ASCFEROIDEUS

INTERTIDAL VASCULAR PLANTS OF RIVER SYSTEMS NEAR PHILADELPHIA

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Intertidal Vascular Plants of River Systems Near Philadelphia

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ABSTRACT.—Nineteen taxa of vascular plants, primarily restricted to intertidal areas, have been collected in freshwater to brackish water portions of four river systems near Philadelphia: the Delaware, Raritan, Mullica, and Great Egg Harbor. The past and present distribution of these intertidal plants and the ecological conditions under which they grow are discussed. Ten more taxa appear to be phenotypic variants of more wide-ranging species and do not warrant taxonomic recognition as endemics in intertidal areas. Many intertidal plants are low rosettes or low cespitose caulescent plants rooting at nodes—growth forms that may be responses to periodic inundation. Reproductive morphology indicates that intertidal plants are adapted for limited dispersal or non-dispersal. Extirpations among the nineteen restricted intertidal taxa include: (1) two species from the entire study area, (2) three species from the Delaware system, (3) six species from the Delaware River, (5) seven species from the Schuylkill River, and (6) possibly five or more species from the Raritan River. Range extensions, primarily because of increased collecting activity and not from spread of plants, include eight taxa for Rancocas Creek (freshwater) and three taxa in generally poorly collected brackish portions of the Delaware, Mullica, and Great Egg Harbor systems. Some of the factors considered responsible for extirpations and range reductions include dumping of dredging spoil, landfill, and refuse, bulkheading, damming tributaries, and diking. The Mullica and Great Egg Harbor systems have a more limited freshwater intertidal flora, presumably because of their location in the New Jersey pine barrens. [collecting history, Delaware River, distribution, ecology, Great Egg Harbor River, intertidal, Mullica River, Raritan River, vascular plants]

Intertidal zones in freshwater to brackish water portions of large river systems provide isolated habitats for numerous rare plants. In counties within a 50 mile radius of Philadelphia, there are four such river systems: (1) the Delaware, (2) the Raritan, (3) the Mullica, and (4) the Great Egg Harbor. Despite the longevity of botanical investigation in the Philadelphia area, no thorough inventory of plants restricted to or nearly restricted to such intertidal zones has been compiled. The purpose of this study is to record the past and present distribution of these rare intertidal plants and discuss some of their ecological and morphological characteristics.

Our field work was conducted primarily between the summer of 1971 and the fall of 1977. The distribution maps (Figs. 3–22) are based on collections at the Academy of Natural Sciences (PH and PENN), the University of Delaware (DELS), Harvard University (GH), the New York Botanical Garden (NY), Rutgers University (CHRB), the Smithsonian Institution (US), and West Chester College (DARL). Our collections made during this study are at PH. Collections made after 1970 are represented by

Correction: Figs. 1-22, bar scale = 10 mi or 16 km.

circles and those made before 1970 are represented by dots on the distribution maps in Figs. 3–21. Localities in the study area where collections were made are shown in Fig. 1 and the rivers and creeks are shown in Fig. 2.

Plants Mostly Confined to Intertidal Zones

1. **Cyperus brevifolioides** Thier. & Delahous., Fig. 3

This sedge, which is reported from a few widely separated localities from Connecticut to North Carolina (Delahoussaye and Thieret 1967), is a suspected introduction from eastern Asia. It is known from numerous localities in the Philadelphia area where it usually grows along the upper borders of freshwater tidal marshes and shores.

The collected range of *C. brevifolioides* along the Delaware River extends from Croydon, Pennsylvania (nr. high tide limits, ca .6 mi NE of mouth of Neshaminy Cr., 6 Oct 1971, *Ferren 837,* PH), and Edgewater Park, New Jersey (mouth of lagoon, 22 Oct 1971, *Ferren 861,* PH), downstream to South Philadelphia (along Delaware Ave. S of Bigler St., driveway nr. dispatcher's box, 11 Oct 1937, *O'Neill,* PENN) and Pennsauken, New Jersey (on log just below high tide limits, SW end of Fisherman's Cove, 22 Sep 1971, *Ferren 791,* PH). It has been collected along the tidal Delaware River tributaries of Rancocas Creek (Centerton, sandy muddy shore above *Nuphar* flats, 17 Oct 1973, *Ferren 1349,* PH) and Alloway Creek (Deep Run, ca 1 mi W of Alloway, edge of swamp above *Nuphar* flats on mud-covered log, 4 Oct 1973, *Ferren 1329,* PH). There also are specimens of *C. brevifolioides* from Fairmount Park in Philadelphia (Japanese Garden, PENN; centennial grounds, 1878, *Burk 17,* PH), which probably were introduced with other Asiatic plants displayed for the centennial celebration.

Cyperus brevifolioides frequently occurs on firm sandy muddy substrates, often on or among debris, near the high tide limit. Here it generally is associated with *Cyperus rivularis* Kunth, *Bidens bidentoides* (Nutt.) Britt., *Bidens laevis* (L.) BSP., *Panicum virgatum* L., *Scirpus pungens* Vahl, and many other plants found on moist substrates. Occasionally it grows on firm clay margins of marshes dominated by *Nuphar luteum* (L.) Sibth. & Smith where it is associated with *Isoëtes riparia* Engelm., *Sagittaria rigida* Pursh, *Scirpus smithii* Gray, *Eleocharis obtusa* var. *peasei* Svens., and *Cyperus rivularis*.

The first known local collection of *C. brevifolioides* made in tidal conditions was southeast of Eddington, Pennsylvania in 1932 (along Delaware R., border of dredged sand over marsh, 24 Sep 1932, *Long 38543 & 38547,* PH). However, nearly all other collections of this species were made during recent years. Since extensive collecting was done along the Delaware River in the 19th and early 20th centuries, it is unlikely that *C. brevifolioides* would have been overlooked. Therefore this species probably is more abundant than it ever was in the Delaware River system. It frequently grows in places where debris accumulates, a habitat that probably has become increasingly available during the past 50 years.

2. **Bidens frondosa** var. **anomala** Port. ex Fern., Fig. 4

This variety differs from typical plants of the species in having antrorsely instead of retrorsely barbed awns. The typical variety is widespread in North America on moist substrates and frequently occurs on waste or cultivated ground. Variety *anomala* has a more restricted distribution (Sherff 1937) and near the Atlantic coast it is mostly found on tidal substrates.

Nearly all local collections of *Bidens frondosa* var. *anomala* are from tidal portions of the Delaware system although at

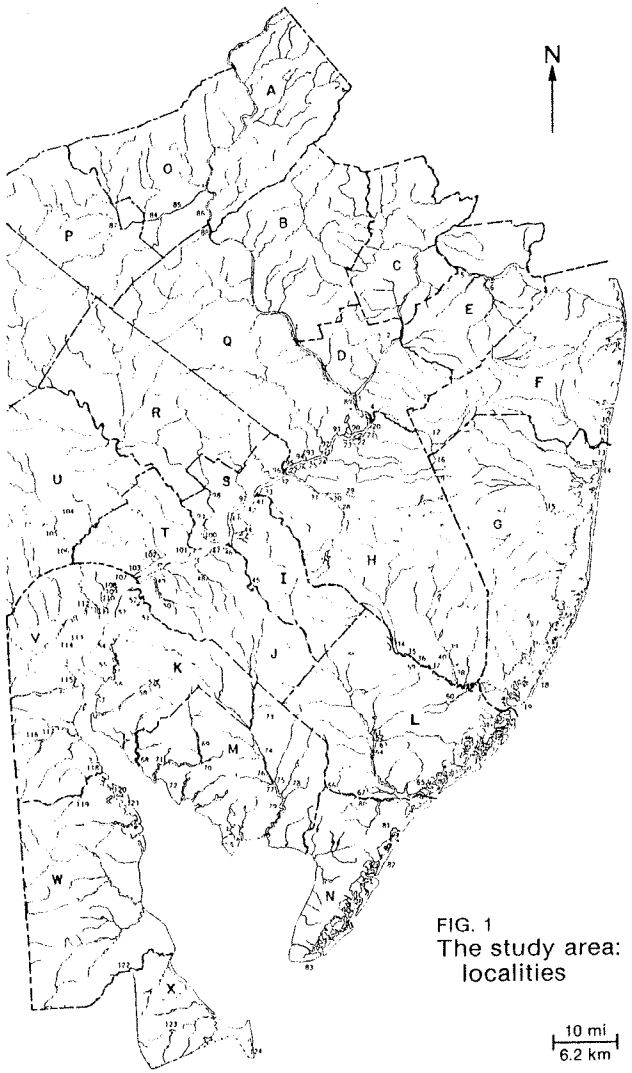

FIG. 1
The study area: localities

FIG. 1. Counties and selected localities of the study area:

NEW JERSEY

A. Warren County
B. Hunterdon County
1. Lambertville
C. Morris County
D. Mercer County
2. Princeton
3. Trenton
4. White Horse
E. Middlesex County
5. New Brunswick
6. Sayreville
F. Monmouth County
7. Bradevelt
8. Long Branch
9. Belmar
10. Como
11. Sea Girt
12. Cream Ridge
G. Ocean County
13. Point Pleasant
14. Mantoloking
15. Toms River
16. New Egypt
17. Manahawkin
18. Beach Haven
19. Sea Haven
H. Burlington County
20. Bordentown
21. Fieldsboro
22. Kinkora
23. Roebling
24. Burlington
25. Edgewater Park
26. Beverly
27. Delanco
28. Lumberton
29. Mount Holly
30. Hainesport
31. Centerton
32. Delran
33. Palmyra
34. Batsto
35. Crowleytown
36. Green Bank
37. Lower Bank
38. New Gretna
39. Chips Folly
40. Wading River
I. Camden County
41. Delair
42. Fisherman's Cove
43. Camden
44. Fairview
45. Blackwood
J. Gloucester County
46. Westville
47. Red Bank
48. Mount Royal
49. Bridgeport
50. Swedesboro
K. Salem County
51. Auburn
52. Pedricktown
53. Penns Grove
54. Pennsville
55. Harrisonville
56. Salem
57. Alloway
58. Quinton
L. Atlantic County
59. Weekstown
60. Port Republic
61. Mays Landing
62. Clarkstown
63. Thompsontown
64. Catawba
65. Linwood
66. Head of River
67. Corbin City
M. Cumberland County
68. Bay Side
69. Bridgetown
70. Fairton
71. Greenwich
72. Sea Breeze
73. Vineland
74. Millville
75. Manantico
76. Laurel Lake
77. Buckshutem
78. Port Elizabeth
79. Mauricetown
N. Cape May County
80. Tuckahoe
81. Palermo
82. Sea Isle City
83. Cape May

PENNSYLVANIA

O. Northampton County
84. Bethlehem
85. Freemansberg
86. Raubsville
P. Lehigh County
87. Allentown
Q. Bucks County
88. Riegelsville
89. Morrisville
90. Pennsbury Manor
91. Tullytown
92. Bristol
93. Croydon
94. Eddington
95. Andalusia
R. Montgomery County
S. Philadelphia County
96. Torresdale
97. Kensington
98. Laurel Hill
99. Woodlands
100. Penrose Ferry
T. Delaware County
101. Tinicum
102. Chester
103. Marcus Hook
U. Chester County
104. West Chester
105. Lenape
106. Brintons Bridge

DELAWARE

V. New Castle County
107. Claymont
108. Holly Oak
109. Bellvue
110. Gorden's Heights
111. Cherry Island
112. Wilmington
113. New Castle
114. Deemar's Beach
115. Delaware City
116. Middletown
117. Odessa
118. Collins Beach
W. Kent County
119. Smyrna
120. Woodland Beach
121. Fraland Beach
122. Milford
X. Sussex County
123. Milton
124. Rehoboth Beach

least one early collection apparently was made at a non-tidal locality (Philad, Laurel Hill, Oct 1866, *Burk*, PH). Along the Delaware River, the collected range of var. *anomala* extends from Bristol, Pennsylvania (rocky shore just below high tide limits, 6 Oct 1971, *Ferren 825*, PH), and Palmyra, New Jersey (ca .5 mi N of Tacony-Palmyra Bridge, high tide limits along sandy debris-covered shore, 22 Sep 1971, *Ferren 818*, PH), downstream to below New Castle, Delaware (Deemer's Beach, on debris at upper tidal limits, 28 Sep 1972, *Ferren 1161*, PH), and near Bridgeport, New Jersey (Raccoon Is., nr. high tide line along sandy beach, 1 Oct 1971, *Ferren 818*, PH). The Card Catalog of the Society of Natural History of Delaware records a specimen farther south in Delaware (Delaware City, 4 Sep 1910, *Williamson*). On tidal tributaries of the Delaware River, var. *anomala* has been collected from along the Schuylkill River (Gray's Ferry, 23 Sep 1866, *Burk*, PH), [along or near] Darby Creek (Glenolden, 3 Oct 1888, *Brinton*, PENN), the Christiana River (muddy rocky shore below rt. 95 bridge, 28 Sep 1972, *Ferren 1157*, PH), Big Timber Creek (Good Intent Rd., 26 Sep 1972, *Ferren 1136*, PH), the Salem River (tidal banks, 16 Sep 1882, *Commons*, CHRB), the Cohansey River (NW of Fairton, silty shore, 22 Sep 1935, *Long 47597*, PH), and the Maurice River from about 1.5 miles north of Laurel Lake (on stump at high tide limits, 23 Aug 1973, *Ferren 1294*, PH) downstream to Port Elizabeth (high tide limit, sandy shore just N of mouth of Manumuskin R., 18 Sep 1972, *Ferren 1132*, PH).

Bidens frondosa var. *anomala* usually grows near the upper limit of the tide, frequently on debris-littered substrates, in freshwater to somewhat brackish water conditions where it is associated with many of the same plants associated with *Cyperus brevifolioides*.

The earliest recorded collections of var. *anomala* in the local area are from Philadelphia (specimen cited above) and Wilmington (*Canby*, PH) in 1866. Since that time, numerous collections have been made in the Delaware system and there is no evidence that substantial changes in its distribution have occurred in recent years.

3. **Scirpus fluviatilis** (Torr.) Gray, Fig. 5

Although this bulrush occurs across the North American continent, near the east coast it usually grows in freshwater intertidal zones. Locally it is restricted to freshwater or slightly brackish water portions of the Delaware system. In brackish water portions of the Delaware system it is replaced by the closely related *Scirpus cylindricus* (Torr.) Britt.

Scirpus fluviatilis has been collected along the Delaware River from Croydon, Pennsylvania (backwater, 15 Dec 1949, *Long 70672*, PH), and Fieldsboro, New Jersey (Vansants Is., marsh, 18 June 1921, *Long 24622*, PH), downstream to Wilmington, Delaware (muddy banks, 24 Jul 1866, *Commons*, PH), and about 1.6 miles northwest of Bridgeport, New Jersey (below mouth of Raccoon Cr., 26 Jul 1972, *Schuyler 4315*, PH). On tidal tributaries of the Delaware River, the collected range of *S. fluviatilis* extends from Crosswicks Creek in New Jersey (upper limit of intertidal zone S of White Horse, 10 Sep 1972, *Schuyler 4345*, PH), and Common Creek in Pennsylvania (border of marsh S of Tullytown, 6 Sep 1927, *Long 33800*, PH), southward to the Alloway Creek system in New Jersey (edge of shrubby marsh on muddy shore of Deep Run, 1 mi W of Alloway, 4 Oct 1973, *Ferren 1334*, PH), and Tom Creek in Delaware (above and below Hamburg Rd., ca 3.75 mi SW of New Castle, 27 Oct 1972, *Schuyler 4378*, PH).

Scirpus fluviatilis is more abundant in marshes along the downstream portions of freshwater tributaries of the Delaware River than along the river itself. Extensive stands grow on muddy peaty substrates

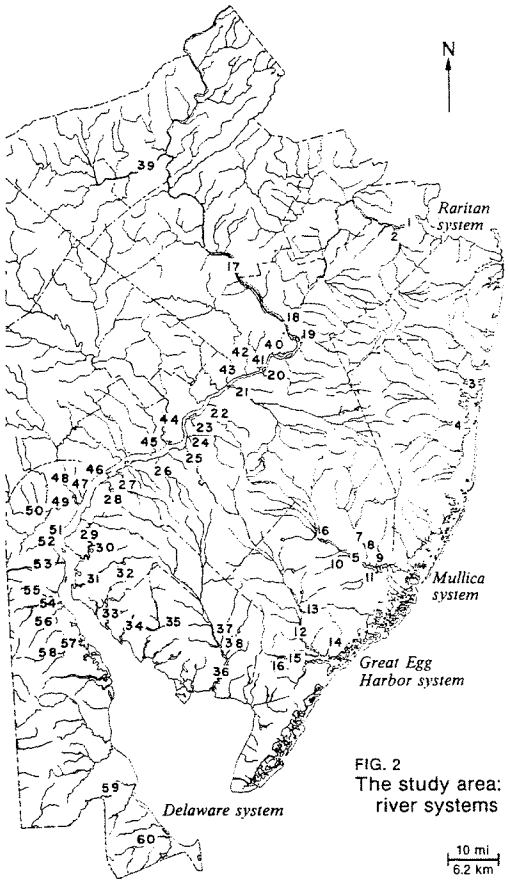

FIG. 2
The study area: river systems

FIG. 2. Selected rivers and creeks of the study area:

1. Raritan River
2. South River
3. Metedeconk River
4. Toms River
5. Mullica River
6. Batsto River
7. Wading River
8. Merrygold Branch
9. Bass River
10. Landing Creek
11. Nacote Creek
12. Great Egg Harbor River
13. Gravelly Run
14. Patcong Creek
15. Tuckahoe River
16. Mill Creek
17. Delaware River
18. Assunpink Creek
19. Crosswicks Creek
20. Assiscunk Creek
21. Rancocas Creek
22. Pennsauken Creek
23. Cooper River
24. Newton Creek
25. Big Timber Creek
26. Mantua Creek
27. Raccoon Creek
28. Oldman's Creek
29. Salem River
30. Mannington Creek
31. Alloway Creek
32. Deep Run
33. Stow Creek
34. Cohansey River
35. Mill Creek
36. Maurice River
37. Manantico Creek
38. Manumuskin River
39. Lehigh River
40. Common Creek
41. Mill Creek
42. Neshaminy Creek
43. Poquessing Creek
44. Schuylkill River
45. Darby Creek
46. Naaman's Creek
47. Shellpot Creek
48. Brandywine Creek
49. Christiana River
50. White Clay Creek
51. Gambles Gut
52. Tom Creek
53. Chesapeake and Delaware Canal
54. Appoquinimink Creek
55. Drawyer Creek
56. Blackbird Creek
57. Smyrna River
58. Duck Creek
59. Mispillion River
60. Broadkill Creek

with *Typha angustifolia* L., *Sagittaria latifolia* Willd., *Impatiens capensis* Meerb., *Nuphar luteum, Amaranthus cannabinus* (L.) Sauer, *Polygonum arifolium* L., *Polygonum sagittatum* L., and *Bidens laevis* in the upper portions of the intertidal zone. Along peaty margins and shrubby borders of the high tide limit, *S. fluviatilis* is associated with *Acorus calamus* L., *Peltandra virginica* (L.) Schott & Endl., *Sagittaria latifolia, Lythrum salicaria* L., *Hibiscus moscheutos* L., *Cephalanthus occidentalis* L., and *Rosa palustris* Marsh.

Throughout its local range, most culms of *S. fluviatilis* lack inflorescences, although a few inflorescence bearing culms can be found in some of the larger stands. The extensive tuberous rhizome system frequently forms a thick tough turf which persists in areas where culms no longer develop. Although large stands of *S. fluviatilis* are currently only known from tributaries, extensive turf has been found in disturbed areas on islands and along the shore of the Delaware River (exposed in places along the eroded E bank of Burlington Is. beneath 3 ft of dredging spoil and trees ca 20 yr old, 25 Jul 1972, *Ferren 987*, PH). Rhizomes and tubers also are found washed along shores of the Delaware system where they may function as agents of vegetative dispersal.

The earliest known local collection of *S. fluviatilis* was made about 1825 in or near Camden, New Jersey (banks of Coopers Ck, *Conrad*, PH), and the next known collection was made in 1862 in Camden (*Parker*, CHRB). Since 1862, additional collections of *S. fluviatilis* have been made sporadically. This collecting pattern probably does not reflect the actual distribution of *S. fluviatilis* in past time. We suspect collectors avoided this species because of the large size of the plants, the scarcity of culms with inflorescences necessary for identification, and their greater interest in the Delaware River instead of tributaries where *S. fluviatilis* was most abundant. Although we have recently collected *S. fluviatilis* in several localities in the Delaware system, we suspect that the dumping of land fill and dredging spoil, as well as wave generated erosion, have considerably reduced stands of this species and it is less common now than it was in the past.

4. **Bidens bidentoides** (Nutt.) Britt., Fig. 6

This species is known only from tidal shores of the Hudson, Raritan, Delaware, and Maurice rivers and some of their tributaries. A closely related species, *Bidens mariana* Blake, is reportedly endemic to tidal shores of the Northeast River and lower Susquehanna River in Maryland (Fernald 1950).

Along the shores of the Delaware River, the collected range of *B. bidentoides* extends from Morrisville, Pennsylvania (9 Oct 1910, *Bartram 1295*, PH), and Trenton, New Jersey (opp. NW end of Biles Is., 10 Sep 1972, *Schuyler 4349*, PH), downstream to about 1.5 miles below New Castle, Delaware (Deemers Beach, growing among *Scirpus pungens* in firm peaty areas above sands, 28 Sep 1972, *Ferren 1159*, PH), and south of Pennsville, New Jersey (marsh S of Kelly's Pt., 8 Oct 1934, *Long 44945*, PH). Four collections with little data appear to be from Delaware River tributaries (NJ: tidal bank, Salem City, 16 Sep 1882, ex Herb. A. Commons, PH; PA: Darby, Phila., 1855, *Durand*, GH; DE: Brandywine, 1885, ex Herb. E. Tatnall, GH; DE: Townsend, *Canby*, PENN). Along the Maurice River, *B. bidentoides* has been collected from below Millville (muddy shore, 7 Oct 1909, *Long*, PH) south to the slightly brackish shore at Manantico (20 Oct 1935, *Long 47875*, PH). On the Raritan River it has been collected opposite New Brunswick (Oct 1918, *Mackenzie*, PH, CHRB).

Along freshwater shores of the Delaware River, *B. bidentoides* occurs in the middle to upper portion of the intertidal zone on firm substrates consisting of sands, gravels, or mud covered sands and gravels. It commonly grows in open to dense stands of *Scirpus pungens* where it is associated with *Amaranthus cannabinus*, *Bidens laevis*, *Cyperus rivularis*, *Juncus acuminatus* Michx., *Lindernia dubia* (L.) Penn., *Polygonum punctatum* Ell., *Sium suave* Walt., and *Zizania aquatica* L. Plants of *B. bidentoides* growing lower in the intertidal zone tend to become dwarfed and prostrate, and have blunter less serrate leaves than plants growing higher in the intertidal zone. Such plants occur on open sands and gravels at the lower limits of *Scirpus pungens* and on open firm peaty banks below upper tidal marshes. In both habitats, *B. bidentoides* is associated with *Cyperus rivularis*, *Eleocharis obtusa* var. *peasei*, *Juncus acuminatus*, *Lindernia dubia*, *Ludwigia palustris* (L.) Ell., and *Scirpus smithii*.

Bidens bidentoides was first collected locally by Thomas Nuttall in Philadelphia prior to his original description of it in 1841. The next known local collection was in 1865 (nr. the Delaware above Wilmington, Oct 1865, *Canby*, PENN). Since then numerous collections of *B. bidentoides* have been made along the Delaware River where it still can be found throughout much of its range. However, it is presently common only above Philadel-

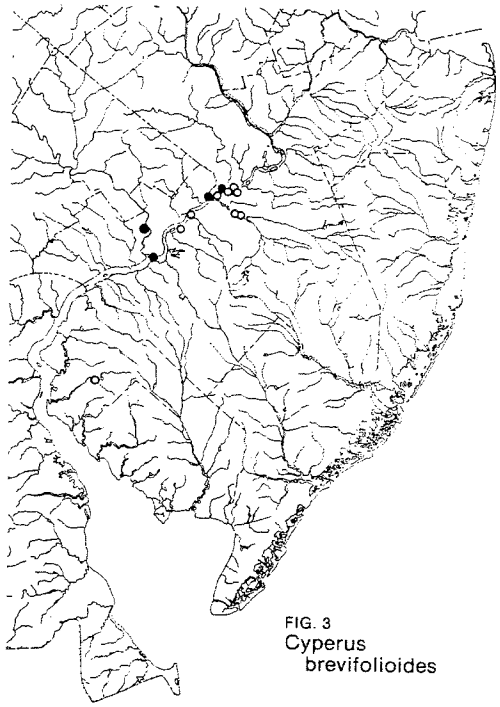

FIG. 3
Cyperus brevifolioides

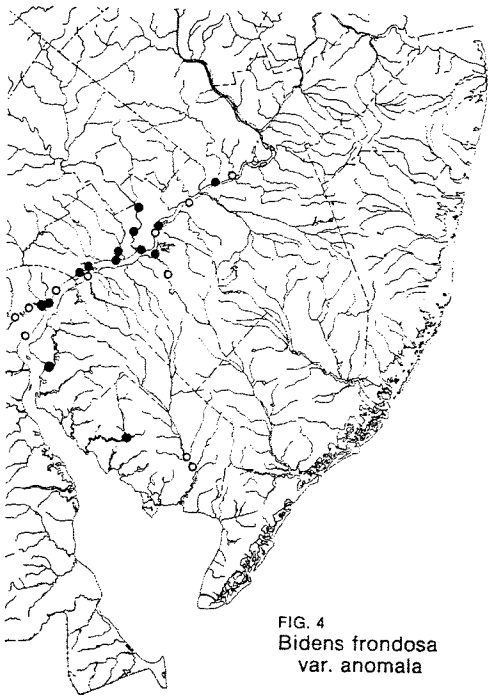

FIG. 4
Bidens frondosa var. anomala

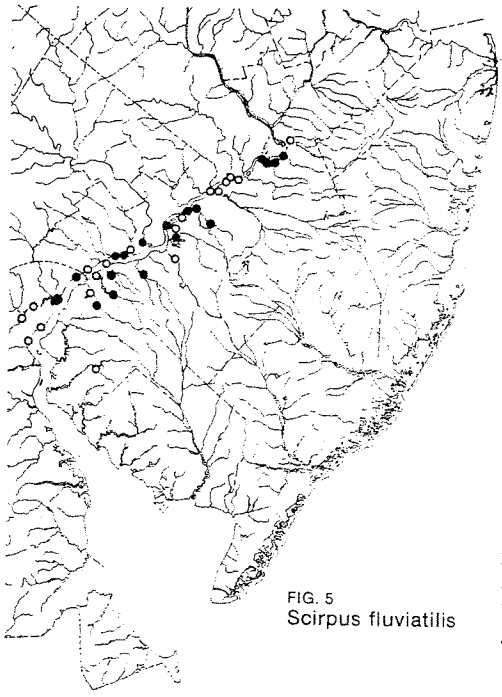

FIG. 5
Scirpus fluviatilis

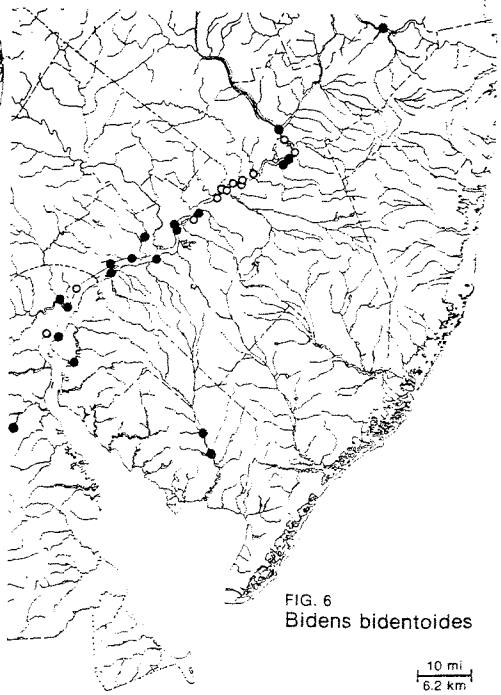

FIG. 6
Bidens bidentoides

phia and Camden. Although numerous 19th century collections were made between these cities and Wilmington, it has only been collected three times in the 20th century along this stretch of the river (NJ: West Deptford, muddy shores, 20 Sep 1900, *MacElwee 1992*, PH: DE: Holly Oak, firm interrupted peaty substrate toward upper tidal limits, 15 Sep 1972, *Ferren 1107*, PH; DE: ½ mi S of Edgemoor Iron Works, 2 Sep 1923, *R. Tatnall*, PENN). Along the Maurice River, *B. bidentoides* has not been collected since 1935 (specimen cited above) and along the Raritan it has not been collected since 1918 (specimen cited above).

5. **Scirpus smithii** Gray var. **smithii**, Fig. 7

This variety, which lacks bristles attached to achenes, is distributed from Quebec to Virginia and westward through the Great Lakes states to Minnesota and Iowa. In eastern New York, New Jersey, eastern Pennsylvania, and northern Virginia, var. *smithii* is almost entirely restricted to the freshwater intertidal zones of the Hudson, Raritan, Delaware, and Potomac rivers. Another widespread variety, var. *setosus* Fern., has well-developed barbed bristles and grows in and around lakes, ponds, and quagmires, but is rarely found in intertidal zones. A third variety, var. *levisetus* Fass., has nearly smooth bristles and is restricted to freshwater intertidal zones of rivers in New England and Quebec.

Scirpus smithii var. *smithii* reaches the upstream limit of its collected range in the Delaware system at Trenton, New Jersey (sandy-gravelly shore of Delaware R., Mercer Co. Public Boat Launching Area, 10 Sep 1972, *Schuyler 4348*, PH), and the downstream limit in the vicinity of Claymont, Delaware (muddy shores of Delaware R. nr. Hollyoak, 17 Aug 1896, *Commons*, PH). On tributaries of the Delaware River it has been collected along Rancocas Creek at Centerton, New Jersey (sandy muddy tidal shore, 17 Oct 1973, *Ferren 1354*, PH), and along the Schuylkill River in Philadelphia (Penrose ferry, in tidal mud, 14 Sep 1867, *C. E. Smith*, PH). Elsewhere in the local area var. *smithii* has been collected once along the Raritan River (tidal flats opp. New Brunswick, Oct 1918, *Mackenzie*, PH), and near the Atlantic coast of southern New Jersey (Cape May Co.: Sea Isle, 26 Aug 1894, *Lippincott*, PH). Adjoining the area of this study in Morris County, New Jersey, var. *smithii* has been collected from two non-tidal localities (Lake Hopatcong, 21 Sep 1898, *Fisher 9163*, WIS; and Budd's Lake, 6 Aug 1869, *Porter*, CHRB).

Along the Delaware River var. *smithii* grows in relatively open portions of the middle to upper intertidal zone on compact sandy gravelly shores or occasionally clayey peaty river margins of marshes, and is associated with *Sagittaria rigida*, *Sagittaria graminea* Michx., *Scirpus pungens*, *Cyperus rivularis*, *Eleocharis obtusa* var. *peasei*, *Polygonum punctatum*, *Lindernia dubia*, and *Ludwigia palustris*.

Currently, *Scirpus smithii* var. *smithii* is locally restricted to tidal portions of the Delaware system above Philadelphia and Camden, and field work has failed to locate it farther downstream than Palmyra, New Jersey (sandy cobbly tidal beach of Delaware R., ca 2.5 mi N of Tacony-Palmyra Bridge, 24 Sep 1971, *Ferren 806*, PH). Along or near the Delaware River below Philadelphia only two collections of var. *smithii* have ever been made, both in the 19th century. These are from Chester, Pennsylvania (Chester Cr., Aug 1866, PENN), and near Holly Oak, Delaware (cited above).

6. **Eleocharis obtusa** var. **peasei** Svens., Fig. 8

This variety, which ranges from Maine to Delaware, grows mostly on freshwater tidal shores but also grows inland on non-tidal shores of lakes and ponds in New England and Quebec (Svenson 1929). The plants dif-

fer from the widespread var. *obtusa* by not having bristles attached to achenes or the bristles are very reduced. Previous authors (Long 1929) have treated these plants as *Eleocharis diandra* C. Wright.

Locally, *Eleocharis obtusa* var. *peasei* has been collected along the Delaware River from Bristol, Pennsylvania (mudflat, mouth of tidal stream, 6 Oct 1971, *Ferren 821 & 822*, PH), and below Trenton, New Jersey (Duck Is., 10 Sep 1972, *Schuyler 4353*, PH), downstream to Hollyoak, Delaware (silt-covered gravels in the upper tidal zone, 15 Sep 1972, *Ferren 1109*, PH), and the vicinity of Bridgeport, New Jersey (sandy beach, Raccoon Is., 1 Oct 1971, *Ferren 814*, PH). Elsewhere in the Delaware system, var. *peasei* has been collected along Common Creek (Tullytown, tidal mud, 30 Aug 1929, *Benner 3747*, PH), Rancocas Creek (sandy muddy tidal shore above *Nuphar* flats, Centerton, 17 Oct 1973, *Ferren 1356b*, PH), Raccoon Creek (intertidal zone nr. mouth, 26 Jul 1972, *Schuyler 4316*, PH), and the Christiana River (SW of Wilmington, top of muddy clayey slope to upper tidal marsh opp. mouth of White Clay Cr., 28 Sep 1972, *Ferren 1153*, PH). The only local collection from outside the Delaware system is from the Raritan River (tidal flats opp. New Brunswick, very local, Oct 1918, *Mackenzie*, NY).

Eleocharis obtusa var. *peasei* is often associated with *Scirpus smithii* var. *smithii* on firm, sandy gravelly or peaty clayey substrates toward the high tide limit. It also grows on less compact mud-covered substrates with *Heteranthera reniformis* R. & P. and other species characteristically found on such substrates.

Eleocharis obtusa var. *peasei* seems to be more common than its representation in herbaria prior to 1970 indicates. Collected along the Delaware River once early in the 19th century (Philadelphia, *Nuttall*, PH) and again much later (on dredging at Camden, Sep 1899, *Heritage*, PH), var. *peasei* was until recently only known from a few localities at and above Philadelphia and Camden. However we have recently collected it at numerous localities in the Delaware system, and have extended its collected range to the state of Delaware (specimen cited above). Either collectors have overlooked var. *peasei* or ecological changes have occurred enabling this species to become a more conspicuous element of the intertidal flora.

7. **Sagittaria subulata** (L.) Buch., Fig. 9

Plants of this species with linear or narrowly oblong leaves are designated as var. *subulata* and mostly grow in freshwater to brackish water tidal mud from Florida and Alabama north to Massachusetts. Submerged plants with prolonged leaves and inflorescences are designated as *Sagittaria subulata* var. *gracillima* (S. Wats.) J. G. Sm. and grow in the deep water of streams over much of the same range (Fernald 1950). All local collections of *S. subulata* are from the Delaware system except for one from the Raritan River (tidal shores, opp. New Brunswick, Oct 1918, *Mackenzie*, PH). All are var. *subulata* except for one 19th century collection from Bristol, Pennsylvania, lacking precise locality data.

Along tidal portions of the Delaware River, *S. subulata* has been collected from just below Pennsbury Manor State Park, Pennsylvania (muddy shore, 21 Jul 1972, *Ferren 950*, PH), and Bordentown, New Jersey (mouth of Crosswicks Cr., steep open gravelly slope, 24 Sep 1971, *Ferren 811*, PH), downstream to Wilmington, Delaware (Edgemoor, duPonts Wharf, 21 Jul 1894, *E. Tatnall*, DELS), and near Bridgeport, New Jersey (shore, 12 Aug 1905, *S. Brown*, PH). Along the Delaware River above its upstream tidal limit, two collections of *S. subulata* are known (PA: NW of Morrisville, shallow backwater pool, alluvial shore, 1 Nov 1931, *Long 35896*, PH; NJ: Lambertville, shallow water, sandy gravelly shore,

Lewis's Is., 29 Sep 1932, *Long 38586*, PH). Along tidal tributaries of the Delaware River, the collected range of *S. subulata* extends from Crosswicks Creek (Bordentown, mud flat just NE of RR bridge, 24 Sep 1971, *Ferren 810*, PH) and the Schuylkill River (mud, *C. E. Smith*, CHRB) to the downstream tributary systems of the Cohansey River (S of Bridgeton, muddy shore, 21 Oct 1936, *Long 59263*, PH) and Appoquinimink Creek (2 mi SE of Middletown, 16 Aug 1908, *Van Pelt & Long*, PH).

Pursh (1814) gave the earliest account of *S. subulata* in the local area as growing, "plentifully on the shores of the Delaware River near Philadelphia to the edge of the low water mark." Barton (1818) stated that it grew, "on the low, gravelly shores of the Delaware at low tide," and associated it with *Micranthemum micranthemoides* (Nutt.) Wettst., *Isoëtes riparia*, *Limosella subulata* Ives, *Eriocaulon parkeri* Robins., and *Elatine minima* (Nutt.) Fisch. & Mey. More recently, we have collected and observed *S. subulata* in (1) upper limits of mud flats dominated by *Nuphar*, (2) sandy lower limits of *Scirpus pungens*, (3) low areas of open muddy sandy marshes and shores dominated by *Zizania*, *Pontederia cordata* L., *Peltandra*, and *Nuphar* and associated with *Najas flexilis* (Willd.) Rostk. & Schmidt, *Zannichellia palustris* L., *Elatine americana* (Pursh) Arn., *Sagittaria graminea*, *Callitriche* spp., and *Elodea* sp., and (4) mud-covered sandy shores toward the upper intertidal zone associated with *Sagittaria rigida*, *Sagittaria graminea*, *Cyperus rivularis*, *Juncus acuminatus*, *Eleocharis erythropoda* Steud., *Ludwigia palustris*, and *Isoëtes riparia*. At one transitional freshwater to to brackish water locality, *S. subulata* was found in dense mats with *Lilaeopsis chinensis* (L.) Ktze. in an open stand of *Spartina alterniflora* Loisel. (NJ: Fairton, mud-covered gravelly shore of Mill Cr., ca 1 mi below dam, 18 Aug 1972, *Ferren 1032*, PH).

In recent years, *S. subulata* has not been collected along the Delaware River below northeast Philadelphia (Torresdale, 12 Sep 1972, *Ferren 1082*, PH) and Delanco, New Jersey (SW end of Hawk Is., just above Rancocas Cr., 19 Aug 1971, *Ferren 740*, PH), even though it was previously known from many localities along the river far below these points. The last time *S. subulata* was collected farther downstream was in 1923 at Westville, New Jersey (mouth of Big Timber Cr., 8 Aug 1923, *Long 28355*, PH). Thus the present range and distribution of this species along the Delaware River is considerably reduced from what it was in the past.

8. **Limosella subulata** Ives, Fig. 10

This species is found along fresh to brackish tidal shores and sandy margins of pools and ponds behind coastal beaches and dunes from Newfoundland to North Carolina. Locally it is restricted to fresh tidal portions of the Delaware system, and pools and ponds along the New Jersey coast. Pennell (1935) designated the coastal plants as *Limosella subulata* f. *maritima* (Raf.) Penn.

In the Delaware system, the collected range of *L. subulata* extends from Burlington, New Jersey (shores of Barrack Cr., PH), and near Andalusia, Pennsylvania (Mud Is. in Delaware, Aug 1898, *Williamson*, PH), to Camden, New Jersey (banks of River Delaware opp. Philadelphia, 1848, *James*, PH), and just north of Wilmington, Delaware (Belleview, brackish mud, banks of Delaware, 1 Oct 1873, *Commons*, PH). The Card Catalog of the Society of Natural History of Delaware records two collections farther south (Brandywine Cr. below RR bridge, 1867, *Canby*; banks of Delaware R. nr. duPonts wharf, 1873, *Commons*). There also is an early collection of *L. subulata* from along the Schuylkill River near its mouth (Penrose ferry, above the

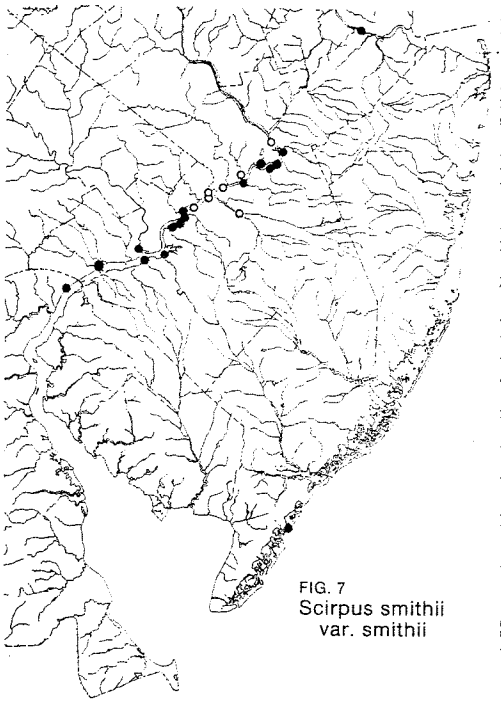

FIG. 7
Scirpus smithii
var. smithii

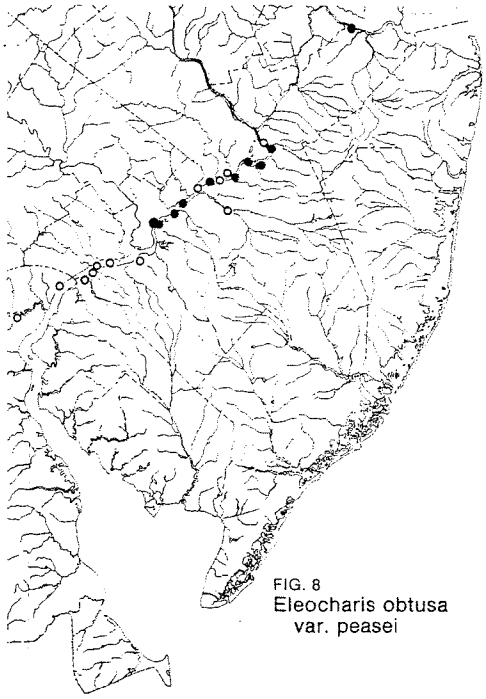

FIG. 8
Eleocharis obtusa
var. peasei

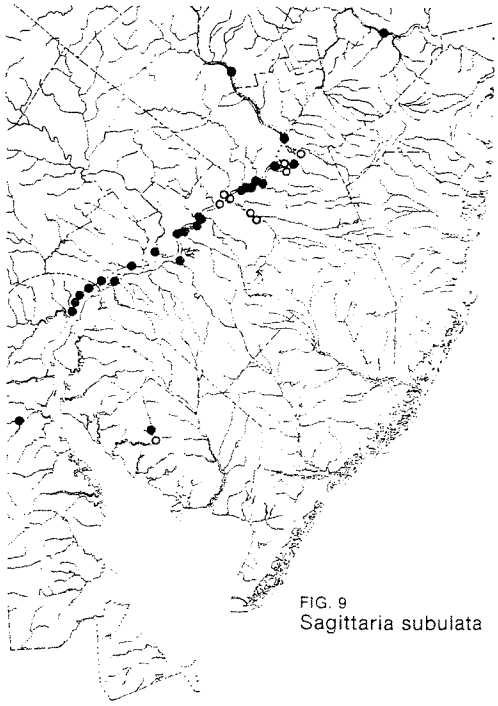

FIG. 9
Sagittaria subulata

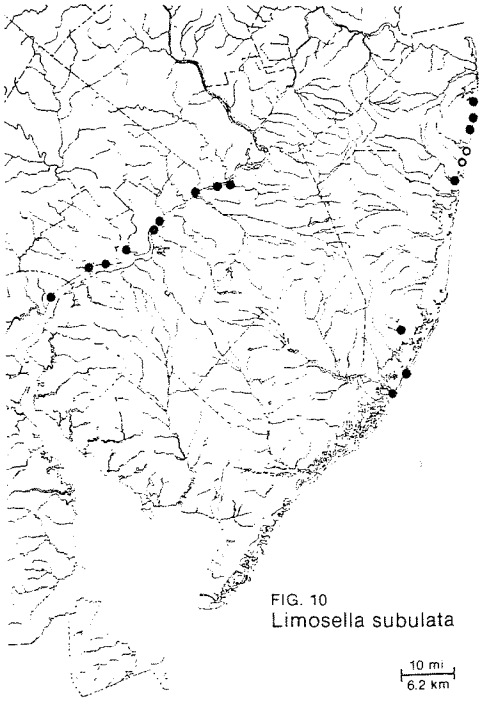

FIG. 10
Limosella subulata

bridge, 20 Nov 1866, ex herb. C. E. Smith, PH).

Along the coast of New Jersey, *L. subulata* has been collected between Long Branch (*Read*, PH) and the southern end of Long Beach Island (Sea Haven, 20 Oct 1907, *Long & Stone 9585*, PENN). In Sea Girt at Wreck Pond we collected it in shallow water with *Eleocharis parvula* (R. & S.) Link and *Pluchea odorata* (L.) Cass. (muddy bottom adjacent to fill, 9 Sep 1971, *Ferren 768*, PH). Nearby at Lake Como it grew along the margin with *Elatine minima* and in shallow water with *Najas guadalupensis* (Spreng.) Magnus and *Myriophyllum tenellum* Bigel. (sandy bottom and limits of water level, probably slightly tidal, 9 Sep 1971, *Ferren 775a & b*, PH). Most other collections of *L. subulata* from coastal New Jersey lack habitat information.

Nuttall (1817) first reported *L. subulata* in the Delaware system as growing on the, "miry and gravelly banks of the Delaware, near Kensington [Philadelphia]," in association with *Crassula aquatica* (L.) Schoen., *Elatine minima, Micranthemum micranthemoides*, and *Isoëtes riparia*. Of these species, *L. subulata* is ecologically most closely associated with *Crassula aquatica*. Long collected both species near Andalusia in 1917 and Canby reportedly collected them in Wilmington near the mouth of Brandywine Creek in 1867. Published distribution maps of *L. subulata* (Pennell 1935) and *C. aquatica* (Fassett 1928) show that these species have similar geographical ranges as well as ecological affinity. The discussion under *Crassula aquatica* has further remarks on *L. subulata's* association with this and other species.

Although Barton (1818) reported that *L. subulata* was, ". . . abundant on the shores of the Delaware at low tide . . . ," and although it was collected numerous times throughout the 19th century, it has only been collected twice in the Delaware system during the 20th century (PA: Andalusia, sandy muddy tidal shore, mouth of Poquessing Cr., 23 Oct 1917, *Long 18255*, PH; NJ: Edgewater Park, sandy gravelly tidal shore along Delaware R., 3 Nov 1916, *Long 15526*, PH). Many localities where it was previously collected now contain land fill and dredging spoil, which may account for the elimination of *L. subulata* from the Delaware system.

9. **Crassula aquatica** (L.) Schoenl., Fig. 11

Widespread but local in North America, this species occurs in both intertidal zones and other wet situations (Fernald 1950). Locally, however, collections have been restricted to fresh tidal portions of the Delaware system. The farthest upstream collections are from Andalusia, Pennsylvania (sandy muddy shore, mouth of Poquessing Cr. on Delaware R., 23 Oct 1917, *Long 18257*, PH; Andalusia marsh, 23 Oct 1918, *Stone*, PENN). The only other known local collections were made during the early 19th century in Philadelphia (W. Kensington, banks of the Delaware, inundated by the tide, Jul 1817, *Nuttall*, PH; [probably collected at the same time and place as Nuttall's specimen] *Collins*, PH). There is, however, a report by Tatnall (1946) that *C. aquatica* was, ". . . collected by *Canby* in 'Brandywine Creek above (Penna.) railroad bridge,' Wilmington, in 1867."

Available data indicate that *C. aquatica* occurs or occurred in similar ecological conditions throughout the portion of its range near the east coast of North America. Nuttall (1817) stated that *C. aquatica* grew along the, "miry, gravelly shore of the Delaware River above Kensington," with *Limosella subulata* and *Micranthemum micranthemoides*. Barton (1818) added that *C. aquatica, Isoëtes riparia, Limosella subulata, Elatine minima, Eriocaulon parkeri*, and *Sagittaria subulata* grew with *Micranthemum micranthemoides* near Kensington. On collections from Andalusia (cited

above), Long indicated that *C. aquatica* was growing on bases of stalks of *Zizania*, a few inches above the mud, and the largest were about the roots of *Zizania*. Other published accounts (Ives 1817; Engelmann 1882) and specimen data indicate an association among *C. aquatica* and the above mentioned species in Quebec, New Brunswick, Connecticut, and Maryland.

Although Barton (1818) reported that *C. aquatica* was abundant above Kensington, and although numerous duplicates collected by Long indicate that it was common at Andalusia a century later, it has not been collected in the Delaware system for over 50 years. Stone's label accompanying the last local collection of *C. aquatica* (cited above) included the statement, "Exactly a year after Mr. Long's rediscovery, I visited the spot with him and we could find only this one plant." Today there is an apartment complex built over the Andalusia locality. *Crassula aquatica* apparently no longer grows along the Delaware River.

10. **Micranthemum micranthemoides** (Nutt.) Wettst., Fig. 12

This species is restricted to fresh tidal river shores from the Hudson River in New York to the Chickahominy River in southeastern Virginia. In the Delaware system, collections of *M. micranthemoides* are known from southeast of Tullytown, Pennsylvania (sandy muddy tidal shore along Delaware R., 6 Sep 1927, *Long 33785*, PH), and Burlington, New Jersey (Barrack Cr., [*Conrad,*] PH), downstream to near Claymont, Delaware (tidal shore of Delaware R., 3 Oct 1866, *Commons*, PH), and below Gloucester City, New Jersey (river swamp above Red Bank, 19 Jul 1868, *Diffenbaugh*, PH). Elsewhere in the local area it has been collected once along the Raritan River (tidal flats opp. New Brunswick, Oct 1918, *Mackenzie*, CHRB, NY).

When he originally described this species from along the Delaware River near Kensington, Nuttall (1817) gave the substrate as, "gravelly banks." Subsequent collectors have recorded the substrate as mud, sandy muddy, sandy, or sandy gravelly at various other localities in the Delaware system. At the locality near Kensington, Nuttall (1817) also reported that *Micranthemum micranthemoides* grew with *Crassula aquatica, Limosella subulata, Elatine americana,* and *Isoëtes riparia*. At the same locality, Barton (1818) reported it also grew with *Eriocaulon parkeri* and *Sagittaria subulata*. Two 19th century specimen labels indicate *M. micranthemoides* was associated with *Isoëtes riparia, Scirpus smithii,* and *Eriocaulon parkeri* near the mouth of the Schuylkill River (Penrose ferry, abundant in tidal mud, 28 Oct 1866, *C. E. Smith,* PH) and with *Elatine americana* and *Scirpus smithii* along the Delaware River in Camden (tidal mud, 7 Oct 1877, *Parker*, CHRB). In the early 20th century, Pennell (1924 and 1935) indicated that *M. micranthemoides* was abundant but local on tidal flats and sandy gravelly shores of the Delaware River and grew with *Lindernia dubia* and *Ludwigia palustris*.

Although *M. micranthemoides* apparently was locally abundant at numerous localities along the Delaware River during the 19th and early 20th centuries, the last collections were made almost 50 years ago near Eddington, Pennsylvania (sandy fill at Delaware R., 10 Sep 1932, *Fogg 5339,* PENN; sandy muddy tidal shore along Delaware R., 24 Sep 1932, *Long 38542*, PH; mouth of Neshaminy Cr., muddy tidal shore, 9 Oct 1932, *Pennell 16131*, GH, PH) and it is now apparently extirpated from the Delaware system.

11. **Elatine americana** (Pursh) Arn., Fig. 13

In the local area this widespread species is nearly restricted to tidal habitats although its range extends inland to Missouri and Oklahoma (Fernald 1950). A closely related species, *Elatine minima* (Nutt.)

Fisch. & Mey., also occurs locally but is more common in non-tidal habitats.

In the intertidal zone of the Delaware River, *E. americana* has been collected from southwest of Fieldsboro, New Jersey (sandy shore, 1 Sep 1923, *Long 29163*, PH), and southeast of Eddington, Pennsylvania (sandy muddy shore, 9 Oct 1932, *Long 38768*, PH), downstream to Camden, New Jersey (mud, 7 Oct 1877, *Parker*, CHRB), and Bellevue, Delaware (mud, 8 Aug 1896, *Canby*, DELS). On tidal tributaries along the eastern side of the Delaware River, the collected range of *E. americana* extends from Crosswicks Creek (Bordentown, 15 Jul 1911, *Long 6049 & 6066*, PH) to the Maurice River (Millville, ca 1.5 mi N of Laurel Lake, sandy shore, 23 Aug 1973, *Ferren 1292*, PH) and the Manumuskin River (Port Elizabeth, muddy margin of cove, 8 Aug 1973, *Ferren 1274*, PH). On the western side of the Delaware River, the mapped range extends from the Schuylkill River (Woodl[ands], *P[ursh]*, PH) to Appoquinimink Creek (nr. Middletown, Noxontown Pond, 16 Aug 1908, *Bartram*, CHRB, PH). The only tidal locality for *E. americana* outside of the Delaware system is from the Raritan River (very local, opp. New Brunswick, Oct 1918, *Mackenzie*, PH). It also has been collected in non-tidal localities along the Lehigh River (Laurys, alluvium, 14 Aug 1956, *Schaeffer 52867*, PH) and Lake Hopatcong (24 Sep 1869, *Porter*, PH) in northern New Jersey. *Elatine minima* is locally abundant on tidal shores of the Great Egg Harbor River and reports of *E. americana* from ponds near the coast in Ocean County, New Jersey (Stone 1911) are probably erroneous since all specimens from these localities are *E. minima*.

Pursh (1814) stated that *E. americana* was, "inundated during its flowering time, in slow-flowing places of rivers in Pennsylvania." Barton (1818) reported that *E. minima* (which was confused with *E. americana* at that time) grew, "on the gravelly banks of the Delaware, subject to the overflowing of the tide, a little above Kensington, both on the Pennsylvania and New Jersey shores," and was associated with *Micranthemum micranthemoides*, *Isoëtes riparia*, *Crassula aquatica*, *Limosella subulata*, *Eriocaulon parkeri*, and *Sagittaria subulata*. Early collections of *Elatine* from the Delaware River occasionally contain both species, indicating they probably grew together in the preceding association. There are, however, many more collections of *E. americana* than *E. minima*.

On tributaries of the Delaware River, we have found *E. americana* growing on soft muddy, clayey peaty, and sandy substrates in freshwater to somewhat brackish water conditions associated with *Zizania*, *Peltandra*, *Pontederia*, *Nuphar*, and *Polygonum punctatum*. On low muddy substrates dominated by *Nuphar* and *Zizania*, *E. americana* grows with *Sagittaria subulata*, *Callitriche* spp., *Ludwigia palustris*, and *Sagittaria graminea*. On firmer substrates and/or higher in the intertidal zone, it grows with *Lindernia dubia*, *Ludwigia palustris*, *Cyperus rivularis*, *Polygonum punctatum*, *Scirpus smithii*, *Eriocaulon parkeri*, *Isoëtes riparia*, and *Gratiola virginiana* L. In somewhat brackish conditions, *E. americana* grows in lower muddy coves with *Gratiola virginiana* and *Sagittaria graminea* and less frequently on upper sandy shores with *Pluchea odorata*, *Scirpus pungens*, *Spartina alterniflora*, *Typha angustifolia*, *Aeschynomene virginica* (L.) BSP., and *Aster subulatus* Michx. Although *E. americana* occurs on various substrates and is associated with diverse plant species, in general the substrates are softer than those of most other intertidal plants.

Recent local collections of *E. americana* are only known from Rancocas Creek (Delran, upper limits of mostly barren clayey peaty creek-side escarpment to tidal marsh and low soft muddy areas towards edge of marsh, 8 Sep 1972, *Ferren 1075 & 1079*, PH;

Centerton, soft mud at edge of old bulkhead nr. mouth of streamlet, 16 Jul 1975, *Ferren 1415,* PH), a tributary of Alloway Creek (mud-covered gravelly point bar along Deep Run ca 1 mi W of Alloway, 4 Oct 1973, *Ferren 1327,* PH), the Maurice River, and a tributary of Appoquinimink Creek (open clayey muddy flat along Drawyer Cr. below Shallcross Lake, 30 Oct 1973, *Ferren 1315,* PH). *Elatine americana* has not been collected along the Delaware River for almost 50 years where its habitat has been altered by land fill and dredge spoil. On tributaries of the Delaware River, damming and subsequent lake production near the upstream limit of the tide probably have eliminated habitats where *E. americana* was previously collected (e.g., Big Timber Cr., Blackwood Lake, dam now out, exsiccating sandy shore, 4 Jun 1922, *Long 25742 & 25744,* PH).

12. **Eriocaulon parkeri** Robins., Fig. 14

This species of tidal shores from Quebec to North Carolina has been collected in freshwater to slightly brackish water intertidal zones of nearly all local river systems. Along the Delaware River, the collected range of *E. parkeri* extends from above Bordentown, New Jersey (shore, *Witte,* PENN), and Bristol, Pennsylvania (mud flats, 2 Oct 1926, *Benner 2897,* PH), downstream to near Bridgeport, New Jersey (shore, 12 Aug 1905, *Brown,* PH), and Bellevue, Delaware (muddy shore, 1 Oct 1873, *Commons,* PH). Along New Jersey tributaries of the Delaware River, the collected range of *E. parkeri* extends from Crosswicks Creek (Bordentown, 15 Jul 1911, *Long 6047,* PH) to the Maurice River (Millville, mud below dam, 5 Jul 1909, *Brown,* PH) and its tributaries. Along tributaries of the Delaware River in Pennsylvania and Delaware, its collected range extends from Common Creek (Tullytown, wet sandy shore, 6 Sep 1927, *Long 33804,* PH) to Broadkill Creek (Milton, border of Mill Pond, 17 Aug 1899, *Commons,* PH). Outside the Delaware system, *E. parkeri* has been collected from the margins of coastal ponds or small lakes and three coastal river systems between Belmar, New Jersey (Lake Como, 20 Sep 1934, *Edwards & Clausen 1419,* PENN), and Rehobeth, Delaware (sandy shores of brackish ponds, 27 Aug 1896, *Commons,* PH). Collections are known from one locality along the Metedeconk River (tidal shores, W of Mantoloking, 21 Sep 1912, *Mackenzie,* PH), and many localities in the Mullica system from Batsto (shore of Batsto Pond, 3 Sep 1944, *Koster C-9-4-5,* PH) to the vicinity of New Gretna (ca 1.4 mi N of Rt. 9, sandy peaty tidal shore of Bass R., 30 May 1973, *Ferren 1216,* PH) and Lower Bank (mud covered gravel of slightly brackish tidal shore of Mullica R., 5 Sep 1972, *Ferren 1052,* PH). In the Great Egg Harbor system, collections are known from Mays Landing (below Lake Lenape, sandy muddy tidal flats along branch of Great Egg Harbor R., 14 Oct 1971, *Ferren 850,* PH), Linwood (tidal mud, Patcong Cr., 4 Aug 1963, *Hirst 89,* PH), within one mile south of Catawba (sandy muddy tidal shore along Great Egg Harbor R., 6 Aug 1937, *Long 51219,* PH), and about two miles west of Corbin City (edge of mud-covered turf of *Spartina alterniflora & Zizania aquatica* tidal marsh along the Tuckahoe R., 4 Oct 1972, *Ferren 1177,* PH).

Barton (1818) reported that *E. parkeri* was, "On the gravelly shores of the Schuylkill opposite Lemon Hill, to be observed only at low ebb tide," and, "On the gravelly shores of the Delaware below high water mark, above Kensington . . . ," associated with *Isoëtes riparia, Micranthemum micranthemoides, Elatine minima,* and *Sagittaria subulata.* We have found *E. parkeri* growing on a variety of substrates and with diverse plant assemblages. Possibly a broader tolerance of substrate and other ecological conditions account for its wider distribution in the local area than

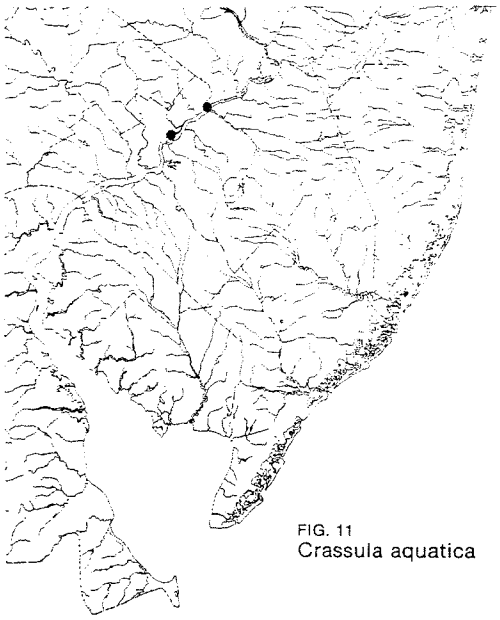

FIG. 11
Crassula aquatica

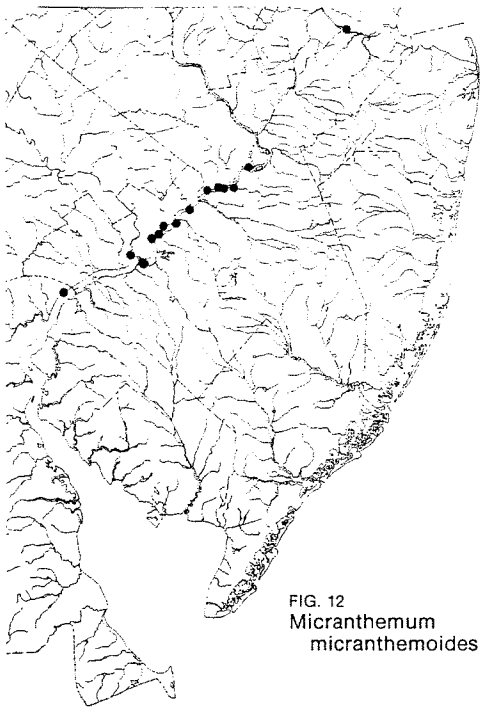

FIG. 12
Micranthemum micranthemoides

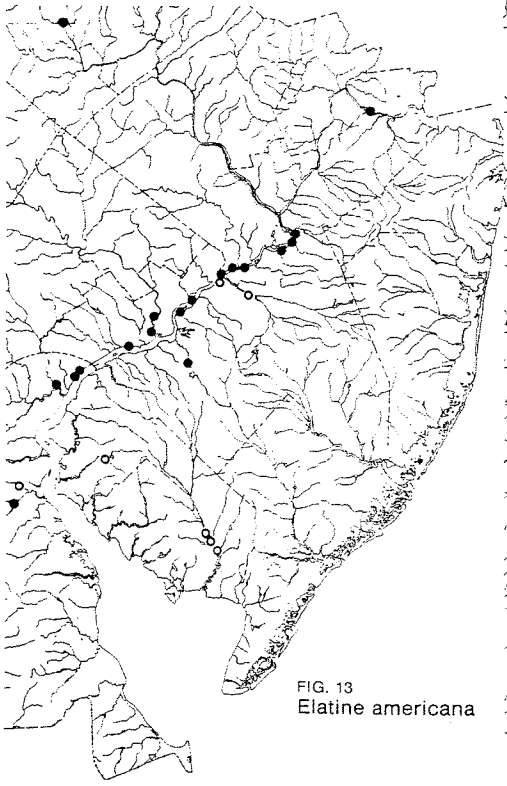

FIG. 13
Elatine americana

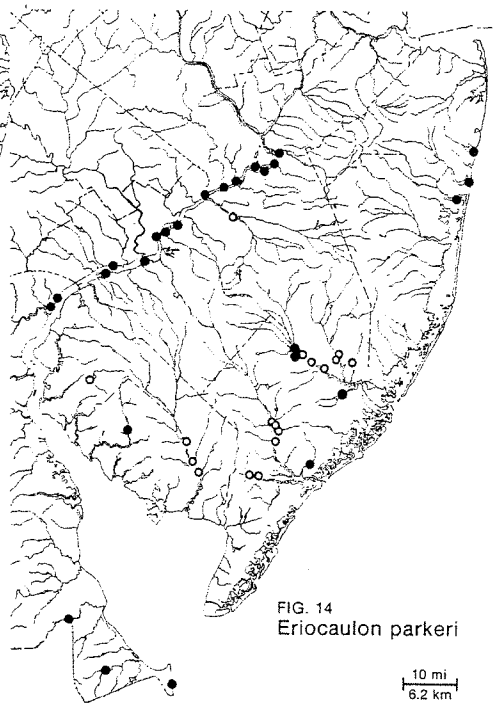

FIG. 14
Eriocaulon parkeri

10 mi
6.2 km

many of the other restricted intertidal plants.

Although *E. parkeri* reportedly was abundant along the Delaware River in the early 19th century (Barton 1818) and numerous collections were made later in the 19th and 20th centuries, it no longer can be found there. The last collection made along the Delaware River was from Bordentown, New Jersey (shores, 25 Sep 1927, *Witte,* CHRB), although a later collection was made near the river shore east of Eddington, Pennsylvania (shores of Neshaminy Cr. nr. its mouth, 24 Sep 1932, *Benner 4654,* PH). Elsewhere in the Delaware system, *E. parkeri* was recently collected at one locality along Rancocas Creek (Centerton, sandy muddy tidal shore, 17 Oct 1973, *Ferren 1357,* PH), and three localities in the Maurice system (Millville, NW of city park, peaty slope to SW tidal tributary of Maurice R., 19 Jul 1972, *Ferren 974,* PH; Buckshutem, sandy tidal slightly brackish shore of Maurice R., 18 Sep 1972, *Ferren 1131,* PH; ca 1.5 mi N of Laurel Lake, tidal shore of Maurice R., 23 Aug 1973, *Ferren 1365,* PH). Many recent collections have been made in the Great Egg Harbor and Mullica systems, but attempts to find it farther north along the coast of New Jersey have failed.

Dredging spoil and land fill have altered the habitat of *E. parkeri* along the Delaware River and undoubtedly have played a role in eliminating it, as has the damming of tidal Delaware River tributaries. Although it was collected in ponds formed by dams at Milton (specimen cited above) and Milford (pond W of RR station and 2nd pond W of RR station, 21 Jul 1908, *Van Pelt & Long,* PH, *Van Pelt,* PH), Delaware, these plants may not have persisted long after the formation of the ponds. *Eriocaulon parkeri* has not been collected in these ponds in recent time.

13. **Isoëtes riparia** Engelm. ex A. Br., Fig. 15

These variable plants, including those identified as *Isoëtes dodgei* A. A. Eat. and *Isoëtes saccharata* Engelm., occur from Quebec and Ontario south to Virginia (Fernald 1950). In the Delaware system, *I. riparia* has been collected upstream well beyond the limit of the tide where the plants generally have more discontinuous megaspore ridges than do plants collected in tidal conditions. The downstream limit of collections along the Delaware River is near Salem, New Jersey (2 mi SW of Harrisonville, 5 Nov 1934, *Long 45265,* PH), and just above Wilmington, Delaware (Bellvue, rivershore, 1 Oct 1873, herb. Commons, PH). On Delaware River tidal tributaries, collections have been made along Rancocas Creek (sandy muddy shore, 17 Oct 1973, *Ferren 1353,* PH), the Cohansey River (Bridgeton, sandy gravelly shore, 25 Oct 1936, *Long 49254 & 49265,* PH), Mill Creek (mud-covered gravel along shore, 18 Aug 1972, *Ferren 1037,* PH), the Maurice River (ca 1.5 mi N of Laurel Lake, clayey marsh, mouth of small creek, 28 Aug 1973, *Ferren 1298,* PH; ca .3 mi SE of Manantico Cr., sandy shore, 8 Aug 1973, *Ferren 1259,* PH), and the Mispillion River (Milford, pond at RR station, 21 Jul 1908, *Long,* PH). Outside the Delaware system, *I. riparia* has only been collected from one locality in the Mullica system (Green Bank, exposed at low tide on N side of Mullica R., 14 Jul 1940, *Edwards,* CHRB) and two localities in the Great Egg Harbor system along the Tuckahoe River (ca 3.5 mi W of Tuckahoe, open mud-covered sandy gravelly shore, 4 Oct 1972, *Ferren 1167,* PH; edge of muddy turf, ca 2 mi W of Corbin City, 4 Oct 1972, *Ferren 1175,* PH).

Nineteenth century botanical literature (Nuttall 1818; Barton 1818; Braun 1846 & 1847; Engelmann 1882) gives the substrate

of *I. riparia* as miry and gravelly, mud covering gravel, or gravel and mud. Associated plants mentioned in this literature are *Sagittaria subulata, Eriocaulon parkeri, Elatine minima, Limosella subulata,* and *Micranthemum micranthemoides*. More recently, we have found *I. riparia* on sand, gravel, and cobble substrates which may or may not be mud-covered, and associated with *Sagittaria graminea, Eleocharis erythropoda, Scirpus pungens, Ludwigia palustris, Lindernia dubia,* and *Bidens bidentoides*. In more local conditions, we also found *I. riparia* growing with *Scirpus smithii, Eleocharis obtusa* var. *peasei, Cyperus brevifolioides, Eriocaulon parkeri, Gratiola virginiana, Elatine americana, Spartina alterniflora, Polygonum punctatum,* and *Zizania aquatica*.

Nuttall (1818) stated that *I. riparia* was, "abundant along the inundated, gravelly and miry shores of the Delaware, near Philadelphia and other places." However, there are no 20th century Delaware River collections from Pennsylvania and Delaware below Philadelphia, and it has not been collected in New Jersey below Camden since 1934. Some of our recent Delaware River collections were oil-soaked and on gravelly substrates associated with dredging spoil. Apparently, more so than the species previously associated with it, *I. riparia* has endured alterations in its habitat. Nevertheless, our field work indicates its range along the Delaware river is much more limited now than it was in the past.

14. **Eleocharis olivacea** var. **reductiseta** (Schuyl. & Ferr.) stat. et comb. nov.,[1] Fig. 16

Plants of this variety have reduced smooth bristles attached to achenes in contrast to the longer retrorsely barbed bristles attached to achenes of plants of the typical variety. Variety *olivacea* grows in wet sands and peats from Nova Scotia to Florida and inland to Ontario, Minnesota, Ohio, Michigan, and Pennsylvania (Fernald 1950) while var. *reductiseta* is only known from tidal river systems in southern New Jersey. A collection reported as var. *reductiseta* from Fairfax County, Virginia (Schuyler and Ferren 1975) is *Eleocharis flavescens* (Poir.) Urban.

All collections of var. *reductiseta* are from river systems which drain the pine barrens except for one along the Delaware River at Delair, New Jersey (river shore, 24 Jul 1905, *S. Brown, Crawford & Van Pelt,* PH). Two collections are known from along the Maurice River (Manantico, sandy muddy shore, by old brickyard, 1 Nov 1936, *Long 49275,* PH; S of Manantico, sandy muddy shore, 20 Oct 1935, *Long 47869,* PH) and all other collections are from coastal river systems. Along the Mullica River, the collected range of var. *reductiseta* extends from below "The Forks" near Batsto (21 Aug 1910, *Long 4720,* PH) downstream to Herman (muddy flats, 3 Sep 1944, *Koster C5-9-7,* PH). On Mullica River tributaries, it has been collected along the Wading River (ca 1.2 mi N of the village of Wading River, mud-covered gravelly shore, 29 Aug 1971, *Ferren 751,* PH; W shore just above bridge for Rt. 542, 7 Jul 1975, *Ferren 1406,* PH) and Nacote Creek (Port Republic, below dam, 19 Aug 1962, *B. Hirst,* PH). Along the Great Egg Harbor River, the collected range extends from 1.5 miles southwest of Gravelly Run (mud, 30 Aug 1933, *Benner 5390,* PH) downstream to within one mile south of Catawba (sandy & muddy shore, 6 Aug 1937, *Long 51218,* PH). On the Tuckahoe River, a tributary of the Great Egg Harbor River, it was collected about 2.6 miles west northwest of Tuckahoe (4 Oct 1972, *Schuyler 4374,* PH).

[1] Based on *Eleocharis olivacea* f. *reductiseta* Schuyl. & Ferr., Bartonia No. 43: 46, 1975 (*Benner 5390,* PH, type).

Eleocharis olivacea var. *reductiseta* mostly grows on sand and gravel or mud-covered sand and gravel of freshwater to slightly brackish water intertidal zones. Occasionally it grows on peat. We have observed this plant in open situations or among plants of *Scirpus pungens*. It is associated with *Isoëtes muricata*, *Isoëtes riparia*, *Eriocaulon parkeri*, and *Lindernia dubia* in open situations. In stands of *Scirpus pungens* it is also associated with *Juncus acuminatus*, *Cyperus rivularis*, and *Eleocharis ambigens* Fern.

This variety was not recognized as a taxon until recently (Schuyler and Ferren 1975). Early collections were either mixed with typical *E. olivacea* or overlooked. The first collection was made in 1905 (*S. Brown* et al. cited above) and it was only collected nine times before 1960. However it is common along portions of the Wading River and locally abundant at a few places in the Mullica and Great Egg Harbor systems but probably no longer occurs along the Delaware River.

15. **Aeschynomene virginica** (L.) BSP., Fig. 17

This species occurs along freshwater to brackish water shores near the Atlantic coast from southern New Jersey to South Carolina (Beal 1977). In the local area, it is almost completely restricted to freshwater or slightly brackish water tidal shores of the Delaware, Great Egg Harbor, and Mullica systems.

Aeschynomene virginica has been collected along the Delaware River from Philadelphia (*Conrad*, PH) and Camden (ex herb. Wister, PH), downstream to Wilmington, Delaware (muddy bank, 31 Aug 1899, *Commons*, PH), and south of Pennsville, New Jersey (marsh S of Kelly's Point, 8 Oct 1934, *Long 44943*, PH). Keller & Brown (1905) also reported that it occurred farther downstream at and below Delaware City. Elsewhere in the Delaware system, late 19th century collections were made along Oldmans Creek (7 Aug 1892 & 5 Aug 1893, *Lippincott*, PH; 2 Aug 1893, *Heritage*, PH), and recent collections were made in the Maurice system (sandy shore just S of the mouth of the Manumuskin R. just below RR bridge at Manumuskin, 2 Aug 1975, *Ferren 1416*, PH). Keller & Brown (1905) also cite a location on Brandywine Creek near Shelpot, Delaware. One specimen with the locality recorded as Haverford, Pennsylvania (3 Aug 1875, *Eckfeldt*, PH), if correct, is the only local collection known from non-tidal conditions. In other New Jersey river systems, collections of *A. virginica* are known from one locality along the Wading River at the village of Wading River (sandy gravelly shore, 10 Sep 1914, *Long 10818*, PH; firm peaty edge of tidal marsh on S shore, 27 Sep 1974, *Ferren 1371*, PH), and one locality along the Great Egg Harbor River (border of tidal marsh within 1 mi S of Catawba, 6 Aug 1937, *Long 41232*, PH). There also is one collection from Cape May (River landing, 20 Sep 1894, *Mohr*, US).

In the local area, *A. virginica* grows on firm sandy gravelly substrates on upper tidal shores and in high peaty marshes. It has been found growing with *Peltandra*, *Pontederia*, *Sagittaria latifolia*, *Zizania*, *Scirpus pungens*, *Scirpus tabernaemontanii* Gmel., *Polygonum punctatum*, and *Sium suave*. In freshwater conditions, additional associated species are *Acorus calamus*, *Dulichium arundinaceum* (L.) Britt., *Carex stricta* Lam., *Cinna arundinacea* L., *Leersia oryzoides* (L.) Sw., *Juncus acuminatus*, *Polygonum arifolium*, *Polygonum sagittatum*, *Hypericum virginicum* L., *Hypericum mutilum* L., *Impatiens capensis*, *Helenium autumnale* L., and *Bidens laevis*. In slightly brackish conditions, it grows with *Typha angustifolia*, *Spartina alterniflora*, *Pluchea odorata*, *Amaranthus cannabinus*, and *Aster subulatus*. On more open sandy gravelly shores, *Elatine americana*, *Ludwigia pa-*

lustris, Lindernia dubia, and *Gratiola virginiana* occur as undergrowth (Ferren 1976).

First reported from the local area by Pursh (1814) and collected several times in the vicinity of Philadelphia in the early 19th century, the only 20th century collections of *A. virginica* from the Delaware system are Long's 1934 collection at Kelly's Point and Ferren's 1973 and 1975 collections along the Maurice and Manumuskin rivers. Unlike most other freshwater tidal species, it has never been collected along the Delaware River above Philadelphia and Camden. It is unlikely that *A. virginica* now occurs anyplace along the Delaware River since many upper tidal marshes have been filled. However, we suspect that this species is more common than collections indicate along downstream tributaries of the Delaware River and in coastal river systems. It can be easily overlooked among other tall plants characteristic of upper tidal shores and marshes.

16. **Zizania aquatica** L., Fig. 18

This species commonly occurs in the freshwater to slightly brackish water intertidal zones of rivers from Maine to Florida. It also grows inland along rivers and lakes in the northern United States and southern Canada to Indiana and Illinois (Dore 1969). Locally *Z. aquatica* is abundant in the freshwater to slightly brackish water portion of every river system. It is also known from non-tidal localities where, in most instances, we suspect the plants were introduced as food for waterfowl.

Along tidal portions of the Delaware River the collected range of *Z. aquatica* extends from Trenton, New Jersey (marshes, 26 Sep 1911, *Long 17826,* PH), and Tullytown, Pennsylvania (7 Aug 1899, ex herb. Fretz, PH), downstream to north of Penns Grove, New Jersey (marsh, 9 Aug 1935, *Fogg 9327,* PH), and Augustine Beach, Delaware (marsh, 3 Aug 1916, *Pennell 7797,* NY). Along tidal tributaries of the Delaware River, collections are known from Crosswicks Creek in New Jersey (Bordentown, 15 Jul 1911, *Long 6038,* PH) and Scott's Creek in Pennsylvania (Falls Tp., 1 Sep 1921, *Benner 1759,* PH) downstream to the vicinity of West Creek in New Jersey (Eldora, 10 Aug 1915, *O. H. Brown,* PH) and Swan Creek in Delaware (ca 1.2 mi NE of Milford City limits, 28 Jun 1973, *Ferren 1219,* PH). Outside of the Delaware system, *Z. aquatica* has been collected along the Metedeconk River (2 Sep 1890, *Lighthipe,* NY), Toms River (7 Aug 1907, *W. Stone,* PH), the Mullica River from the mouth of the Batsto River (below "The Forks," 21 Aug 1910, *Long 4726,* PH) downstream to Lower Bank (scattered among *Spartina alterniflora,* sandy gravelly shore just E of bridge, 5 Sep 1972, *Ferren 1057,* PH), the Wading River (*Ferren 1370* cited below), the Bass River (*Ferren 1218 & 1252* cited below), Landing Creek (soft mud of open *Peltandra* flat, Gloucester Landing, 27 Sep 1974, *Ferren 1385,* PH), the Great Egg Harbor River from Mays Landing (below dam, 28 Aug 1910, *W. Stone,* PH) downstream to within one mile south of Catawba (marsh, 6 Aug 1937, *Long 51215,* PH), and the Tuckahoe River from Head of River (sandy bank, 4 Oct 1972, *Ferren 1170,* PH) downstream to Marshallville (firm peaty upper edge of marsh along Mill Cr., 4 Oct 1972, *Ferren 1164,* PH).

Zizania aquatica is most abundant on soft mud flats where it frequently grows in large pure stands. Such stands are commonly found in dock areas, along bulkheaded shores, and in abandoned dredge coves where silt is accumulating. On mud-covered gravelly shores and bars, *Elodea nuttallii* (Planch.) St. John, *Zannichellia palustris, Najas flexilis, Sagittaria graminea,* and *Sagittaria subulata* commonly grow among plants of *Zizania.* In freshwater tidal marshes along Delaware River tributaries, *Z. aquatica* grows on firmer peaty substrates with *Sagittaria latifolia,*

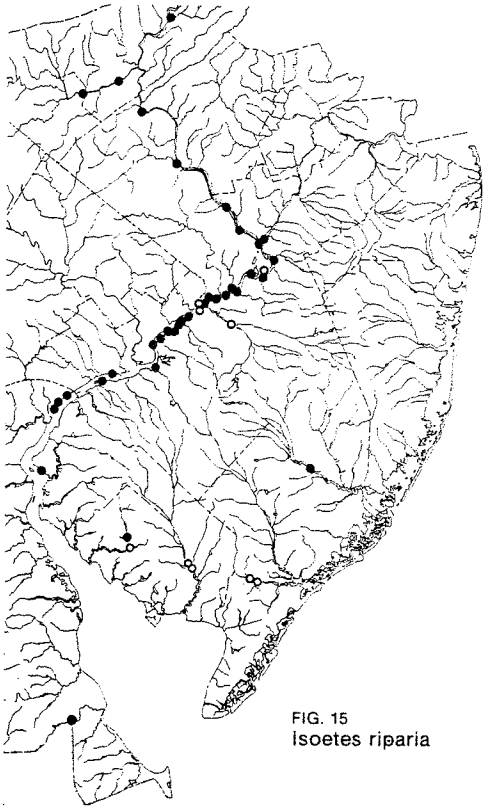

FIG. 15
Isoetes riparia

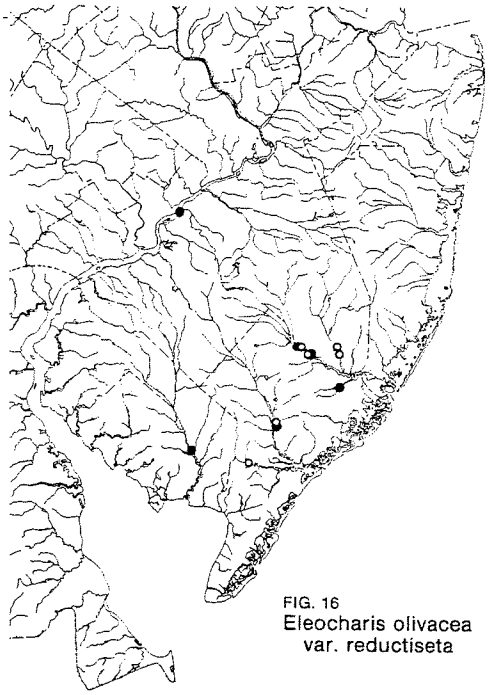

FIG. 16
Eleocharis olivacea
var. reductiseta

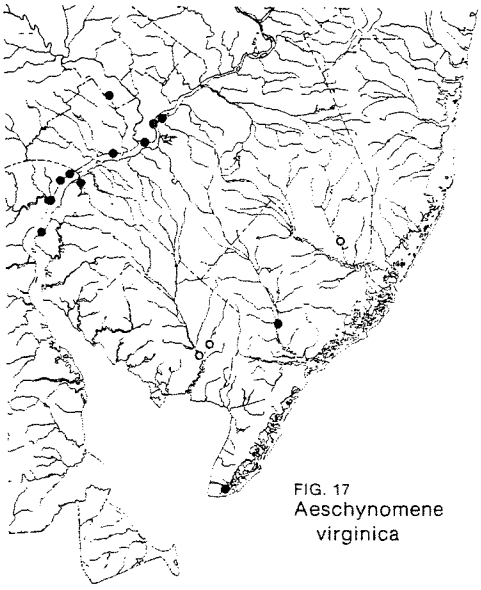

FIG. 17
Aeschynomene
virginica

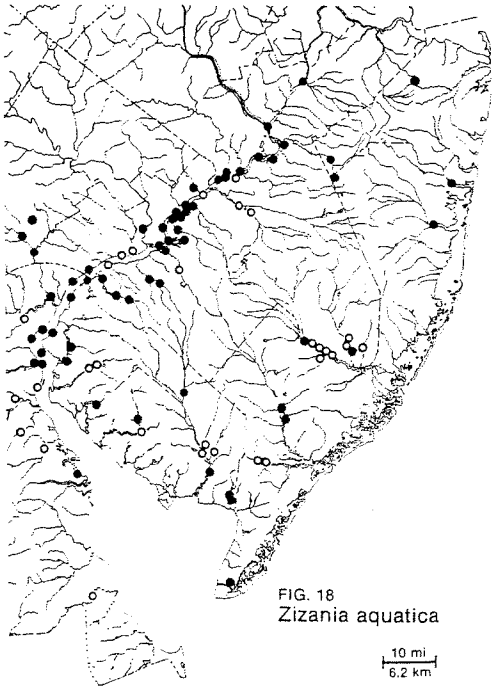

FIG. 18
Zizania aquatica

Peltandra, *Pontederia*, *Amaranthus cannabinus*, *Nuphar*, *Polygonum punctatum*, and *Bidens laevis* among others. Additional species associated with it in brackish marshes are *Sagittaria calycina* Engelm., *Scirpus cylindricus*, *Eleocharis ambigens*, and *Spartina cynosuroides* (L.) Roth. On compact sand and gravel shores, *Z. aquatica* grows scattered among plants of *Scirpus pungens* in freshwater conditions and among plants of *Scirpus pungens* and *Spartina alterniflora* in brackish conditions.

At two localities in the Mullica system, flaccid elongate plants of *Z. aquatica*, which root at the nodes and have very long lemma awns, grow submerged in shallow water at low tide (Ferren and Good 1977). In the Wading River near the village of Wading River, these plants are associated with *Scirpus subterminalis* Torr. (below low tide in 2–5 ft of water, soft muddy bottom, 27 Sep 1974, *Ferren 1370*, PH). Along the Bass River north of New Gretna, such plants are associated with *Ceratophyllum echinatum* Gray, *Najas flexilis*, and *Potamogeton pectinatus* L. at low tide (soft muddy edges, 30 May 1973, *Ferren 1218*, PH) and with *Scirpus subterminalis* and *Potamogeton epihydrus* Raf. below low tide (muddy gravelly channel, 30 May 1973, *Ferren 1252*, PH).

Although *Z. aquatica* was rarely collected along the Delaware River during the first half of the 19th century and only infrequently thereafter, Barton (1818) stated that it grew in profusion here. Most late 19th and early 20th century collections are from protected areas along the river or from tributaries, which is where the greatest concentrations of *Zizania* are in the Delaware system today. Although collected only once prior to 1900 in coastal New Jersey river systems, it probably was as common and widespread then as it is there today. Along the Delaware River, the deposit of dredging spoil and landfill has eliminated extensive stands of *Zizania* such as those once found in the vicinity of Tullytown and Essington, Pennsylvania. The damming of rivers and creeks in such places as Toms River, Batsto, Mays Landing, and Millville has also affected its local distribution. Despite such alterations of its habitat, *Z. aquatica* is still common along our local rivers and is often locally abundant and invades areas that agrade above low tide through siltation.

17. **Scirpus cylindricus** (Torr.) Britt., Fig. 19

Restricted to brackish streams and rivers along the Atlantic coast from Maine to Georgia (Schuyler 1975), this species is known from every major river system in the local area. Along the Delaware River, collections are restricted to the vicinity of Salem, New Jersey (marsh 2 mi SW of Harrisonville, 5 Nov 1934, *Long 45263*, PH; ca 3.8 mi SW of Salem, marsh NE of Elsinboro Point, 15 Aug 1972, *Schuyler 3329*, PH) and between Wilmington (muddy banks, 21 Jul 1866, *Commons*, PH) and Collins Beach (1866, *Commons*, NY) in Delaware. Along Delaware River tributaries in Delaware, its collected range extends from Drawyer Creek (N of Odessa, edge of brackish marsh, 3 Oct 1973, *Ferren 1369*, PH) to Swan Creek (ca 2.2 mi NE of Milford, brackish marsh, 28 Jun 1973, *Schuyler 4388*, PH). Along Delaware River tributaries in New Jersey, it has been collected from Mannington Creek (firm peaty upper tidal marsh ca 3 mi NE of Salem, 15 Aug 1972, *Ferren 1025*, PH) to the Maurice River (firm peaty upper tidal marsh ca .35 mi N of Manantico Cr., Millville, 8 Aug 1973, *Ferren 1264*, PH). In coastal New Jersey river systems, collections are known from the South River (Sayreville, 15 Aug 1916, *Wiegmann*, NY), the Wading River (NW of bridge for rt. 542, just below high tide level, 1 Sep 1971, *Schuyler 4282*, PH), the Merrygold Branch of the Wading River (adjacent to bridge for rt. 542, nr. upper tidal limit, 3

Aug 1972, *Schuyler 4320*, PH), the Mullica River (nr. bridge to Lower Bank, locally abundant in marsh, 1 Sep 1971, *Schuyler 4286*, PH; sandy muddy shore, Clarks Landing, 27 Sep 1974, *Ferren 1386*, PH), Landing Creek (ca 2 mi SW of Lower Bank, Gloucester Landing, firm peaty marsh, 27 Sep 1974, *Ferren 1384*, PH), the Great Egg Harbor River (peaty upper tidal marsh along E bank of Miry Run, Catawba, 20 Oct 1972, *Ferren 1203*, PH), and a tributary of the Tuckahoe River (marsh along Mill Cr. ca 1.25 mi WNW of Tuckahoe, *Schuyler 4371*, PH). In the freshwater tidal marshes of the Delaware River, *S. cylindricus* is replaced by the closely-related *Scirpus fluviatilis*, and in the more saline portions of the Delaware and other river systems, it is replaced by the closely-related *Scirpus robustus*.

The affinity of *S. cylindricus* for low and moderate salinities is indicated by its limited range in each river system. It generally occurs in the firm peaty upper margins of marshes but occasionally occurs in more sandy or muddy substrates along the river edge of these marshes. We have frequently found *S. cylindricus* along road embankments and other high areas in marshes resulting from construction activity.

Along the upper margins of slightly brackish marshes, *S. cylindricus* often grows with *Spartina cynosuroides* and *Typha angustifolia*. Other wetland species found with it in this habitat include *Osmunda regalis* L., *Carex stricta*, *Eleocharis ambigens*, *Zizania aquatica*, *Acorus calamus*, *Lobelia cardinalis* L., *Hibiscus moscheutos*, *Toxicodendron radicans* (L.) Kuntze, *Cephalanthus occidentalis*, and *Rosa palustris*. Along sandy river edges of marshes *S. cylindricus* is commonly associated with *Spartina alterniflora* and *Scirpus pungens*. Along more muddy shores, *Peltandra*, *Polygonum punctatum*, and *Sagittaria calycina* also grow with *S. cylindricus*.

Scirpus cylindricus was first collected locally in 1866 at Wilmington and Collins Beach in Delaware (specimens cited above). It was not collected again until 1916 (DE: New Castle Co.: swale of brackish marsh, 3 Aug 1916, *Pennell 7809*, PH). Perhaps because it is easily confused with related species, frequently lacks an inflorescence, and has a restricted habitat, *S. cylindricus* was rarely collected until recently. It was unknown in the Mullica and Great Egg Harbor river systems until we began searching for it in the proper habitat. Although *S. cylindricus* is infrequent to rare in local river systems, it often is locally abundant. This frequency and abundance were probably about the same in the past, although this is difficult to interpret from its collecting history. Except for the potential loss of its restricted habitat through damming of tributaries or dumping on marshes, both of which have occurred in the past to a limited extent in brackish marshes, there are no obvious adverse impacts affecting the habitat of this plant. Actually, judging from its occurrence along road embankments, some of man's activity is beneficial to *S. cylindricus*.

18. **Sagittaria calycina** Engelm., Fig. 20

Variously treated as *Lophotocarpus spongiosus* (Engelm.) J. G. Sm. and *Lophotocarpus calycinus* (Engelm.) J. G. Sm. (Fernald 1950), as *Sagittaria montevidensis* Cham. & Schlecht, and *Sagittaria spathulata* (J. G. Sm.) Buch. (Gleason 1952), and as *Sagittaria montevidensis* ssp. *spongiosa* (Engelm.) Bog. and *Sagittaria montevidensis* ssp. *calycina* (Engelm.) Bog. (Bogin 1955), we prefer recognizing *S. calycina* as a wide ranging North American species separable from *S. montevidensis*. Near the Atlantic coast, *S. calycina* is restricted to brackish water and occasionally freshwater tidal shores and marshes from New Brunswick to North Carolina (Bogin 1955; Beal 1977).

In the Delaware system, the collected range of *S. calycina* extends from freshwater localities west of Stevens, New Jersey (below River Rd., 25 Jul 1972, *Ferren 990*, PH), and at Bristol, Pennsylvania (mouth of Mill Cr., 12 Jul 1972, *Ferren 942 & 944*, PH), downstream to brackish water localities along the tributaries of the Cohansey River (NJ: ca .7 mi S of Bridgeton, mouth of Rocaps Run, 8 Oct 1972, *Ferren 1039*, PH) and Swan Creek (DE: ca 1.2 mi NE of Milford city limit, 28 Jun 1973, *Ferren 1223*, PH). With the exception of freshwater localities in Bucks County, Pennsylvania, and Burlington County, New Jersey, all localities in the Delaware system are in brackish water (see Fogg 1936, Adams 1938, and Ferren 1974 for further distributional data). Despite extensive searching, we have not been able to find *S. calycina* along the Maurice River. In New Jersey river systems outside the Delaware system, *S. calycina* was collected in the Raritan system at Sayreville (tidal mud, 7 Oct 1906, *Mackenzie 2506*, NY), and recently in the Mullica system where all collections were made after 1965. Its collected range along the Mullica River extends from the vicinity of Lower Bank (low open muddy areas of brackish marsh below bridge, 1 Sep 1971, *Ferren 764*, PH) downstream to the northwest end of Hog Island (soft peaty mud of open *Peltandra* marsh, 6 Jul 1972, *Ferren 927*, PH). On Mullica River tributaries, collections are known from along the Wading River (low open muddy area nr. low tide just N of rt. 542, 29 Aug 1971, *Ferren 756*, PH), the Merrygold Branch (low open muddy areas of brackish marsh just NW of Rt. 542, 29 Aug 1971, *Ferren 750*, PH), Nacote Creek (Port Republic, small stream in tidal marsh, 4 Aug 1965, *Cavileer 7*, PH), and Landing Creek (ca 2 mi SW of Lower Bank, soft mud of open *Peltandra* flat, 27 Sep 1974, *Ferren 1383*, PH). Despite extensive searching for *S. calycina* in the Great Egg Harbor River system, we have not found it there.

The habitat of *S. calycina* in the Delaware system was described by Ferren (1974). In the Mullica system it grows in similar conditions: low open marshes and shores of soft peat or more firm clayey mud where the dominant plant species usually is *Peltandra virginica*. Here *S. calycina* is occasionally associated with scattered plants of *Scirpus pungens, Zizania aquatica, Spartina alterniflora,* and *Pluchea odorata*. Going from upstream less saline localities to downstream more saline localities, there are changes in altitudinal zonation of *S. calycina* in the intertidal zone. At upstream localities, it grows near the limit of low tide and species generally found in freshwater (e.g., *Eriocaulon parkeri* and *Lindernia dubia*) grow above it. At downstream localities, *S. calycina* grows higher in the intertidal zone above plants generally associated with brackish conditions (e.g., *Lilaeopsis chinensis*).

Sagittaria calycina was first collected locally in 1860 near Wilmington, Delaware (muddy shores Shelpot Cr., 1860, *Tatnall*, NY). Except for additional 19th century specimens collected in the vicinity of Wilmington, all local collections of this species have been made in the 20th century and many in very recent time. The lack of early collections is probably because botanists overlooked its restricted habitat and did not actively botanize downstream tributaries of the Delaware River until the 20th century. Late discoveries of *S. calycina* in the Mullica system also probably reflect the recent thorough collecting of intertidal plants and not the recent establishment of this species. However, its recent discovery (Ferren 1974) in more heavily botanized freshwater portions of the Delaware system indicates it has recently and perhaps temporarily extended its range upstream. In most situations where we've collected *S. calycina* it is locally abundant. Although diking has

eliminated some populations of this species, its present day distribution and abundance probably are not much different now than they were in the past.

19. **Lilaeopsis chinensis** (L.) Ktze., Fig. 21

Restricted to brackish tidal shores from Nova Scotia to Florida and Mississippi, this species grows in the most saline and seaward habitats of the species included in this study. It has been collected along the Delaware River from 4 miles south of New Castle, Delaware (shore, Hamburg Cove, 5 Dec 1934, *E. L. Larsen 869,* PENN), and south of Pennsville, New Jersey (mud, 3 Oct 1934, *Fogg 7567,* PH, PENN), downstream to below Fraland Beach, Delaware (16 Sep 1934, *Larsen 836,* PENN), and north northwest of Sea Breeze, New Jersey (tributary along Delaware Bay, 28 Oct 1934, *Long 45209,* PH). Along Delaware River tributaries, collections are known from the Appoquinimink River in Delaware (Odessa, sandy gravelly shore below bridge, 3 Oct 1973, *Ferren 1367,* PH), and from the Salem River (edge of *Spartina alterniflora* turf ca .75 mi SE of Delaware R., 25 Aug 1971, *Ferren 745,* PH), the Cohansey River (ca 1.5 mi W of Fairton, edge of *Spartina alterniflora* turf, 15 Jun 1972, *Ferren 884,* PH), and Mill Creek (Fairton, mud-covered gravelly shore among *Spartina alterniflora* and *Sagittaria subulata,* 18 Aug 1972, *Ferren 1033,* PH) in New Jersey. Along the Mullica River, *L. chinensis* has been collected from Lower Bank (silt and mud-covered gravelly shore, 5 Sep 1972, *Ferren 1051,* PH) downstream to just above the Garden State Parkway Bridge (edge of *Spartina alterniflora* marsh, 22 Mar 1976, *Ferren,* PH). On Mullica River tributaries, collections are known from the Bass River (nr. New Gretna, sandy peaty shore, 30 May 1973, *Ferren 1215,* PH), the Wading River (sandy muddy shore .5 mi below rt. 542, 27 Sep 1974, *Ferren 1377,* PH; sandy shore 1 mi E of New Gretna, 8 Nov 1975, *Ferren 1429,* PH), and Nacote Creek (Port Republic, edge of turf and brackish marsh just below bridge, 19 Jul 1971, *Ferren 716,* PH). Along the Great Egg Harbor River, collections are known from just south of Catawba (mouth of Miry Run, peaty muddy shore, 25 Jul 1973, *Ferren 1232,* PH) downstream to Skull Landing (edge of turf along brackish marsh at mouth of stream, 30 Jun 1972, *Ferren 908,* PH). Along the Tuckahoe River it has been collected one mile west of Corbin City (muddy depression, brackish marsh, 1 Sep 1971, *Ferren 882,* PH). At localities closer to the New Jersey coast, *L. chinensis* has been collected in Ocean County along Barnegat Bay (halfway between Mantoloking and Chadwick, 8 Sep 1906, *Mackenzie 2391,* PH) and in Cape May County at Palermo (border of salt marsh, by little streamlet, 30 Aug 1908, *Van Pelt,* PH).

At upstream localities, at or near the interface between freshwater and brackish water, *L. chinensis* grows in sand or mud-covered sands and gravels in open stands of *Scirpus pungens* and *Spartina alterniflora*. Other species associated with *L. chinensis* at such localities include *Eriocaulon parkeri, Polygonum punctatum, Juncus acuminatus, Sagittaria graminea,* and *Sagittaria subulata*. At downstream localities, *L. chinensis* grows in firm peaty turf at the lower edge of *Spartina alterniflora* marshes. These marshes often form the lower border of *Spartina cynosuroides* dominated marshes. In its most seaward habitats, *L. chinensis* is associated with such characteristic salt marsh plants as *Spartina alterniflora, Spartina patens,* and *Juncus gerardii* Loisel. However, even in this habitat, *L. chinensis* grows where there is some freshwater intrusion (Johnson and York 1915).

Until Fogg (1935) and Larsen (1935) reported numerous localities for *L. chinensis* along the Delaware River in Salem County, New Jersey, and New Castle County, Del-

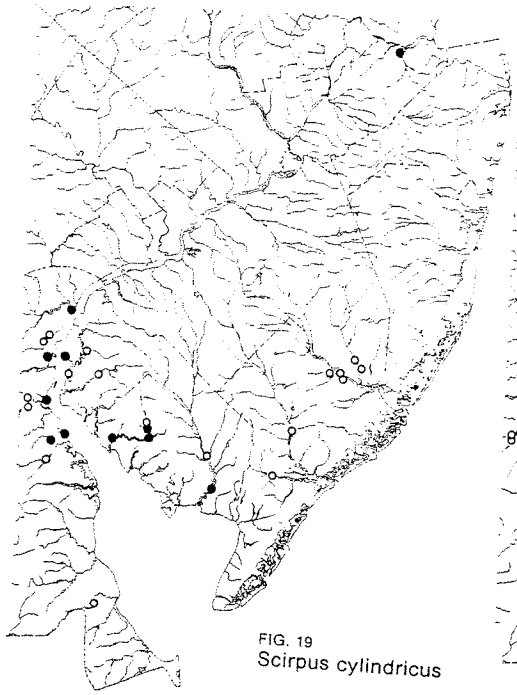

FIG. 19
Scirpus cylindricus

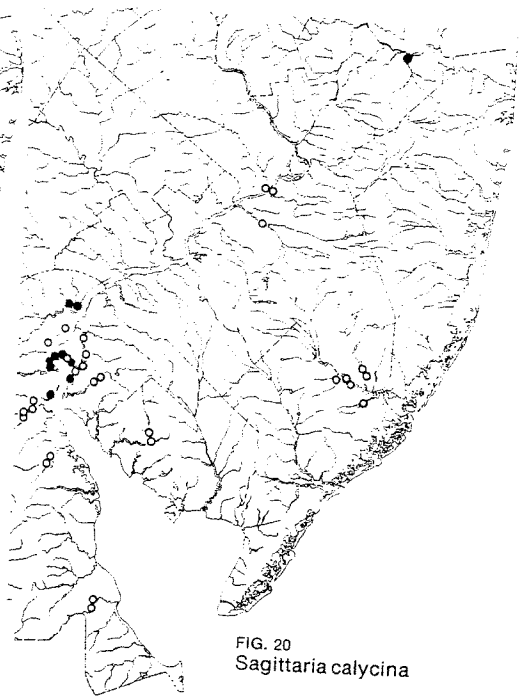

FIG. 20
Sagittaria calycina

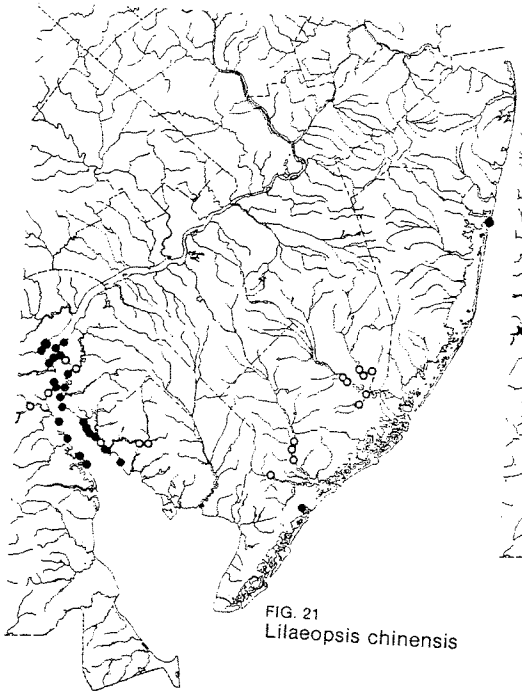

FIG. 21
Lilaeopsis chinensis

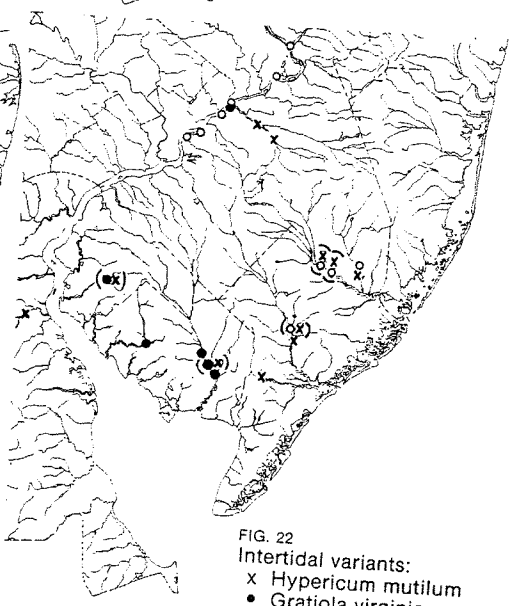

FIG. 22
Intertidal variants:
x Hypericum mutilum
• Gratiola virginiana
o Gratiola aurea
( ) Same locality

10 mi
6.2 km

aware, little was known about this species in the local area. Nuttall (1818) collected *Lilaeopsis* in a "salt marsh" near Egg Harbor, New Jersey, and it was not collected again in the local area until the early 20th century when it was discovered in Cape May County (Stone 1909). The absence of early collections of this species reflects the lack of botanical investigation in the brackish environments of New Jersey and Delaware and not the rarity of *Lilaeopsis*. It is common, and undoubtedly has been for some time, in the brackish portions of major local river systems.

Variation in Species of Both Tidal and Non-Tidal Habitats

Plant species which grow in both tidal and non-tidal habitats often exhibit variation correlated with these habitat differences. Such variation involves differences in habit, pubescence, leaf size, leaf shape, leaf thickness, leaf margin, pedicel length, pedicel thickness, flower size, sepal size, sepal shape, color of petals, and degree to which flowers open. Although botanists have given taxonomic rank, usually as varieties, to plants exhibiting such differences, we feel that such distinctions are not warranted in most cases.

1. **Lindernia dubia** (L.) Penn.

This widespread species is found in the freshwater to slightly brackish water intertidal zones of all major rivers and streams in the local area. Plants subject to tidal inundation have a more prostrate habit, more rooting at the nodes, leaves with lower length-width ratios, thicker leaves, shorter and thicker pedicels, and less opened flowers than plants of non-tidal habitats. They have been given taxonomic recognition as *Lindernia dubia* var. *inundata* (Penn.) Penn. However, plants growing continuously from tidal to non-tidal conditions exhibit gradual transitions between the extremes of the above characteristics. Furthermore, these characteristics vary on the same plant when the lower portion is inundated by the tide and the upper portion is not. Such variable plants have been collected along the Delaware River in Burlington County, New Jersey (Vansant Is., moist sandy tidal shore, 1 Sep 1923, *Long 29183,* PH) and along Raccoon Creek in Gloucester County, New Jersey (ca 1 mi S of Bridgeport, muddy sand at upper tidal limit of marsh, 25 Aug 1971, *Ferren 749,* PH).

2. **Gratiola virginiana** L., Fig. 22

Intertidal collections of this locally rare species have been made along the Maurice River from about 1.5 miles north of Laurel Lake (marsh at mouth of small creek, 23 Aug 1973, *Ferren 1295,* PH) downstream to about .25 mile south of the mouth of Manantico Creek (shore, 8 Aug 1973, *Ferren 1256,* PH), the Manumuskin River northwest of Port Elizabeth (shore, 8 Aug 1973, *Ferren 1273,* PH), the Delaware River at Delran (nr. edge of muddy clayey marsh on S bank at mouth of Rancocas Cr., 10 Oct 1972, *Ferren 1187,* PH), Oldmans Creek northwest of Auburn (11 Oct 1917, *Long 18055,* PH), Deep Run about 1.3 miles northeast of Quinton (16 Oct 1972, *Ferren 1190,* PH), and Mill Creek at Fairton (18 Sep 1972, *Ferren 1133,* PH).

Plants of *G. virginiana* growing in tidal habitats differ from those of non-tidal habitats by having shorter and broader leaves, thicker leaves, less toothed leaf margins, shorter pedicels, and less opened flowers. They have been given taxonomic recognition as *Gratiola virginiana* var. *aestuariorum* Penn. However, we do not think there is sufficient discontinuity among characteristics to warrant the recognition of this taxon.

3. **Gratiola neglecta** Torr.

Plants of this common widespread species are generally more branched and

less pubescent when they grow in tidal habitats. The tidal plants also have blunter less-toothed leaves with a lower length-width ratio, thicker leaves, shorter pedicels, and less yellow in the petals. However, there is substantial variation in these characteristics among plants just growing in the intertidal zone alone. Plants in the upper portion of the intertidal zone have smaller leaves and shorter pedicels but otherwise do not differ much from non-tidal plants. Plants in the middle and lower portions of the intertidal zone are glabrous and have blunter broader-based leaves and still shorter pedicels. Often the leaves are entire or only juvenile leaves at the tips of the plants have teeth. The most extreme tidal variants examined were glabrous plants with succulent much-branched stems having small narrow leaves with coarse dentation (opp. Andalusia in Delaware R., Mud Island, open clayey peat, 25 Oct 1972, *Ferren 1204*, PH).

Fernald (1950) recognized glabrous intricately-branched plants with milk-white corollas from the St. Lawrence River as *Gratiola neglecta* var. *glaberrima* (Fern.) Fern. Judging from our observations of similar plants in local river systems, identifying plants as var. *glaberrima* or as the typical variety is extremely arbitrary.

4. **Hypericum mutilum** L., Fig. 22

In the local area, intertidal plants of this species are mostly found along streams and rivers that flow through the pine barrens. They are generally smaller and more decumbent, have thinner leaves with a lower length-width ratio, and have blunter more leaf-like sepals than plants of non-tidal habitats. However the entire range of variation among the extremes of these characteristics can be found in populations distributed continuously from non-tidal to tidal conditions (NJ: Lumberton, along Rancocas Cr., 26 Sep 1972, *Ferren 1142a & 1142b*, PH). Although plants of intertidal zones have been given recognition as *Hypericum mutilum* var. *latisepalum* Fern., their distinctions from non-tidal plants are not clearly definable.

5. **Ludwigia palustris** L.

This common widespread species extends into freshwater to slightly brackish water intertidal zones of all major local river systems. Some tidal plants differ from non-tidal plants by having thicker, longer, less-branched stems, more green color in the whole plant, leaves more confined to tips of stems, smaller flowers, more conspicuous fruits, and larger and whiter seeds. Such plants have been given recognition as *Ludwigia palustris* var. *inundata* Svens. (Svenson 1935). However, we have observed considerable variation in the characteristics used to define this variety just among plants in the intertidal zone alone, and therefore do not think taxonomic recognition is warranted.

6. **Polygonum punctatum** Ell.

This common widely distributed species is also one of the most common elements of the local intertidal flora. Plants which are inundated have obtuse nearly sessile leaves and a very short flowering axis with 4 to 7 flowers. They have been given taxonomic recognition as *Polygonum punctatum* var. *parvum* Vict. & Rous. (Victorin and Rousseau 1940). However, individual plants that are partially inundated have characteristics of var. *parvum* on inundated portions that grade into characteristics of the typical variety on non-inundated portions, indicating that the morphological variation is not taxonomically significant.

7. **Sagittaria graminea** Michx.

This widespread species has been collected in the intertidal zones of the Delaware, Mullica, and Great Egg Harbor river systems. Plants that grow toward the upper part of the intertidal zone usually have lanceolate leaf blades and several verticils of

flowers on the inflorescence axis. Those growing lower in the intertidal zone have linear-lanceolate leaf blades and one to rarely three verticils of flowers. Frequently, in the lowermost part of the intertidal zone, the plants occur as low rosettes and do not produce inflorescences. Fruits have only been found on plants that have more than three verticils of flowers and grow in the upper part of the intertidal zone. Plants with three or less verticils have been given recognition as *Sagittaria eatonii* J. G. Sm. (Smith 1900). Whether or not these plants merit taxonomic recognition needs further study. There is considerable variation in leaf size and shape among all plants of *S. graminea* sensu lato, indicating these characteristics do not have taxonomic significance.

8. **Gratiola aurea** Muhl., Fig. 22

Intertidal plants of this species have been collected in the Delaware, Mullica, and Great Egg Harbor river systems. Generally the intertidal plants have blunter sepals and leaves with a lower length-width ratio than those of non-tidal plants. Although the intertidal variants were recognized by Pennell (1919) as *Gratiola aurea* var. *obtusa* Penn., even he stated that the taxon was, "A tidal extreme, perhaps only ecologically distinguishable."

9. **Cyperus rivularis** Kunth

This widespread sedge occurs in all major local tidal river systems. Generally the spikelet scales are purplish-brown but plants in the intertidal zone often have pale greenish or brownish scales. The pale-scaled plants have been given taxonomic recognition as *Cyperus rivularis* f. *elutus* (C. B. Cl.) Kük. (Fernald 1940). However scale color is variable and intermediate colors are frequent on plants growing near the limit of high tide.

10. **Xyris difformis** Chapm.

Included in this taxon (Kral 1966) are plants that Fernald (1940) named *Xyris caroliniana* f. *flaccida* Fern. from tidal areas of southeastern Pennsylvania, southern New Jersey, eastern Delaware, and southeastern Virginia. The tidal plants have thinner (often translucent) and broader leaves than the non-tidal plants. Locally these tidal variants are rare. They have been collected along the Delaware River southeast of Tullytown (sandy shore, 6 Sep 1927, *Long 33786*, PH), the Mullica River near Batsto (below the Forks, 21 Aug 1910, *Long 4727*, PH), and the Great Egg Harbor River within one mile south of Catawba (tidal marsh, 6 Aug 1937, *Long 51208*, GH, PH) and at Clarkstown (shore, 17 Aug 1975, *Ferren 1423b*, PH).

Growth and Reproductive Patterns

GROWTH FORMS. Two growth forms are predominant among intertidal plant species: (1) low rosettes with short narrow leaves and (2) low cespitose opposite-leaved plants rooting at the nodes.

The rosette plants have comparatively short, narrowly oblong, linear, or subulate leaves (or culms) and include *Sagittaria subulata*, *Sagittaria calycina*, *Eriocaulon parkeri*, *Limosella subulata*, *Isoëtes riparia*, and *Eleocharis olivacea* var. *reductiseta*. Two of the species have different growth forms in non-tidal conditions: continuously submerged plants of *Sagittaria subulata* have long ribbon-like leaves and non-tidal plants of *Sagittaria calycina* have longer leaves with dilated sagittate blades. Also the close non-tidal relatives of some intertidal species have longer more dilated leaves, e.g., compare *Eriocaulon parkeri* and *E. septangulare*, *Lilaeopsis chinensis* and *L. carolinensis*, *Limosella subulata* and *L. aquatica*. Apparently, the development of short narrow leaves in small rosettes is a trend associated with the inter-

tidal environment that has occurred in unrelated groups of plants.

The low-growing cespitose plants, which have small entire opposite leaves and root at the nodes, include *Elatine americana*, *Micranthemum micranthemoides*, and *Crassula aquatica*. Other species often found in the intertidal zone also often have this growth form, e.g., *Gratiola aurea*, *Gratiola virginiana*, *Lindernia dubia*, and *Ludwigia palustris*.

Plants having these two kinds of low-growing growth forms may be less subject to drying out as the tide recedes because their water requirements are lower than those of taller plants. Also they may be better adapted to microenvironmental conditions such as small depressions which remain wet or retain water after the tide recedes.

UNOPENED FLOWERS AND SELF POLLINATION. The occurrence of unopened flowers and self pollination has been reported in intertidal populations of *Micranthemum micranthemoides* and *Lindernia dubia* by Pennell (1924). He also reported that intertidal plants of *Ludwigia palustris* had incurved stamens that deposited pollen against the stigma. Ferren has observed unopened flowers, which were fully mature, in *Elatine americana* and self pollination in florets of the small tight spikelets of *Eleocharis olivacea* var. *reductiseta*.

Insect pollination is less likely to occur among intertidal plants because the plants may be submerged when insects are active. Wind pollination wouldn't be as effective either because the pollen would be submerged or wet. Thus the development of unopened flowers and self pollination probably are important adaptations to the intertidal environment.

RECURVED FLOWER STALKS. *Sagittaria calycina* and *S. subulata* have recurved scapes while most other local species of this genus, not so confined to the intertidal zone, do not. *Limosella subulata* and *Micranthemum micranthemoides* eventually develop recurved pedicels and their non-tidal counterparts (i.e., *Limosella aquatica* and *Micranthemum umbrosum*) do not. The culms of *Eleocharis olivacea* var. *reductiseta* frequently recurve at maturity and culms of *E. olivacea* var. *olivacea*, which generally is non-tidal, are more upright. Finally, the umbellate inflorescence of *Lilaeopsis chinensis* terminates a scape which usually recurves late in the growing season.

We suspect that recurved flower-bearing structures have an important role in getting the seeds near or into the substrate near the parent plants. Since the intertidal environment is a narrow transition zone between aquatic and terrestrial environments, there would be a selective advantage for intertidal plants to have seeds deposited close to the parents instead of in an environment a short distance away where offspring could not survive.

STEM AND FRUIT BURIAL. Plants which grow prostrate on soft tidal mud frequently become partially or completely buried in the substrate. Mature seed capsules in the leaf axils of these plants eventually decay and thus their small seeds are deposited in the proper substrate for optimum germination and development. Species exhibiting stem and fruit burial in the intertidal zone include *Elatine americana*, *Ludwigia palustris*, *Lindernia dubia*, and *Gratiola virginiana*.

AWNS AND BRISTLES. The presence of antrorsely barbed lemma awns in *Zizania aquatica*, antrorsely barbed achenial awns in *Bidens bidentoides* and *Bidens frondosa* var. *anomala*, and reduced or no achenial bristles in *Eleocharis obtusa* var. *peasei*, *Eleocharis olivacea* var. *reductiseta*, and *Scirpus smithii* var. *smithii* are characteristics that are correlated with the intertidal zone habitat. They appear to promote limited dispersal, or non-dispersal, of diaspores.

In *Zizania aquatica*, the elongate spikelets with antrorsely barbed lemma awns are constructed so they drop directly into the substrate when the inflorescences shatter. Even when shattering occurs over water, the lemma awn helps direct the diaspore through the water and into the substrate (Dore 1969; Ferren and Good 1977). Thus the seeds are deposited into the parental substrate and not carried into less favorable conditions.

Antrorsely barbed achenial awns of *Bidens bidentoides* and *Bidens frondosa* var. *anomala* facilitate dispersal by hydrochory instead of epizoochory because antrorse barbs to not enhance attachment as well as retrorse barbs. Also the antrorse barbs would prevent the achenes from being stranded in litter as they are washed about by the tides. Presumably, the antrorse barbs will enable achenes to reach moist substrates more readily while achenes with retrorsely barbed awns remain anchored in litter where they would be more exposed to adverse conditions. Similarly, the reduction or loss of retrorsely barbed achenial bristles in *Eleocharis obtusa* var. *peasei*, *Eleocharis olivacea* var. *reductiseta*, and *Scirpus smithii* var. *smithii* also reduces the chance for achenes to be dispersed by epizoochory or stranded in litter near the upper limit of the tide where conditions may not be continuously wet enough for survival of offspring (Schuyler and Ferren 1975).

Patterns of Floristic Change

EXTIRPATIONS AND REDUCTIONS. As shown in Table 1, *Limosella subulata*, *Crassula aquatica*, and *Micranthemum micranthemoides* no longer occur any place in the Delaware River system, and *Elatine americana*, *Eriocaulon parkeri*, and *Aeschynomene virginica* no longer occur along the Delaware River. *Scirpus smithii*, *Sagittaria subulata*, and *Isoëtes riparia* used to occur downstream along the Delaware River to the vicinity of Wilmington, Delaware, but now are restricted to portions of the river above Philadelphia or to tributaries. All intertidal plant populations, except perhaps for *Bidens frondosa* var. *anomala*, have been significantly reduced or eliminated from the Camden and Philadelphia counties portion of the Delaware River. Along the Schuylkill River, *Bidens frondosa* var. *anomala*, *Scirpus fluviatilis*, *Scirpus smithii*, *Sagittaria subulata*, *Limosella*, *Micranthemum*, *Elatine americana*, and *Zizania* are extirpated. In the Raritan River system, *Bidens bidentoides*, *Scirpus smithii*, *Eleocharis obtusa* var. *peasei*, *Sagittaria subulata*, *Micranthemum micranthemoides*, and *Elatine americana* have not been collected since 1918 and probably are extirpated from there.

EXTENSIONS. Only one intertidal species, *Cyperus brevifolioides*, appears to have increased its occurrence in local river systems. Along the Delaware River, it is often found in debris stranded near the high tide limit. Other introduced plants are found here and *Cyperus brevifolioides* appears to be an introduction that has recently become widespread in this unstable habitat.

Our field work has extended the collected ranges of several intertidal species. However, these extensions probably do not reflect changes in the flora as much as the lack of botanical exploration. Recent discoveries of *Cyperus brevifolioides*, *Scirpus smithii*, *Eleocharis obtusa* var. *peasei*, *Sagittaria subulata*, *Elatine americana*, *Eriocaulon parkeri*, *Isoëtes riparia*, and *Sagittaria calycina* along Rancocas Creek are among the more significant extensions in this category. Additional extensions include new localities for *Aeschynomene virginica* in the Maurice River system and new localities for *Eriocaulon parkeri* and *Isoëtes riparia* in coastal New Jersey river systems. The most range extensions were found for species that grow in brackish conditions. Thus *Scirpus cylindricus*, *Sagittaria calycina*, and *Lilaeopsis chinensis* are

TABLE 1. Occurrence of intertidal plants in major river systems and selected tributary systems near Philadelphia (P = taxon present in 1970's; date = last collection of taxon; blank = taxon never collected).

	Delaware system											Raritan system		Mullica system				Great Egg Harbor system	
Taxon	Delaware R.	Rancocas Cr.	Schuylkill R.	Christiana R.	Salem R.	Alloway Cr.	Appoquinimink R.	Smyrna R.	Cohansey R.	Maurice R.	Mispillion R.	Raritan R.	South R.	Mullica R.	Wading R.	Bass R.	Nacote Cr.	Great Egg Harbor R.	Tuckahoe R.
Cyperus brevifolioides	P	P				P													
Bidens frondosa var. *anomala*	P		1866	P	1882				1935	P									
Scirpus fluviatilis	P	P	1867	P		P													
Bidens bidentoides	P			1885	1882		18??			1935		1918							
Scirpus smithii var. *smithii*	P	P	1867									1918							
Eleocharis obtusa var. *peasei*	P	P		P								1918							
Sagittaria subulata	P	P	18??				1911		P			1918							
Limosella subulata	1917		1866																
Crassula aquatica	1917																		
Micranthemum micranthemoides	1932		1866									1918							
Elatine americana	1932	P	1866	1873		P	P			P		1918							
Eriocaulon parkeri	1932	P				P			1936	P	1908			P	P	P		P	P
Isoëtes riparia	P	P							P	P	1908			1940					P
Eleocharis olivacea var. *reductiseta*	1905									1936				P	P		1962	P	P
Aeschynomene virginica	1934									P					P			1937	
Zizania aquatica	P	P	1895	P	P	P	P	P	P	P	P			P	P	P		P	P
Scirpus cylindricus	P				P	P	P	P	P	P	P		1916	P	P			P	P
Sagittaria calycina	P	P		1894	P	P	P	P	P		P		1906	P	P		P		
Lilaeopsis chinensis	P				P		P		P					P	P	P	P	P	P

now known from many more localities than they were before our collecting activity in the 1970's. These plants grow in a restricted transitional habitat between freshwater and salt water which botanists generally overlooked.

FACTORS CAUSING EXTIRPATIONS AND REDUCTIONS. The dumping of dredging spoil, sanitary landfill, and refuse have eliminated or substantially altered many habitats for intertidal plants along the Delaware River. Notable sites where dredging spoil has been a factor are Burlington Island, Delanco, Delair, Petty's Island, Tinicum Island, Essington, Chester Island, and Bridgeport. Sanitary landfill and other refuse have been dumped on localities for intertidal plants at Andalusia, Beverly, Camden, and Tinicum.

Bulkheading the shore of the Delaware River has been a common practice and is particularly extensive in Philadelphia and Camden counties. Historic plant localities at Richmond (Philadelphia) and Cooper's Point (Camden) have been eliminated by bulkheading.

Damming of tidal tributaries in all local river systems has converted tidal habitats to non-tidal habitats. Notable examples of tidal habitats lost by damming occur in the Great Egg Harbor River (Mays Landing), the Mullica system (Port Republic), the Cohansey River (Fairton and Bridgeton), and the Mispillion River (Milford). Diking has also been a common practice which has altered habitats of intertidal plants along the Delaware River and its tributaries between Trenton and Wilmington.

Additional factors affecting plant habitats are channel dredging and the subsequent slumping and erosion of the shoreline (Clark 1974). More erosion results from waves caused by ship and boat traffic. In tributaries that have been channellized. loss of habitat has also occurred.

Undoubtedly more factors than the above have had a role in extirpations and range reductions of intertidal plants. However, once such habitat destruction occurs, revegetation by the original intertidal flora probably is hampered by limited dispersal mechanisms.

FLORISTIC RELATIONSHIPS AMONG RIVER SYSTEMS

Floristically, the four major local river systems break down into two groups: (1) the Delaware and Raritan systems and (2) the Mullica and Great Egg Harbor systems. Many of the rare plants (Table 1) primarily confined to freshwater portions of the Delaware and Raritan systems have been collected farther north in the Hudson system and farther south in the Chesapeake system but not in the Mullica and Great Egg Harbor systems. The latter systems drain the New Jersey pine barrens and their freshwater portions have fewer mud flats and a lower pH than freshwater portions of the Delaware and Raritan systems. This may account for the floristic differences although other factors may be involved too. The plants more confined to brackish conditions have been collected in both groups of river systems, indicating that salinity may be the major factor accounting for the kinds of plants found there.

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