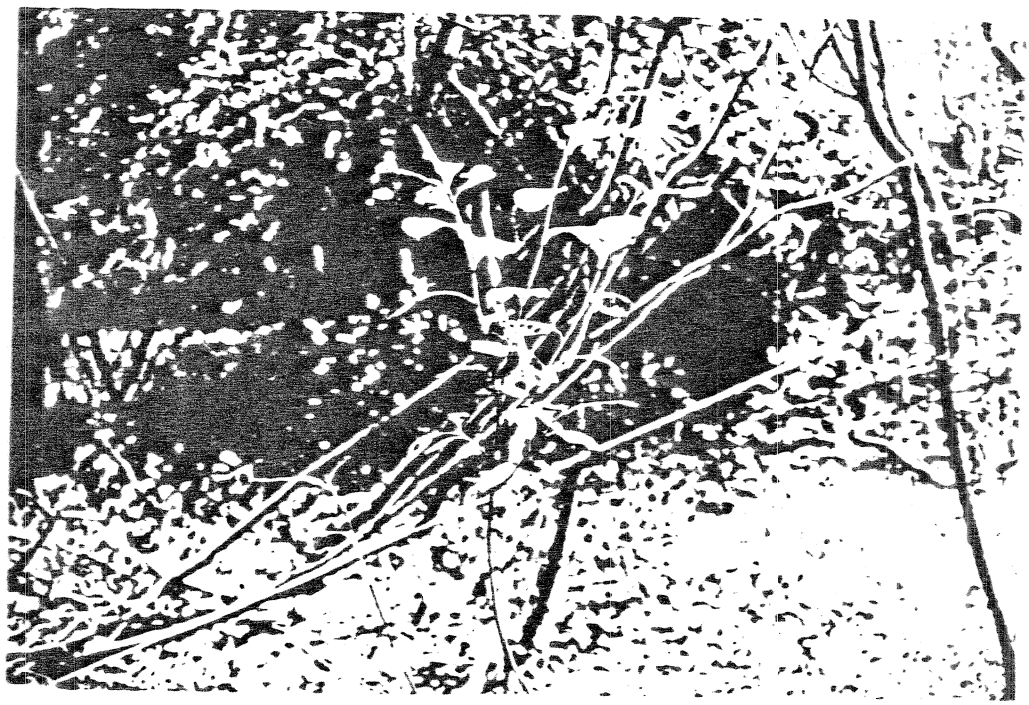


Figure 11b. Pyrus arbutifolia current growth of more than 30 cm in the Plot 20 exclosure, Sunken Forest. Note fruits at the center of the new growth.



Figure 12a. Deer browse impact on Ilex glabra near Plot 34 in the Sunken Forest.



Figure 12b. Typical deer browse of Sassafras root sprouts in control Plot 3 of the Sunken Forest.



Figure 17a. Prunus serotina seedling browsed by deer in control Plot 3, Sunken Forest. Note bunchy habit.



Figure 17b. Deer browse line on Juniperus virginiana on the south face of the secondary dune in the vicinity of Plot 7.

As was expected the greatest changes in the first year of the experiment were seen in the herbaceous layer (Tables 14, 15, 17). The density of woody seedlings remained relatively constant in the control plots, both in the forest and in open habitats. In the forest exclosures, mean seedling density nearly doubled from 14.2 to 25.9 m-2 in the first growing season. The seedling density in exclosed open plots, however, had a slight decrease (23.6 to 19.1 m-2) which accompanied their concomitant increase in herbaceous cover from 66.2% to 79.7%. The herbaceous cover in the forest exclosures increased by about half, from 7.1% to 10.6%. The relative increase (265%) of Trientalis borealis an herbaceous perennial in forest exclosures was impressive. It is probable that if there had been residual populations of Aralia, Smilacina, and Maianthemum that they would have likewise increased. Non-exclosed, control plots, on the other hand either remained at the same level of cover or decreased. Trientalis had been present in forest control plots in 1986 but was not seen in 1987.

Conclusion

While a single year is too short a time period for massive differences between control and exclosed plots to develop, there are clear indications that the differences are likely to be dramatic in the intermediate future. While some of the changes, such as tree and shrub mortality in the Sunken Forest plots, are probably residual effects of Hurricane Gloria, other changes, such as the flourishing of the herb layer and enhanced extension growth of woody plants in forest exclosures give a clear indication that deer play a primary role in limiting the growth of plants in the lowest strata in the Forest.

entrances, removing the lateral bayside connector in favor of a more interior route, and most recently (Summer, autumn 1987) removing most of the boardwalking south of the east secondary dune cut in favor of a new leeward route which will keep pedestrian traffic even further away from the windward face and crest of the secondary dune.

This study was undertaken in August, 1987, in order to determine the impacts of the boardwalk and the residual relict trails that are periodically used by visitors who wander off the boardwalks. These old trails are also used by deer as they move through the forest. Regardless of their use by deer or humans, the "dirt" trails represent sites of chronic disturbance where light is more abundant, plant competition is reduced, but the hazards of being trampled are omnipresent.

Methods

The object of the study was to determine how the vegetation varied with proximity to the boardwalk and to the old "dirt" trails clandestinely used by some visitors. After a reconnaissance of the Sunken Forest boardwalk with Naturalist/Ranger Beth Fulsom, 12 residual trails were selected for analysis (Figure 14).

A 10m transect was then laid down the center of the trail as it left the boardwalk and plots were laid out pupendicular to the trail at 0, 2, 5, and 10m from the boardwalk (Figure 15). Where the trail bent at an angle, the center line of the trail was used as the primary axis for the distance from the boardwalk and the secondary axis was kept at right angles to the trail in order to assess the variation in vegetation with distance from the center of the trail. Along the

secondary axes, plots were laid out at the trail center line, at 1.5 and at 3.0 meters on either side of the center line. Where one of the plots fell in a secondary 'dirt' trail, the data collected in it was grouped with the plot at the center of the primary trail for analysis of variation of vegetation with trail distance.

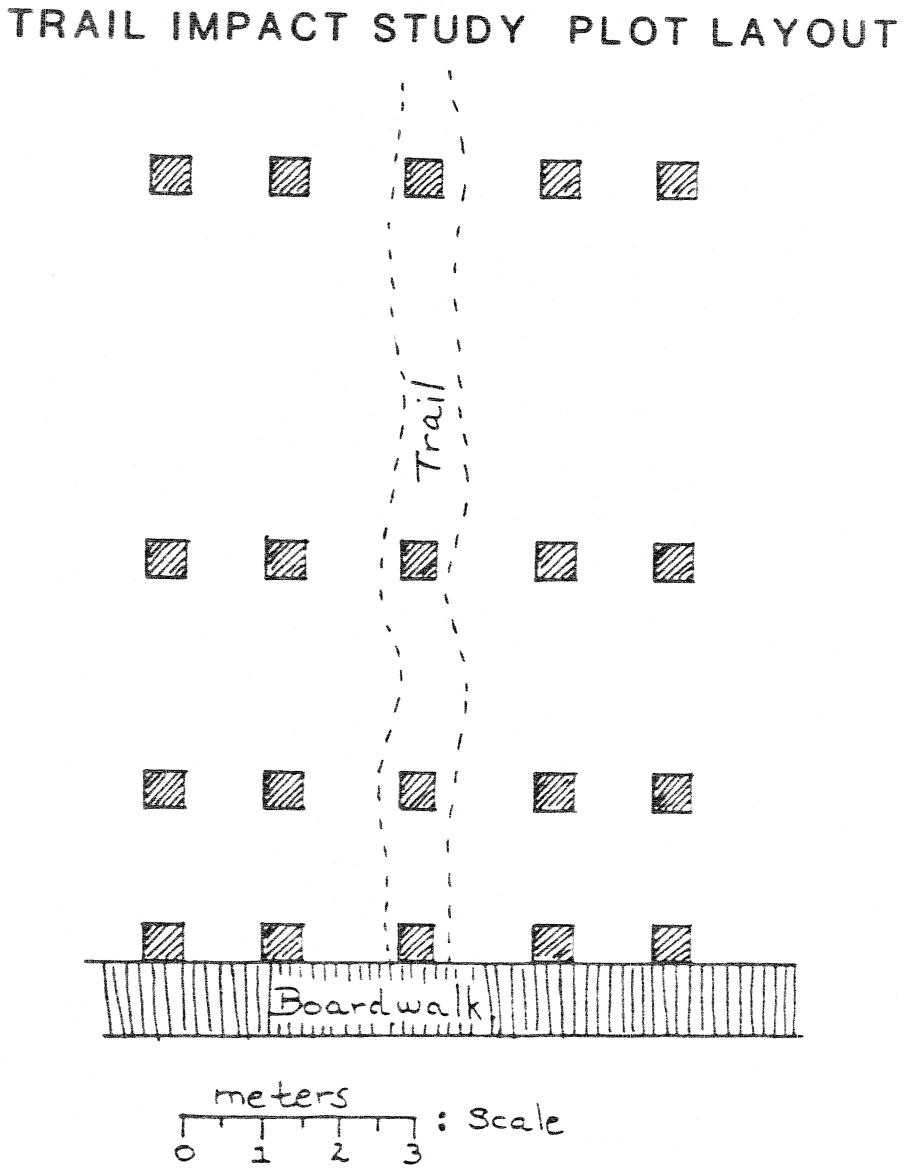
A total of 20 0.25m2 plots (0.5x0.5m) were used for each residual trail grid. The position of plots along the boardwalk were marked with aluminum circular tags and the 2, 5, and 10 meter secondary transects were marked with plastic tent pegs or wooden stakes.

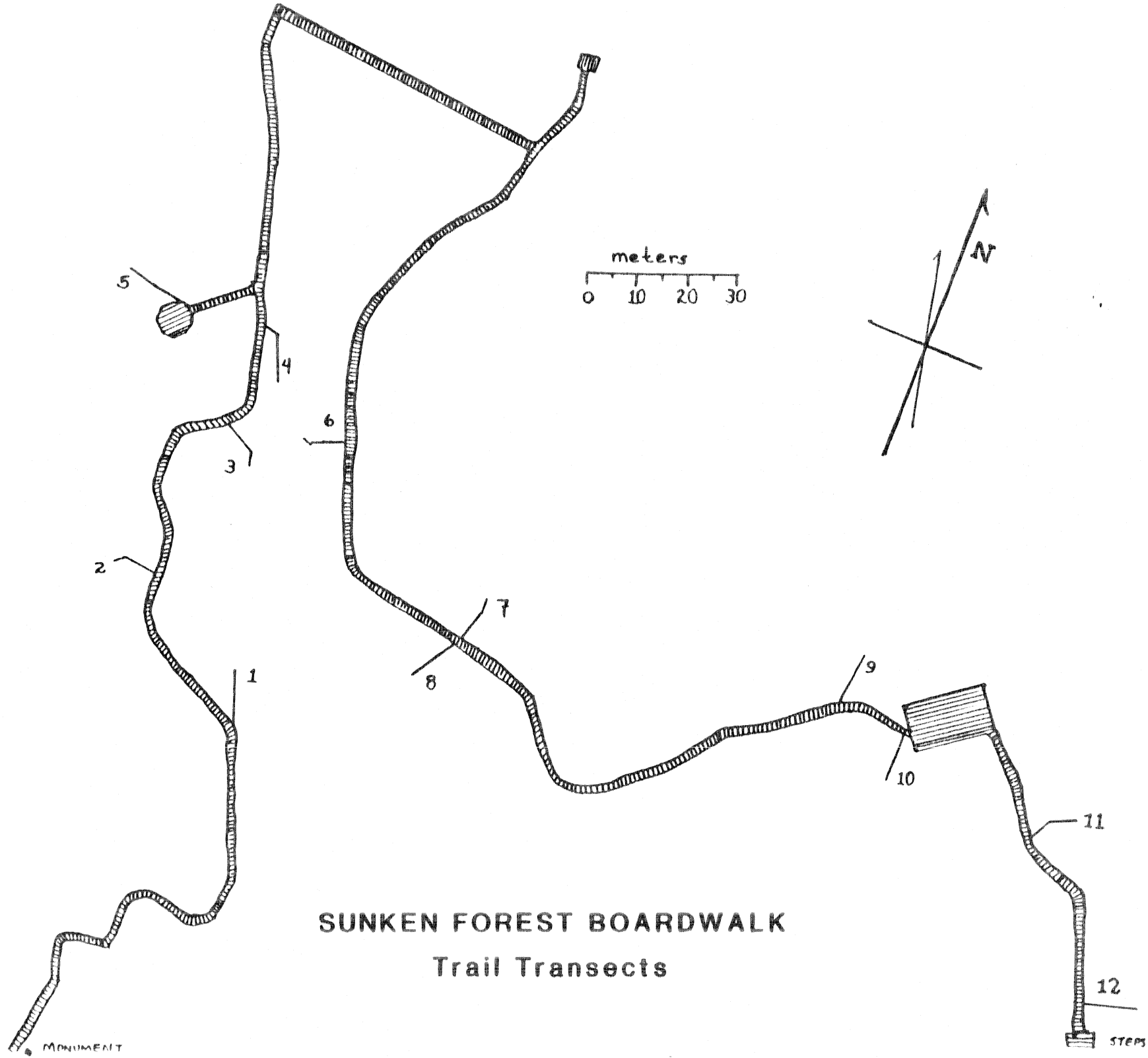
The cover of herbaceous vegetation (<1.0 m) and the density of woody seedlings was recorded for each plot in the resulting grid. Additionally, the density of various lianas was recorded and the degree to which Smilax covered over the plot was given a ranking. I developed a "Smilax abundance" rating for each plot based on a combination of Smilax denisty and draping by stems rooted outside the plot:

Smilax Abundance Rating	Density (m-2) or Amount of Draping
0	0
1	1-8
2	9-12
3	13-16
4	16 - loose tangle
5	Massive tangle

In the presentation of data in Appendix E and Figure 18. Smilax abundance classes 3 and 4 have been combined because there were 5 or fewer of the 240 plots in each of those classes.

Figure 15.


TRAIL IMPACT STUDY PLOT LAYOUT
Trail
Boardwalk
meters
0 1 2 3
: Scale



SUNKEN FOREST BOARDWALK

Trail Transects

Figure 14

Results and Discussion

Tabular data from this study is contained in Appendix E. The impacts of the boardwalk and trails, however is most clearly seen in Figures 16, 17, and 18. In these figures the mean values for seedling density or herb layer cover for all 240 plots are given as grey bands indicating the ranges of standard errors.

The data suggest that the boardwalk itself (other than providing a local environment of increased illumination) does not have much of an adverse effect on the herbaceous layer (Figure 16). Typically, there is either equal seedling density adjacent to the boardwalk and 10m distant, or, as in the case of Sassafras decreasing seedling density with increasing distance. Herbaceous cover patterns showed no stastically significant relationship relative to the boardwalk, although I have noted in parts of the Sunken Forest, where deer appear to avoid the boardwalk, there are sections of boardwalk with high herbaceous perennial cover (Art, 1987).

The old trails emminating from the boardwalk, however, have a distinctly different pattern. It is not really surprising to find that little grows in the middle of a trail, but the impacts of a trail appear to be visible several meters distant from its center (Figure 17). Both the total seedling density and herbaceous cover show a significant pattern of increasing value with increasing distance from the trail center line. Most individual species show the same trends (Appendix E). It is likely that if the secondary transects had been extended for more than 3 meters either side of the trail center line that even higher density and cover values would have been found.

As noted in Chapters 1 and 2 of this report and in Art, 1987,

Figure 16.

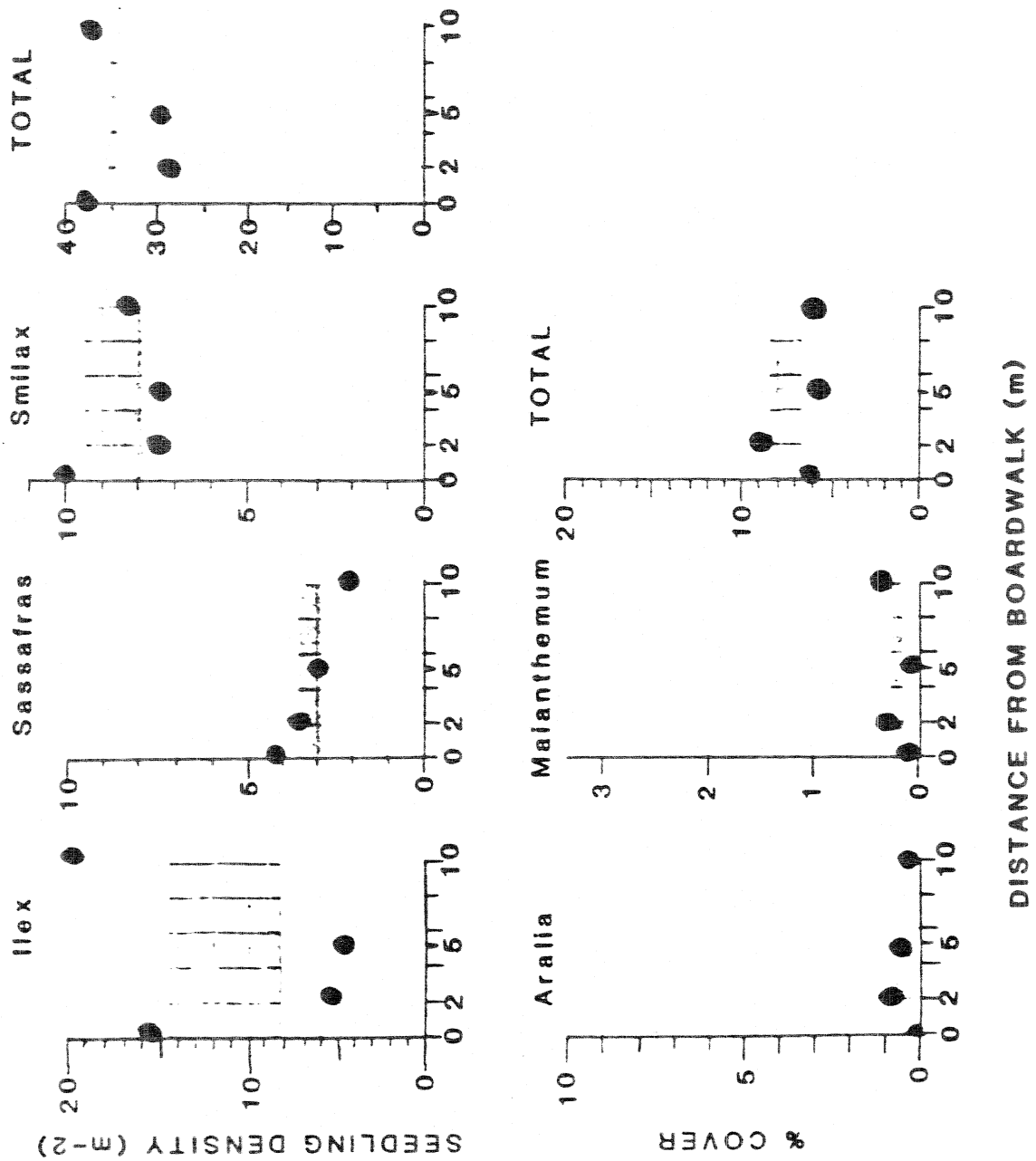

Ilex
Sassafras
Smilax
TOTAL
Aralia
Malanthemum
TOTAL
SEEDLING DENSITY (m-2)
% COVER
DISTANCE FROM BOARDWALK (m)

Figure 17.

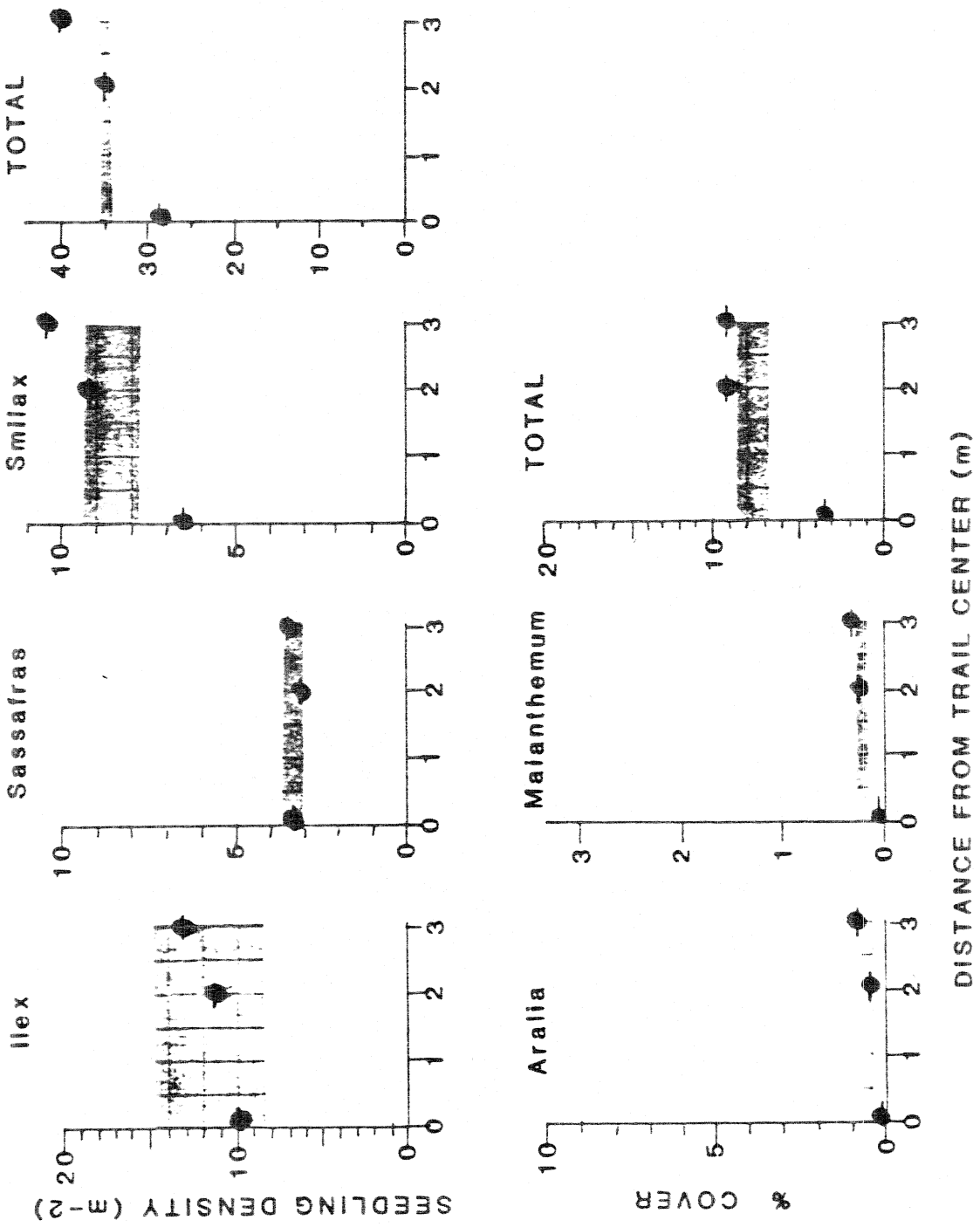
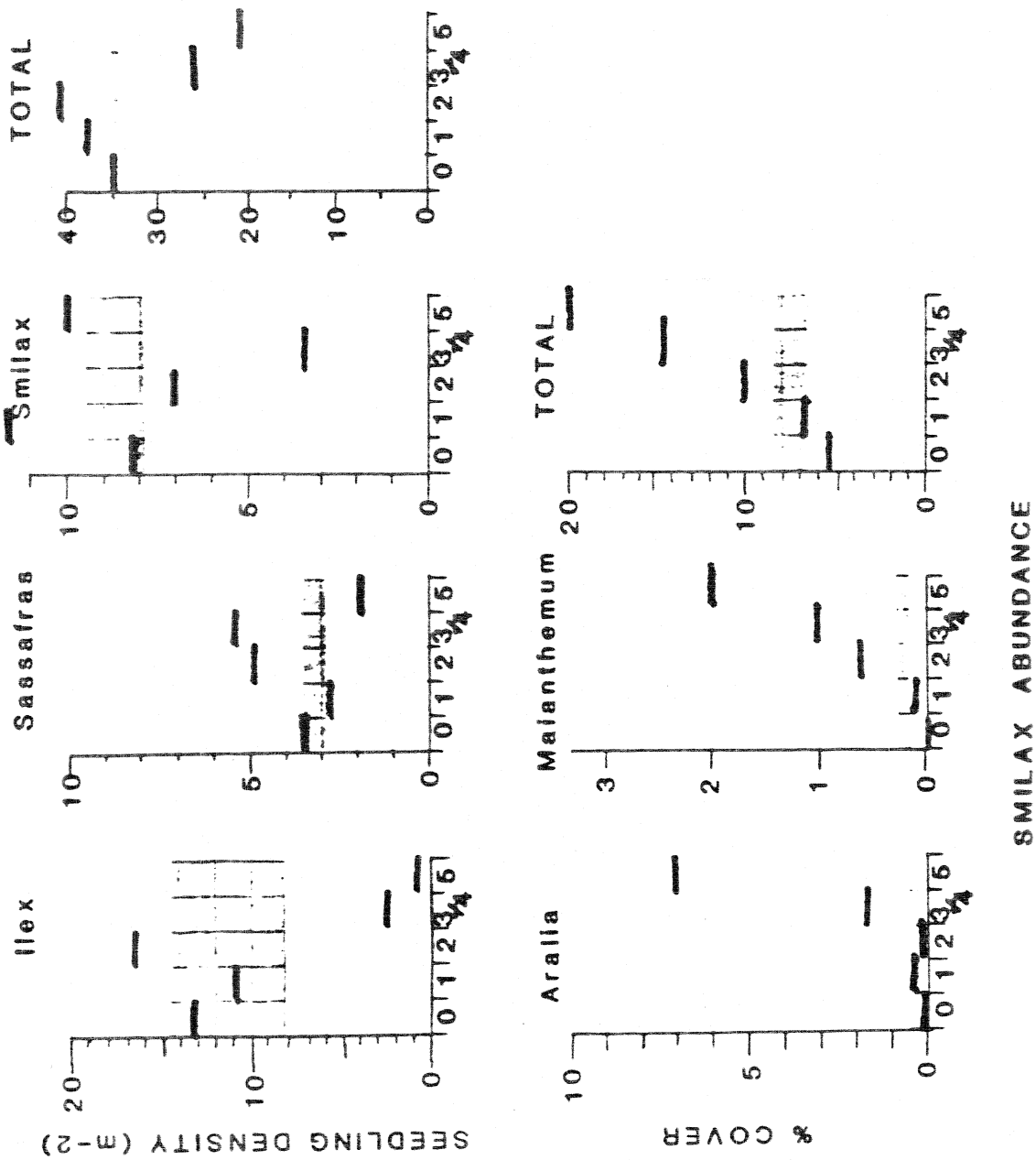

SEEDLING DENSITY (m-2)
% COVER
DISTANCE FROM TRAIL CENTER (m)
Ilex
Sassafras
Smilax
TOTAL
Aralia
Malanthemum
TOTAL

Figure 18.


SEEDLING DENSITY (m-2)
% COVER
SMILAX ABUNDANCE
Ilex
Sassafras
Smilax
TOTAL
Aralia
Malanthemum
TOTAL
0 1 2 3 6

tangles of Smilax represent important refugia for herb layer plants. Undoubtedly the distribution patterns of lianas makes a contribution to the distribution patterns evident in Figure 17, in that generally trails avoid high density of Smilax and if lianas were growing in the trail they would likely be killed by trampling.

The response of seedling density and herbaceous cover to increasing smilax abundance show consistent, but different patterns. In general woody seedlindg densities increase with increasing Smilax from class 0 to 2 or 3 and then decrease as the Smilax abundance increases further. A possible explaination of this pattern is that browsing is reduced as Smilax density increases through the lower abundance classes, but then provides increased competition and dense shading with further increases in its abundance. This hypothesis is based on the balance between protection from herbivores on one hand and the need for relatively high light levels for seedling growth and establishment.

The pattern evident for the more shade tolerant herbaceous perennials is different in that there appears to be little in the way of reduction of cover with increases in Smilax abundance (Figure 18). In fact the shape of the curves suggest that species such as Aralia nudicaulis and Maianthemum canadensis respond exponentially to increasing density of Smilax.

Conclusions

While it is difficult to clearly separate the roles of deer and people in maintaining "dirt" trails in the Sunken Forest, this study demonstrates that the trails do have a substantial negative impact on the vigor and diversity of the herbaceous layer. This is particularly

true for sections of trail that are free from abundant Smilax lianas that provide the herb layer protection from both human feet and the mouths of deer.

The boardwalk within the Sunken Forest, on the other hand appears to have little adverse effect on the vegetation. If anything, it plays a beneficial role of reducing erosion, channeling traffic on a durable confined surface, and where it is fitted with railings, keeps people from wandering across the landscape.

MANAGEMENT IMPLICATIONS

These studies suggest:

1. The Sunken Forest may have benefitted from the level of disturbance generated by Hurricane Gloria crossing the Island in September, 1985, although it is too early to know if many of the recently germinated seedlings will become established as mature individuals. Hurricane disturbances probably play a vital role in the natural regeneration of maritime forests.

2. Having only a single year's data from the deer exclosure experiment it is too early to measure great changes in the tree and shrub layers on Fire Island. The herb layer is more sensitive and does clearly show that even in a period as short as 12 months, significant increases in the herb layer have resulted from the localized exclusion of deer.

It is indeed unfortunate that the populations of herbaceous perennials in the Sunken Forest are not more evenly distributed and present in all of the deer study plots. If they were, the response of the herb layer to protection from deer browsing and grazing might be

even more pronounced. It might be prudent at this point in the history of the Sunken Forest to establish exclosed gardens of herbaceous perennials in various sections of the Forest. Hopefully, by the time effective means of maintaining the deer populations at more optimal levels are found, there may still be some wildflowers to repopulate the Forest. These small gardens, coupled with field experiments to clearly separate the impacts of deer from the impacts of rabbits, might fill this need.

3. The herbaceous layer is also adversely impacted by the continued use of small trails off the boardwalk. While it is difficult to assess the absolute contributions of deer and of people, it is clear from litter found by the sides of many of these trails that human use is a major contributing factor to their persistence. The railings installed on portions of the boardwalk that are perched off the ground should be continued along the entire length of the boardwalk inside the Sunken Forest. The railing would help to keep even more people on the boardwalk and might also encourage local increases in herbaceous perennial populations by reducing deer browsing in the vicinity of the boardwalk. It would also have the added benefit of reducing the omnipresent NPS liability if people should stumble off the sides of the present boardwalk.