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FLOOD PLAIN FORESTS OF THE RARITAN RIVER

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The forests of the flood plain of the Raritan River in New Jersey have been reduced to a few scattered fragments. Most of the flood plain has been cultivated or pastured and is either still so used or is reverting to natural vegetation. Two of the oldest, longest undisturbed, and largest stands of bottomland forest occur along the middle reaches of the river. One is near the town of Raritan a short distance below the confluence of the North Branch and the South Branch of the Raritan River. The other is adjacent to the Somerset airport southwest of Pluckemin and one mile downstream from Burnt Mills which is at the confluence of the Lamington River and the North Branch of the Raritan River. These two forest fragments are suggestive of the magnificent forests that once occurred along this river. Wistendahl (1955) has described the present condition of the rest of the Raritan River flood plain.

The objective of the present study is to record the composition of these forest remnants as indicative of the potentialities of the Raritan flood plain. One can see in these stands what would develop over most of the flood plain with an indefinite period free of man's interference.

The flood plain forest at Raritan occupies a site adjacent to the river. It lies between the river and a poorly drained area typical of the inner side of flood plains. The site is separated from the inner flood plain by a deep slough through which a portion of the river flows at high water, but which is only partially occupied by water during drier seasons. Among local botanists, the site is known as Mertensia "island" because of its islandlike character and the great profusion of *Mertensia virginica* that covers the ground in spring. This site will be referred to as Mertensia "island" in the text of this paper.

The bottom land forests of the river some five miles upriver adjacent to the Somerset airport and near Burnt Mills are more diversified than those at the Raritan location. Three distinctly different stands were studied in detail. One was a small but very fine stand situated topographically very similar to the Mertensia "island" site being only partially separated from the inner flood plain by a deep, water-filled slough. This site will be referred to in the text as the outer flood plain. A second stand lies beyond the deep slough on the inner flood plain, whose surface is undulating, the lower places being shallow, water-filled sloughs in spring and fall, and ice-filled much of the winter. The higher places of the undulating surface support

trees, the trees overhanging and shading the shallow sloughs. A third stand adjacent to the inner flood plain but farther from the river occupies an old river terrace. The terrace lies slightly above the inner flood plain and is apparently rarely flooded. It will be referred to as the river terrace. The three stands were all somewhere near the same size which is approximately 10 acres, the outer flood plain somewhat less, the terrace and inner flood plain stands somewhat more.

Methods. The methods used were the same for all study areas. The sampling of trees that were one inch d.b.h. (diameter at breast height) and over was done on twenty quadrats 10 meters square dispersed at regular intervals along two parallel belts through the stand. Tree cover was measured along four 100 meter transects using the line intercept method as employed by Buell and Cantlon (1950). Sampling of saplings of tree species, those between one foot in height and 1 inch d.b.h., was done on twenty 2×10 meter quadrats nested within the larger quadrats. The numbers of saplings of each species occurring within these was recorded. Also cover contributed by saplings was measured along the transect lines used in obtaining tree cover. At the same time shrub cover was also measured. In both cases the line intercept method was used as developed by Bauer (1943) for study of shrubby vegetation.

Tree seedlings, those individuals less than 1 foot high, were sampled by counts made on 40 $\frac{1}{2} \times 2$ meter quadrats, two of which were located in each of the 10 meter square quadrats.

Nomenclature follows that of Gray's manual, eighth edition (Fernald 1950).

Results. The data obtained by sampling the four stands are presented in three tables: table 1 summarizes transect data for the terrace and the adjacent inner flood plain, table 2 summarizes quadrat data for the outer flood plain and Mertensia "island", and table 3 summarizes the transect data for shrub and sapling cover measurements. All four sites showed certain common features of vegetation but the data do show differences from one site to another that appear obviously to be related to habitat differences.

The total ligneous flora of all four stands, based on the sampling data, consisted of 34 species of which 19 were tree species. The largest number of tree species—14—occurred on the outer flood plain, the smallest number—9—on Mertensia "island", and intermediate numbers—11 and 12—on the terrace and inner flood plain respectively. Eight species of shrubs and 4 species of lianas were recorded in the sampling, with the largest number occurring on the flood plain sites and the smallest number on the terrace (table 3). There were three tree species with individuals which were not over 1″ d.b.h. They contribute as saplings to cover in the shrub layer (table 3). American hornbeam (*Carpinus caroliniana*) is the principal among them

TABLE 1. *Data for tree species of stands located on the terrace and the inner flood plain. D = density or number of individuals per 1000 square meters; F = frequnecy or the number of times a species occurred in the quadrats expressed in per cent; BA = basal area per 1000 square meters. C = per cent of cover based on line transect measurements. In order to express density in terms of 1000 sq. M. the seedling count was multiplied by 50 and the sapling count by 5.*

	Less than 1″ d.b.h.				More than 1″ d.b.h.										
	Less than 1′ tall		More than 1′ tall		1.0–3.9″			4.0–9.9″			10.0″ or more			Total BA	C
	D	F	D	F	D	F	BA	D	F	BA	D	F	BA		
Terrace															
Fraxinus americana	—	—	3	5	—	—	—	4	20	1.48	6	40	6.18	7.66	25
Ulmus americana	1150	48	255	30	—	—	—	2	25	0.60	—	—	—	0.60	2
Carya cordiformis	150	15	15	20	—	—	—	1	5	0.19	1	10	0.83	1.02	8
Acer negundo	375	30	25	35	—	—	—	—	—	—	—	—	—	—	—
Tilia americana	50	5	3	5	1	10	0.05	5	30	1.14	1	5	0.28	1.47	3
Acer saccharum	8050	75	685	85	22	80	0.89	16	80	2.95	2	15	1.61	5.45	85
Ulmus rubra	—	—	—	—	1	5	0.01	—	—	—	1	10	0.80	0.81	2
Quercus rubra	25	3	8	15	—	—	—	1	5	0.17	5	35	4.94	5.11	32
Juglans nigra	—	—	3	5	—	—	—	—	—	—	—	—	—	—	—
Quercus velutina	—	—	—	—	—	—	—	—	—	—	2	10	1.33	1.33	5
Carya ovata	—	—	—	—	—	—	—	1	5	0.15	—	—	—	0.15	1
Total							.95			6.68			15.97	23.60	
Inner Flood Plain															
Fraxinus americana	75	5	23	20	—	—	—	3	20	0.92	5	35	3.96	4.88	10
Ulmus americana	—	—	5	10	1	10	0.02	6	40	1.78	7	50	7.32	9.12	13
Carya cordiformis	50	5	5	10	1	5	0.01	2	20	0.31	2	15	1.55	1.87	2
Acer negundo	25	3	10	10	—	—	—	—	—	—	1	5	0.36	0.36	3
Tilia americana	—	—	—	—	—	—	—	—	—	—	3	10	1.72	1.72	5
Acer saccharum	200	10	100	55	7	40	0.26	9	55	1.57	—	—	—	1.83	35
Quercus rubra	—	—	5	5	—	—	—	1	5	0.06	1	10	1.63	1.69	9
Fagus grandifolia	—	—	53	10	1	10	0.03	1	5	0.11	1	10	0.73	0.87	6
Liriodendron tulipifera	—	—	3	5	—	—	—	—	—	—	1	5	1.67	1.67	1
Quercus palustris	—	—	—	—	—	—	—	—	—	—	1	10	1.52	1.52	1
Acer rubrum	100	7	—	—	2	15	0.07	7	30	1.58	2	20	2.72	4.37	12
Betula nigra	—	—	—	—	—	—	—	1	10	0.31	1	5	0.61	0.92	1
Total							0.39			6.64			23.76	30.82	

TABLE 2. *Data for tree species of stands located on the outer flood plain and Mertensia ''island''. For explanation see table 1.*

	Less than 1″ d.b.h.				More than 1″ d.b.h.										
	Less than 1′ tall		More than 1′ tall		1–3.9″			4–9.9″			More than 10.0″			Total BA	C
	D	F	D	F	D	F	BA	D	F	BA	D	F	BA		
Outer Flood Plain															
Fraxinus americana	—	—	5	10	1	5	0.01	1	10	0.11	2	20	4.97	5.09	7
Ulmus americana	—	—	3	5	6	20	0.10	1	10	0.14	—	—	—	0.24	4
Carya cordiformis	75	7	10	10	—	—	—	—	—	—	—	—	—	—	1
Acer negundo	100	10	125	50	8	40	0.25	1	10	0.31	1	5	0.36	0.92	9
Tilia americana	—	—	5	5	4	5	0.06	2	20	0.64	2	10	4.21	4.91	9
Acer saccharum	125	10	665	90	21	65	0.31	3	20	0.45	—	—	—	0.76	28
Ulmus rubra	—	—	65	50	10	35	0.16	1	10	0.24	1	10	1.39	1.79	14
Quercus rubra	—	—	3	5	—	—	—	—	—	—	—	—	—	—	—
Celtis occidentalis	—	—	—	—	1	5	0.01	—	—	—	—	—	—	0.01	—
Fagus grandifolia	—	—	25	40	2	15	0.03	2	20	0.86	3	25	3.89	4.78	50
Liriodendron tulipifera	—	—	5	10	2	10	0.03	—	—	—	2	15	5.89	5.92	24
Quercus alba	—	—	—	—	—	—	—	—	—	—	1	5	2.34	2.34	5
Acer platanoides	—	—	—	—	1	5	0.01	—	—	—	—	—	—	0.01	—
Platanus occidentalis	—	—	—	—	—	—	—	—	—	—	1	10	0.91	0.91	1
Total							0.97			2.75			23.96	27.68	
Mertensia ''island''															
Fraxinus americana	—	—	3	5	2	15	0.02	3	15	1.34	5	45	6.95	8.31	26
Ulmus americana	—	—	—	—	1	5	0.04	—	—	—	—	—	—	0.04	—
Carya cordiformis	—	—	—	—	—	—	—	1	10	0.28	—	—	—	0.28	7
Acer negundo	25	3	60	45	6	35	0.16	1	5	0.43	—	—	—	0.59	9
Tilia americana	—	—	5	5	5	15	0.10	1	5	0.09	—	—	—	0.19	5
Ulmus rubra	—	—	—	—	3	25	0.09	3	15	0.76	5	15	5.18	6.03	45
Celtis occidentalis	—	—	15	15	4	20	0.07	2	15	0.50	6	45	12.03	12.60	37
Quercus palustris	25	3	—	—	—	—	—	—	—	—	—	—	—	—	—
Juglans nigra	—	—	—	—	—	—	—	—	—	—	1	10	1.15	1.15	14
Total							0.48			3.40			25.31	29.19	

being present on the outer flood plain (1% cover), the inner flood plain (3% cover), and the terrace (4% cover). The other two were present only on the terrace: flowering dogwood (*Cornus florida*) with 1% cover and hawthorn (*Crataegus* sp.) with less than 1% cover.

The forest of the terrace, which is above the flood level, had a practically closed canopy (7% unoccupied space). Within the forest only two species, sugar maple (*Acer saccharum*) and basswood (*Tilia americana*), were present in all size classes (table 1). The sugar maple was by far the most vigorously reproducing tree. Red oak (*Quercus rubra*) and bitternut hickory (*Carya cordiformis*) were absent in only the small tree (1–3.9″) class and

TABLE 3. *Per cent shrub, sapling, and liana cover based on measurements along 400 meters of line transect in each stand.*

	Outer flood plain	Mertensia "island"	Inner flood plain	Terrace
	50	41	66	79
Unoccupied space				
Shrubs				
Lindera benzoin	54	67	33	6
Berberis thunbergii	< 1	—	1	—
Viburnum prunifolium	< 1	—	—	3
Ilex laevigata	—	—	3	—
Rubus sp.	—	< 1	3	—
Cephalanthus occidentalis	—	—	1	—
Staphylea trifolia	—	17	—	—
Evonymus atropurpureus	—	< 1	—	—
Lianas				
Rhus radicans	5	12	2	—
Parthenocissus quinquefolia	< 1	1	—	—
Lonicera japonica	2	—	1	7
Vitis cordifolia	—	1	—	—
Tree saplings (15 species)	55	4	16	84

both had a good number of seedlings and saplings. The other species present were either those represented by large trees with little or no reproduction, white ash (*Fraxinus americana*), black oak (*Quercus velutina*), and shagbark hickory (*Carya ovata*), or by seedlings and saplings, box-elder (*Acer negundo*) and black walnut (*Juglans nigra*). Although ash had the highest total basal area, nearly all was contributed by individuals of the largest size class. Red oak was similar to the ash in distribution of basal area, but the sugar maple differed from them in having more basal area in the smaller size classes.

The forest of the inner flood plain had a canopy only slightly less closed than that of the terrace (11% unoccupied space). The two species that occurred in all size classes were the red maple and the bitternut hickory. However, the American elm and beech were absent only in the seedling class,

the white ash only in the young tree (1–3.9″) class and the sugar maple only in the largest size class. Present as large trees but failing to demonstrate capacity for self-perpetuation in the community were the basswood, box-elder, tulip tree, pin oak and river birch. The elm made the largest contribution to total basal area with the ash second. Most of this was in the 10″ and over size class. Red maple with more participation by the smaller size classes was third in its contribution to basal area. Not in the sampling data but present in the area were swamp white oak (*Quercus bicolor*) and black gum (*Nyssa sylvatica*).

The shrubs and lianas of the inner flood plain were somewhat more important than they were in the vegetation of the terrace. However, unoccupied space in this layer measured 66% (table 3), so that appreciably less than half of the ground was covered. Five species of shrubs and two species of lianas occurred, with spicebush (*Lindera benzoin*) furnishing practically all of the cover, none of the others contributing over 3% (table 3). Saplings contributed less than half as much cover as the shrubs. Three species, red maple, American hornbeam and red oak, not in the sapling quadrat data occurred on the transect lines for the shrub layer.

The forest of the outer flood plain occupies deep, alluvial soil. Being somewhat higher than the inner flood plain it is flooded for shorter periods. In addition both surface and subsurface drainage are good in striking contrast with the inner flood plain, and its surface is not so intensely subjected to scouring erosion as that of the inner flood plain.

One species only, box-elder, ocurred in all size classes. Sugar maple occurred in all but the largest size class. Three others, ash, slippery elm (*Ulmus rubra*) and beech, were in all but the seedling class. A few, white oak (*Quercus alba*), tulip tree (*Liriodendron tulipifera*), and sycamore (*Platanus occidentalis*) were present primarily as large trees with little or no representation in reproduction classes. Large individuals of shagbark hickory also were seen in the stand although none occurred in the quadrats. In contrast, bitternut hickory (*Carya cordiformis*) was vigorous in the smaller size classes. The bulk of the forest consisted of tulip tree, ash, beech, and basswood which contributed most of the basal area. In the smaller size classes, however, the beech, sugar maple and basswood were most important. The largest tree on the outer flood plain was an ash 38″ d.b.h. Honey locust (*Gleditsia triacanthos*), although not present in the quadrat data, occurred on the site.

The shrub layer was much better developed here than in either the inner flood plain or the terrace, only half of the layer was unoccupied by shrubs, lianas or saplings. There were three species of shrubs and three of lianas. Spicebush was again of greatest importance and practically the only shrub of any importance. Japanese barberry (*Berberis thunbergii*) and black haw

(*Viburnum prunifolium*) occurred but contributed an insignificant amount to the cover. Poison ivy (*Rhus radicans*) and Japanese honeysuckle (*Lonicera japonica*) were the two principal lianas (table 3). Eleven saplings contributed to cover in this layer, with the sugar maple contributing 30%, which was by far the most. Hornbeam, hackberry (*Celtis occidentalis*) and black walnut, not present in the quadrat data, occurred in the stand and contributed small amounts of cover as saplings on the transect measurements of the shrub layer.

The forest of Mertensia "island", which is farther downstream, also occupies deep, alluvial soil which is subject to flooding. It also possesses good surface and subsurface drainage, so it is not subject to extended periods of saturation in the upper soil horizons. Deposition, not erosion, is characteristic of its surface. No tree species occurred in all size classes although presumably intensive search or more intensive sampling might place some in this category. This might be true of white ash and hackberry which were not present in any of the small quadrats in which seedlings were sought. The most aggressively reproducing tree was box-elder but none of its individuals had reached the largest size class. Three species, hackberry, white ash and slippery elm form the bulk of the forest, contributing most of the basal area. Cover measurements agree with the basal area measurements in indicating these three species as primarily important. Four species not sampled in the quadrats occurred on the transect line: sycamore (5% cover), hawthorn (2% cover), hornbeam (1% cover) and white mulberry (*Morus alba*) (1% cover). Open space in the tree canopy was about 11%. Among the many large trees, the largest was a hackberry measuring 40″ d.b.h.

The shrub layer was denser (unoccupied space only 4%) than in any of the stands previously discussed. Spicebush reached its best development here but along with it bladdernut (*Staphylea trifolia*) was very important. Poison ivy also produced much more cover than in any of the other stands. Compared with the other stands, the contribution to cover by saplings was low, corresponding to the lower count of saplings on the quadrats. Only three species, hackberry (2%), box-elder (2%), and bitternut hickory (1%), contributed to cover in the shrub layer.

Discussion. The vegetation of the terrace is apparently in the process of becoming relatively stabilized as a predominantly maple-beech-basswood forest. The presence of black oak, shagbark hickory, and white ash primarily in the larger size classes and their failure to reproduce in contrast with the increasing importance of sugar maple, beech and basswood indicates the change toward the dominance of the last three. This situation is suggestive of more open conditions in the recent past. The area certainly had been cut over in the past, as evidenced by the sprout origin of the oaks, and

probably had been pastured. Some of the tree species other than sugar maple and basswood may be successful in perpetuating themselves but they will be outnumbered by the maple and basswood. The relatively open shrub layer which is in striking contrast with the shrub layer of the flood plain communities on the one hand and the more upland forests of this region on the other hand can be ascribed to the heavy shade produced by the dominants. Low light intensity as the cause of the suppression of the shrub layer is suggested at points where an opening in the canopy has resulted from a fallen tree; here a burst of shrub and sapling growth producing a local thicket is in remarkable contrast to the rest of the stand. Flowering dogwood occurs but is too sparse to form a distinct understory tree layer such as is common in the upland oak forests (Bard 1952, Cantlon 1953). The terrace, lying just above the flood plain, is a distinctly mesic site where moisture conditions are especially favorable. This explains in large part the rapid succession from oak-hickory dominance to maple-basswood dominance. This is in contrast to the oak-hickory forest of the region in general where evidence of such a succession is often entirely absent.

The inner flood plain forest is relatively heterogeneous since small undrained sloughs and low ridges and moderately well-drained sloughs produce variable conditions. This affects areal distribution of reproductive stages and consequently the mature plants too. Sugar maple, red maple, bitternut hickory, ash, and beech are more or less equally successful. Their apparent success is indicative of their increasing importance in the future forest if it is left free of disturbance. The absence of elm seedlings at the time of the survey may not be a consistent character. Another year perhaps they would be common. At any rate all other size classes of the elm are present but in numbers that would lead one to believe that this tree will decrease in importance as time goes on. Its present primary importance as a large tree may date back to an earlier time when the elm got established in numbers along with the box-elder, the red and pin oaks, the river birch and the tulip tree which are all failing to maintain themselves in the community now. The pronounced differences between this community and that of the terrace must be due both to the periodic flooding and to the undulating ground with its poorer drainage and surface conditions. The vegetation on this inner flood plain cannot be presumed to exemplify that of the inner flood plain in general since this particular inner flood plain is characterized by erosion. Deposition more often predominates. Very different conditions prevail where deposition rather than erosion is the rule.

The sites near the river at Burnt Mills and at Raritan, the outer flood plain and Mertensia "island", are very similar. Both have deep alluvial soils that drain rapidly after flooding. Water supply is always adequate especially for the deep-rooted species. Both sites support a mixed forest.

They have no one or two dominants, nor does the reproduction indicate that such a situation is developing. Certain species like sycamore and white oak, which are present in the larger size classes only, might be indicative of earlier disturbance. However, their presence might also be indicative of normal local catastrophe characteristic of the flood plain habitat. The high reproductive potential of both the shade tolerant sugar maple and the intolerant box-elder is indicative of the instability and variable surface conditions of the flood plain habitat. It seems likely that the shade tolerant beech, sugar maple, basswood, and bitternut hickory may gain in proportion to the others but the forest seems destined to remain a mixed one.

Perpetuation of a mixed stand is even more pronounced on Mertensia "island" than on the outer flood plain. On both sites catastrophe, characteristic of flood plains, seems to be capable of maintaining the variety of conditions conducive to the regeneration of species of diverse requirements. Fallen trees, resulting in open places in the canopy, were frequent.

The outer flood plain type of site along the Raritan River is exceedingly favorable for species that can withstand a certain amount of flooding. The trees grow rapidly and attain large size. Potentially the site will support as luxuriant a forest as can grow in this climate. A part of the splendor of the forests is the fine display of spring flowering herbs that is surpassed nowhere else in New Jersey. Such excellent growth and variety of tree species is generally characteristic of flood plain forests of the deciduous forest region (Cowles 1901, Lee 1945, Nichols 1916, and Oosting 1942).

The small remnants of the flood plain woodlands now left are indicative of the splendid forests that must once have covered all of the flood plains of the Raritan River system. Perhaps they will again be more extensive since the values of natural areas are being increasingly recognized today. There is a good chance that the plans now being made for a park system along portions of the Raritan flood plain will include natural reservations where flood plain forests will be allowed to develop again to their natural grandeur.

SUMMARY

1. Evidence from the one example studied indicates that the low terraces that lie just above the flood level of the Raritan River can support a forest dominated by sugar maple, beech, and basswood. Their two principal but minor associates will be red oak and bitternut hickory.

2. The flood plains will support forests that are much more varied in composition.

3. The part of the flood plain farthest from the river, the inner flood plain, is less well drained than the part adjacent to the river. The inner flood plain forest which was investigated in this study occupies a site where

surface erosion at flood times scours the ground resulting in an uneven surface. Sugar maple, red maple, ash and beech as a group are becoming dominant in place of the earlier established elm, box-elder, red oak, basswood, pin oak, river birch and tulip tree. This succession cannot be presumed for the inner flood plain of the river as a whole because more often deposition rather than surface erosion occurs during flooding and the conditions then are exceedingly different. No extensive relatively undisturbed stands occur on the latter type of site.

4. The outer flood plain sites or broad more or less level areas of deposition next to the river have a deep, well-drained soil and support a deciduous forest of mixed composition in which no convincing trend toward the dominance of a few species is evident.

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