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LOW-COST, AERIAL PHOTOGRAPHIC INVENTORY OF TIDAL WETLANDS

by D. S. Bartlett, V. Klemas, O. W. Crichton, and G. R. Davis

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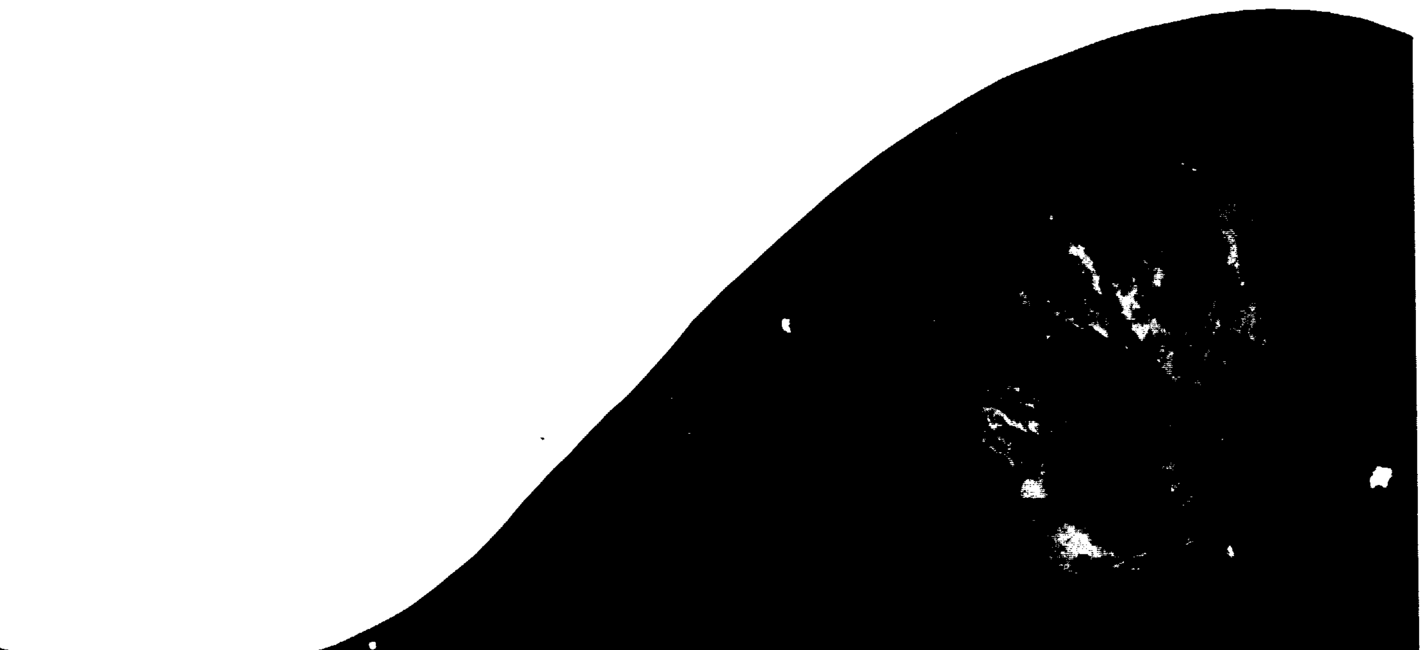

COLLEGE OF MARINE STUDIES
UNIVERSITY OF DELAWARE
NEWARK, DELAWARE 19711

Center for Remote Sensing

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Prepared by
Center for Remote Sensing
College of Marine Studies
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State of Delaware

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INTRODUCTION AND BACKGROUND

During the summer of 1973, the State of Delaware committed itself to regulating and protecting one of its most important and fragile natural resources -- the tidal wetlands. The passage of The Wetlands Act acknowledged the need to "preserve and protect the productive public and private wetlands"[1] and charged the Secretary of the Department of Natural Resources and Environmental Control with inventorying, "as promptly as he is able, all wetlands within the State and prepare suitable maps."[1]

In response to state requirements, the College of Marine Studies mapping team developed an inventory procedure based on aerial photography. Limitations of time and money dictated that maps interpreted from vegetation and drawn on aerial photos were preferable to those which might be compiled by more traditional survey techniques. Delaware's extensive tidal wetlands would take years of work and millions of dollars to survey on the ground. Air photos, on the other hand, can be taken over a period of a few days at comparatively low cost. In addition, specialized photographic techniques may be used to obtain far more information about species composition and other ecologically important characteristics of the wetlands than could ever be assembled by investigators on the ground.[2,3,4] The experience of other states, notably New Jersey[5] and Maryland, has shown that wetlands mapping by aerial photography is a useful and reliable land management tool. Determination of the wetlands boundary by vegetation rather than actual tidal elevation has been the rule in most states that have undertaken wetlands inventories, since to survey tidal elevations is prohibitively expensive and time-consuming. In addition, biological wetlands boundaries have more ecological significance than an arbitrarily chosen elevation with respect to Mean High Water.

Research performed by the Center for Remote Sensing over the past few years has shown that aerial photography and photo-interpretation could be operationally applied to the inventorying of Delaware's wetlands. All of the major salt marsh plant communities were found to be distinguishable at altitudes from 60,000 feet[6] (NASA RB-57 aircraft) up to 500 miles[7]

(NASA-ERTS Satellite). A set of maps of Delaware's coastal wetlands was compiled and published showing major wetland plant species visually interpreted from aircraft imagery.[8] These techniques are applicable to the state requirement, where the only change is one of scale — from 1:24,000 to 1:2400. In short, aerial photography and modern interpretation techniques can be used in making a wetlands inventory that adequately delineates wetlands boundaries and otherwise supports a permit program of the type envisioned by the Delaware Wetlands Act of 1973.

The significant difference between the inventory procedure developed for the state of Delaware and that undertaken in other states, particularly New Jersey, is that the final products are not accurate to National Map Accuracy Standards. While such true "maps" would be desirable, the photogrammetric procedures required contribute greatly to the total cost of the project and were not financially feasible in Delaware. For comparison, New Jersey encountered project costs of approximately $1600/square mile, while Delaware's costs were approximately $490/square mile. Virtually all of the difference may be attributed to New Jersey's requirement for "Map Accuracy" and the additional stress this requirement places on every step of the procedure, from acquisition of photography to compilation of the final map product. The procedure used in Delaware attained adequate geometric accuracy for less than one-third the unit cost. The photo-inventory is used to define wetland areas as well as aid property owners and state officials in applying for and acting on permits for regulated activities. Disputes not resolved by the photo-inventory may be approached through site visits and, if necessary, ground survey. It is thought that such cases will be rare and that the photo-inventory, as produced, constitutes a cost-effective fulfillment of statutory requirements and an effective management tool.

The authors conclude that in states where map accuracy is not economically feasible, an approach similar to the one described in this report could be undertaken at substantially reduced cost while preserving the speed, interpretability of vegetative communities and total coverage inherent in aerial photographic techniques.

INVENTORY PROCEDURE

1. Photo Acquisition: Aerial photos of Delaware's tidal wetlands were obtained during early fall of 1973 and the late spring of 1975 by Photoscience Inc. of Gaithersburg, Md. Photos were taken from a Riley Rocket twin engine aircraft with twin mounted RC-8 Wild aerial mapping cameras using Kodak 2445 color film and Kodak 2443 color infrared film.

The aircraft was flying at an altitude of 6,000 feet, and with six inch focal length cameras, this produced nine-inch original photographs at an approximate scale of 1:12,000. In order to most efficiently cover the wetlands without superfluous flying time being spent over non-wetlands areas, flight-lines were sometimes oriented along the long axes of tidal rivers and streams, thus deviating from the north-south orientation of most of the flight lines. The final photo-enlargements are oriented with the top in the direction of flight, and north arrows are provided on all photographs to facilitate use. Original nine-inch, color transparencies were used to make 5X black and white enlargements on stable "Mylar" film material at an approximate scale of 1:2400. Changes in aircraft altitude or deviations from perfectly level flight introduce geometric distortion (see "Evaluation of Procedure" section), and thus the scale is approximate. It is these enlargements on which wetlands boundaries are interpreted and drawn. Index maps showing the location of all photographs by frame number have been prepared and are included with the final, annotated photographs.

Standard photogrammetric procedures used included providing for 60% overlap between consecutive photographs within a flight-line. In most cases, to avoid excessive duplication of coverage, only alternate frames were actually enlarged and used in the inventory. The 60% overlap was obtained with the dual purpose of insuring complete coverage and providing the means by which photography could be viewed in three dimensions using stereoscopic equipment. Such stereo viewing is useful in identification of some plant species, and the capability for such viewing has been retained by reproduction of all photos on nine-inch, black and white prints. Matching of adjacent photographs with no overlap whatsoever is impossible without geometric correction and thus some overlap is retained in most cases.

2. Photo-interpretation: The black and white "Mylar" enlargements have been interpreted and wetlands boundaries drawn, using color and color-infrared nine-inch prints as aids. The major wetlands plant species are distinguishable on the basis of their appearance (color and texture) on the color and color-infrared prints.[6,8] The wetland - upland boundary is visible in the photographs used for interpretation as the transition from predominantly salt-tolerant (wetlands) plant species to upland species that require freshwater and better drainage than is available in tidally inundated areas.[1,3,5,6] In many cases, this transition is made particularly distinct by the presence of a tree line or plowed field at the boundary. In other areas, the differences in vegetation may be more obscure, particularly if there is not a sharp break in slope at the boundary; however, photo-interpretation combined with field checks can adequately distinguish the transition in species composition in such areas. Wetland boundaries have been drawn and the major plant species present in any tidal marsh area over four acres in size noted on the enlarged photographs. For standardization purposes, a "major species" is defined as one that occupies more than 50% of the total wetlands area. (A key to the identification of wetlands plants, developed as a part of this inventory, is included as an appendix.) In many cases, where mixed stands of vegetation were observed in which several species seem to occupy significant areas, all of those species are noted. Occasionally, a species not listed in The Wetlands Act occupies a significant or even dominant portion of a marsh in association with "bone fide" wetlands plants on the basis of which the area is actually defined as wetland. In such cases, in order not to give an erroneous impression of the species distribution, the non-wetlands plant (usually Phragmites communis) is included in the notation of species present, but the name is placed in parentheses to avoid confusion with the wetlands plants used to define the area. Wetland - upland boundaries are distinguished from species boundaries within the marsh by the thickness of the line used. The wetland - upland boundary is indicated by a thicker line than species boundaries. The thick

line also is used to delineate the wetlands - water boundary, as this transition is often unclear in black and white photography. The thick line was drawn with a #3 rapidograph pen producing a line .035" wide. This width amounts to 7 feet on the ground at the 1:2400 scale of the interpreted photographs. The species delineation line was drawn with a #1 rapidograph having an actual line width of .021", which corresponds to 4.2 feet at the enlarged photograph scale.

In addition to the boundary lines and species names, significant landmarks such as roads, towns and water bodies are noted on the interpreted photographs.

3. Evaluation of the Procedure: Every attempt has been made to minimize the possibility of inaccuracies occurring at each step of the inventory process. Photographs were acquired with the most sophisticated and precise equipment available, and interpretation techniques have been tested and refined through several years of research. Nevertheless, as with any analytical procedure, inaccuracies inherent in the technique may be encountered. An important aspect of the project therefore has been to identify these inaccuracies and to evaluate their effect upon the final product.

As photo-interpretation relies on human observers, the process is subject to the individual perceptions of the interpreter. Since more than one interpreter participated in the inventory, it was important to check the effect of this multiplicity on the uniformity of the final product. Thus, all interpreted photographs were reviewed by the assistant project manager before final drafting. No significant difference in the interpretations produced by different workers was found.

As noted previously, plant species identification depends on the interpreter's recognition that a particular combination of color and texture in a photograph represents a particular species or group of species on the ground. Inaccuracies will be introduced if the interpreter's training and experience do not allow him to draw the correct conclusion about what is on the ground from what he perceives in the photograph. Development of this correlation process has been the subject of much research, both at the

College of Marine Studies[6,7,8] and elsewhere[2,3,4], and the errors involved have been reduced to a minimum. However, field checks were undertaken in roughly half the wetlands areas in order to verify or aid the interpretation.

Changes in the altitude of the aircraft used to acquire the photographs or deviations from level flight will produce small geometric distortions in the final photographs. The removal of such distortion is an extremely expensive and time-consuming process, involving a great deal of field surveying and the application of sophisticated photogrammetric equipment during the production process. The State of New Jersey encountered costs of approximately $1600 per square mile in their wetlands inventory -- in large part because of the procedures involved in producing photomaps that meet National Map Accuracy Standards. Such an approach was not financially feasible in Delaware, although every effort has been made to minimize the occurrence of geometric distortions. Detailed examination of several photographs from different locations was undertaken in order to quantify any such distortion. The procedure was to measure the horizontal distance between prominant landmarks in nine different sections of each photograph and to compare these with measurements between the same points on 1:24,000, USGS Topographic Maps. Differences were then recorded as a percentage of the true (map) distance. The maximum inaccuracy encountered on any of the photographs was found to be 7.5%. Differences of this magnitude were measureed in those sections of the photographs closest to the edges, where the effects of deviation from level aircraft altitude would be expected to be greatest. Thus, such deviations from level flight are thought to be the primary source of geometric distortion. Closer to the center of the photographs, smaller inaccuracies on the order of 0% to 4.0% were found. The maximum geometric error incurred in measurements of horizontal distances based on the approximate scale of the photography is therefore thought to be $\pm 7.5\%$.

It is an interesting aspect of the Delaware Wetlands Act that it includes two different definitions of wetlands. One, based on elevation, defines wetlands as lying below a level two feet above Mean High Water (MHW). The

Act also defines wetlands as areas supporting, or capable of supporting, any of the plant species enumerated in Section 6603, paragraph 9 of The Act. The latter definition was the one applied in this inventory for reasons already stated; however, a survey has been conducted to actually place the interpreted biological boundary in relation to elevation above MHW. The survey was undertaken along the northern edge of Canary Creek marsh, near the University of Delaware's Marine Studies Complex at Roosevelt Inlet, Lewes, Delaware. The interpreted wetlands - upland boundary line on photo #6-27 was found to range in elevation from .6 feet above MHW to 1.2 feet above MHW. At no point was the biological boundary located at or above 2 feet above MHW. Along artificial boundaries, such as the fill underlying Pilottown Road, high slopes were encountered and less than ten feet (horizontally) separated the vegetation transition from a point 2 feet above MHW. In unaltered areas, lower slopes produced a greater horizontal distance between the interpreted biological boundary and the 2 feet above MHW level. At one location, a transect was carried approximately 60 feet from the vegetation boundary into upland trees without reaching a point 2 feet or more above MHW. On the basis of this survey and other investigations[9] it may be said that, while the vegetation boundary as interpreted from aerial photography does not necessarily approximate the 2 feet above MHW, it may be expected to place the wetlands boundary at a point below (i.e., seaward) that which would have been obtained had the elevation definition been applied.

In conclusion, while the objective of the inventory has not been to produce "photomaps" (conforming to National Map Accuracy Standards), the techniques used have been carefully planned and evaluated to produce the best possible final product. Based on the experience of the Center for Remote Sensing, it is confidently asserted that the techniques discussed here have resulted in a high quality, detailed and informative inventory well within the specifications set by the State of Delaware.

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9. Lagna, L., 1975, "The Relationship of *Spartina alterniflora* to Mean High Water," SUNY at Stony Brook, Sea Grant Publication, Jan. 1975.

DICHOTOMOUS KEY TO THE IDENTIFICATION OF WETLAND PLANT SPECIES

Used to Define the Wetlands of Delaware in Accordance with The Wetlands Act, Section 6603, Paragraph 9.

EXPLANATION OF KEY

To use this dichotomous key, choose an illustration and begin with the descriptions numbered 1. Select the description that applies, and then keep moving to the numbered descriptions (following each of your choices) until you have arrived at a specific name for the plant illustrated.

This key includes only those plants listed in Delaware's Wetlands Act, Section 6603, Paragraph 9. Other plants may be found in the wetlands that are not listed in this key.

GLOSSARY

The use of technical botanical terms in this key has been kept to a minimum. However, some are necessary and their definitions are included in this glossary. The terminology used to describe leaf shapes, margins, and the juncture of sheath and blade in grasses is illustrated in Plates I and II.

Achene - a small, dry, one-seeded fruit that does not open at maturity.

Axile - in the angle or space between two structures on the same plant.

Basal - arising from the base of a stem.

Capsule - a dry fruit that opens when ripe and has more than one seed cavity.

Cyme - all floral stems end with a single flower. The central flower terminates the main stem and all other flowers develop from lateral buds.

Dioecious - male and female elements in separate plants.

Filiform - thread-like.

Fleshy - thick, moist, often covered with a thick skin to avoid drying out.

Herbaceous - a plant valued for its medicinal, savory, or aromatic qualities.

Ligule - a projection from the summit of the sheath in grasses.

Mucronate - having a sharp terminal point.

Node - place on a stem where leaves or buds occur.

Orifice - a hole or opening.

Panicle - a loose, irregular, compound flower cluster with flowers on all stems.

Pappus - appendages in tufts at the top of such plants as thistle and dandelion. Usually cottony and useful in the dispersal of the fruits or seeds.

Pedicel - the stem of a single flower in a cluster.

Peduncle - the stem of a singular flower.

Perennial - present at all times of the year.

Petal - a modified leaf on the underside of the flower.

Pistillate - referring to the egg-bearing organ of a seed plant.

Pith - a continuous central strand of spongy tissue in the stem of most plants.

Pubescent - covered with short, soft hairs.

Raceme - a cluster of stemmed flowers on a elongated axis.

Rhizome - an underground stem that runs parallel to the surface and has roots at the nodes.

Rosette - a cluster of leaves in a crowded circle or spiral arising from a crown.

Sepal - a leaf-like outer division of the flower, often green.

Sessile - without an individual stem, as a leaf attached directly to the main stem.

Spike - an elongated flower axis in which the flowers are sessile or almost sessile.

Staminate - refers to the organs of the flower that produce the male gamete or spore.

Stigma - part of a flower which receives pollen grain.

Stipule - an appendage at the base of the petiole or leaf or at each side of the attachment to the main stem.

Umbel - a flower cluster in which the individual flower stems arise from the same level.

Veins - the conducting tissue in a leaf.

Whorl - three or more leaves in a circle around the stem at the node.

1. Woody plants, trees, and shrubs that are more than two feet in height; most are broad leaved trees or shrubs with simple leaves 2

1. Herbaceous plants. 4

2. Leaves are broadly ovate, 7-18 cm long, 3 lobed, upper surface is dark green, lower surface is light dubescent; woody stems with the pith approximately 1/2 the width; in most cases the flowers are large and white with a pink center although in some cases may be pink, 4-10 cm across; this plant is found in the brackish fringe of the tidal marsh . <u>Hibiscus Palustris</u>
Marsh Mallow

2. Maritime shrubs that range from 2-12 feet tall; stems are smooth and tan in color; leaves are thick and fleshy, light green in color; flowers are greenish; usually found on the higher ground of a tidal marsh. 3

3. Leaves opposite with 6-15 sharp teeth on each side, 2-5 cm wide, 3 prominent veins; primarily found in the higher ground in the tidal marsh. . . . . .
. . . <u>Iva frutescens var. oraria</u>
Marsh Elder

3. Leaves alternate, obovate or deltoid-obovate, coarsely toothed on the upper 1/3; plants are dioecious; in the fall the female plant has a white fluffy pappus on the achenes. . . . .
. . . . <u>Baccharis halimifolia</u>
Groundsel Bush

4. Plants not usually covered with water. 8

4. Plants which are covered with water at all times; collapse after removal from the water; includes algae; flowers may grow above the water surface except for algae which does not flower. 5

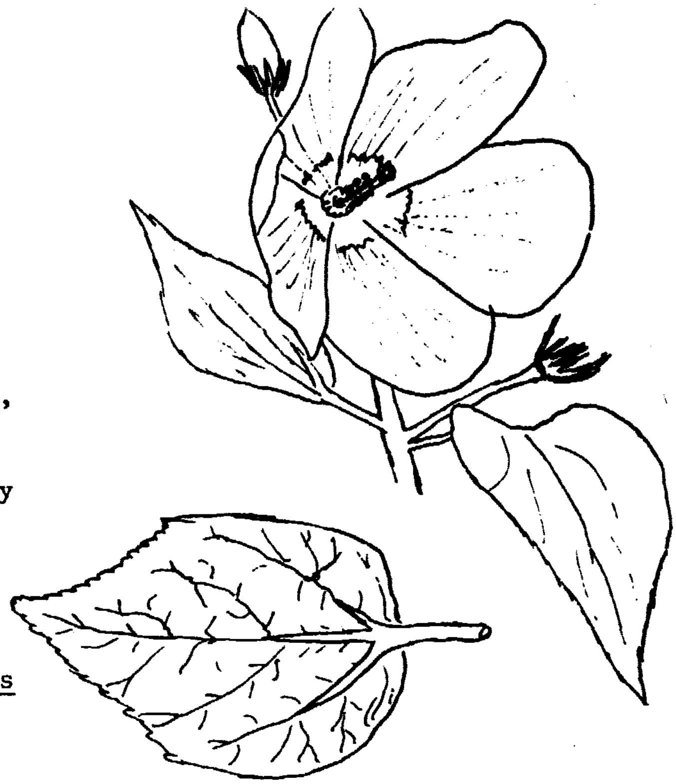


Fig. I. *HIBISCUS PALUSTRIS*

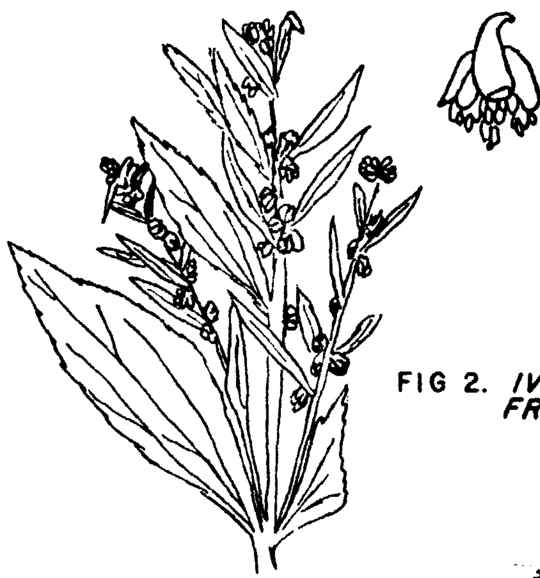


FIG 2. *IVA FRUTESCENS*

Fig. 3. *BACCHARIS HALIMIFOLIA*

5. Plants without true leaves, veins, stems, roots, or flowers; brown to brownish black with flat blades; often with vesicles, except in areas of wave action; attached to a solid substance by a hold fast; member of the Phaeophyceae (brown algae); edges of the blades are smooth with a mid-rib; prominent fruiting recepticles are elipsoid, elongate or pointed; dioecious . . . . <u>Fucus vesiculosis</u>
Bladder Wrach

5. Plants with true leaves, veins, stems, roots, and flowers 6

6. Leaf is long and flat, 1.5-5 mm wide, can be up to a meter in length; rarely <u>flowers</u> locally; grows in soft muddy bottoms. . . . . . <u>Zostera marina</u>
Eel Grass

6. Leaves are threadlike; found in calmer waters of estuaries, tidal marsh pools, and in the brackish pools in back of beaches. 7

7. Flower and fruit spikes originate from isolated whorls of sessile flowers and fruits raised above the stipules; fruit has a short beak . . . .
. . . . . <u>Potamogeton pectenatus</u>
Sago Pond Weed

7. Flower spikes enclosed in sheathing leaf base; asymetrical cone-shaped fruit on a long pedicel; clusters of 4 to 6; peduncles usually in a spiral coil which can pull the fruits below the water. . . . <u>Ruppia maritima</u>
Widgeon Grass

8. Plants, grasses, sedges, or rushes; narrow leaves which sheath the stem. To distinguish between grasses and rushes read the characteristics to determine which class the specie belongs.

   A. Grasses (Gramineae). Hollow, cylindrical stems closed at the nodes; some with a soft pith; leaves are parallel veined and are

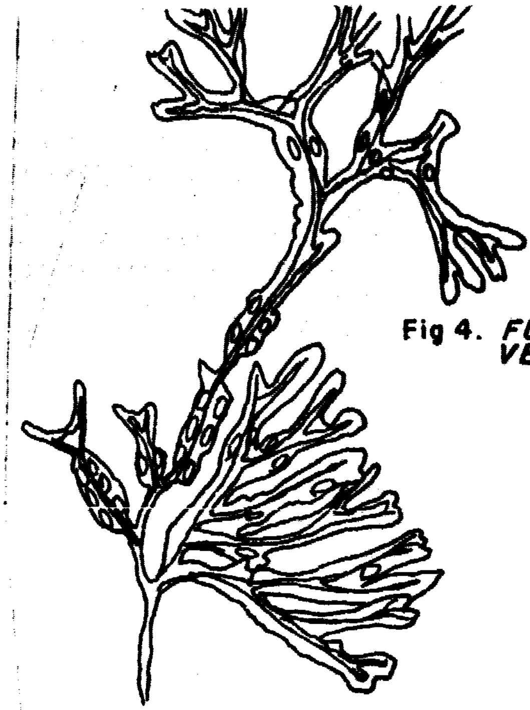


Fig 4. *FUCUS VESICULOSIS*

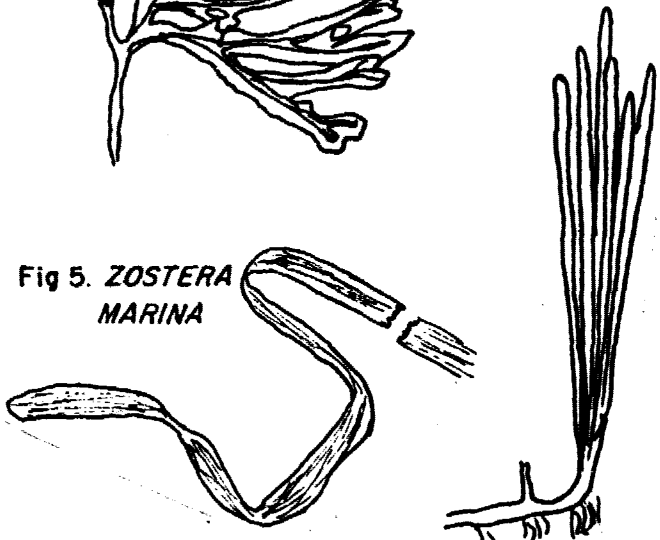


Fig 5. *ZOSTERA MARINA*

Fig 6. *POTAMOGETON PECTENATUS*

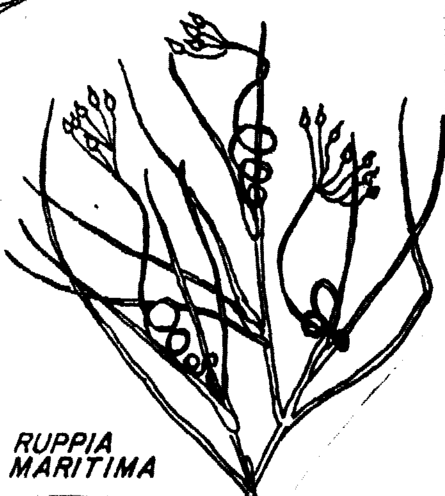


Fig 7. *RUPPIA MARITIMA*

in two ranks on the stem; they form a sheath enveloping the stem that is usually open the whole length; the blades are flat; there is a hairy, membraneous appendage at the junction of the sheath and blade (ligule); fruit is a grain. 9

A. Sedges (Cyperaceae). Solid often triangular stems; roots fibrous; leaves in 3 ranks, when present; sheath closed at the top; a spike or cluster at the top of the stem, flowers lack petals and sepals; fruit an achene. 10

A. Rushes (Juncaceae). Pithy or hollow stems, unbranched; leaves narrowly lanceolate or filliform; grows in basal clumps, or represented by sheaths only; clustered small greenish or brownish flowers; fruit capsule. 11

8. Plants that are not grasses, sedges or rushes, or do not fit in any of the above classes. 12

9. Gramineae (Grasses). The illustrated characters for the grass species is the ligule. This is membraneous and/ or hairy structure found where the blade of the leaf joins the sheath.

A. Spartina alterniflora. Salt Marsh Cord Grass. A large coarse grass found at the margin of tidal marshes and along creek and pools in the marsh. The ligule has a fringe of hairs and the base is fused and membraneous. The blades are around 18 mm wide. A dwarf form occurs in the lower portion of the S. patens zone. It grows from a rhizome that is covered with white papery scales, flowers are tight against the stem in a comb-like cluster.

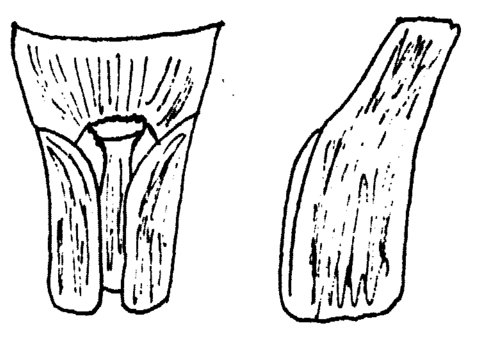


Fig 8. *SPARTINA ALTERNIFLORA*

B. Spartina cynosuroides. Salt Reed Grass. Grows 1-3 m high and blades are 1-2 cm wide at the base. The rhizome is hard and deep-seated, measures 1-2 cm in diameter and is covered with scales. The orifice of the upper sheath is puckered when dried. The spikes are brownish to purple and there are 6-50 in an open raceme. Plant of the fresh or brackish tidal marshes.

C. Spartina patens. Salt Marsh Hay - A slender grass forms pure stands on the lower slope of a marsh. In late summer and early fall the growth has a "cow lick" formation. The basal leaves are filiform with the upper leaves being 1 cm long. The ligule is a fringe of hairs. The flower consists of two or more comb-like spikes forming an open panicle. Flowers are purple.

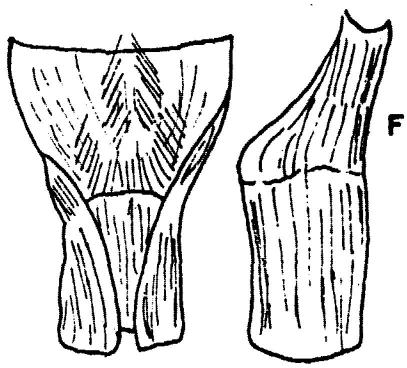


Fig 9. SPARTINA PATENS

D. Distichlis spicata. Spike Grass - Found in dense mats in the Spartina patens zone, sometimes in pure stands. Leaves are 2-3 mm wide. Flowers are a compact subcylidrical panicle. Ligule is membraneous. It has a creeping rhizome that often invades bare areas.

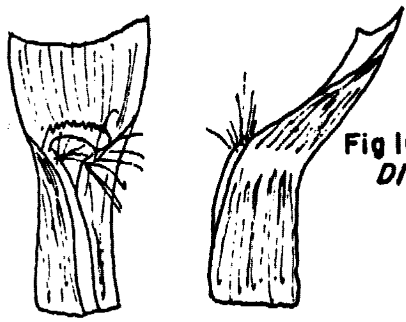


Fig 10. DISTICHLIS SPICATA

E. Panicum virgatum. Switch Grass - A large coarse grass that grows in thick hummocks or tussocks. Blades are 10-15 mm wide. Ligule is a fringe of hairs. Flowers are a loose wide spreading panicle Found in the transition zone of the marsh border.

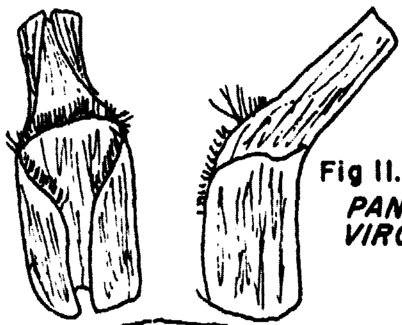


Fig 11. PANICUM VIRGATUM

F. Phragmites communis.[1] Reed Grass - A large erect grass which can grow to 6 meters tall, from long creeping rhizomes. Ligule is a fringe of hairs some up to 6 mm long. Feathery flower with long silky hairs, tawny or purplish in color.

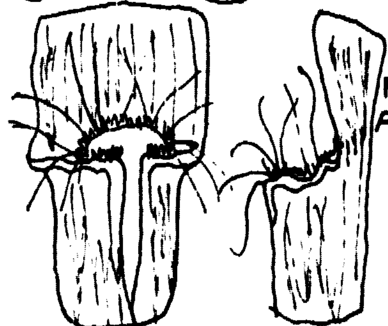


Fig 12. PHRAGMITES COMMUNIS

[1] Although P. communis is not listed in the Wetlands Act, it is found quite extensively in the marshes of Delaware and is used as an indicator species.

PLATE I   LEAF SHAPES AND MARGINS

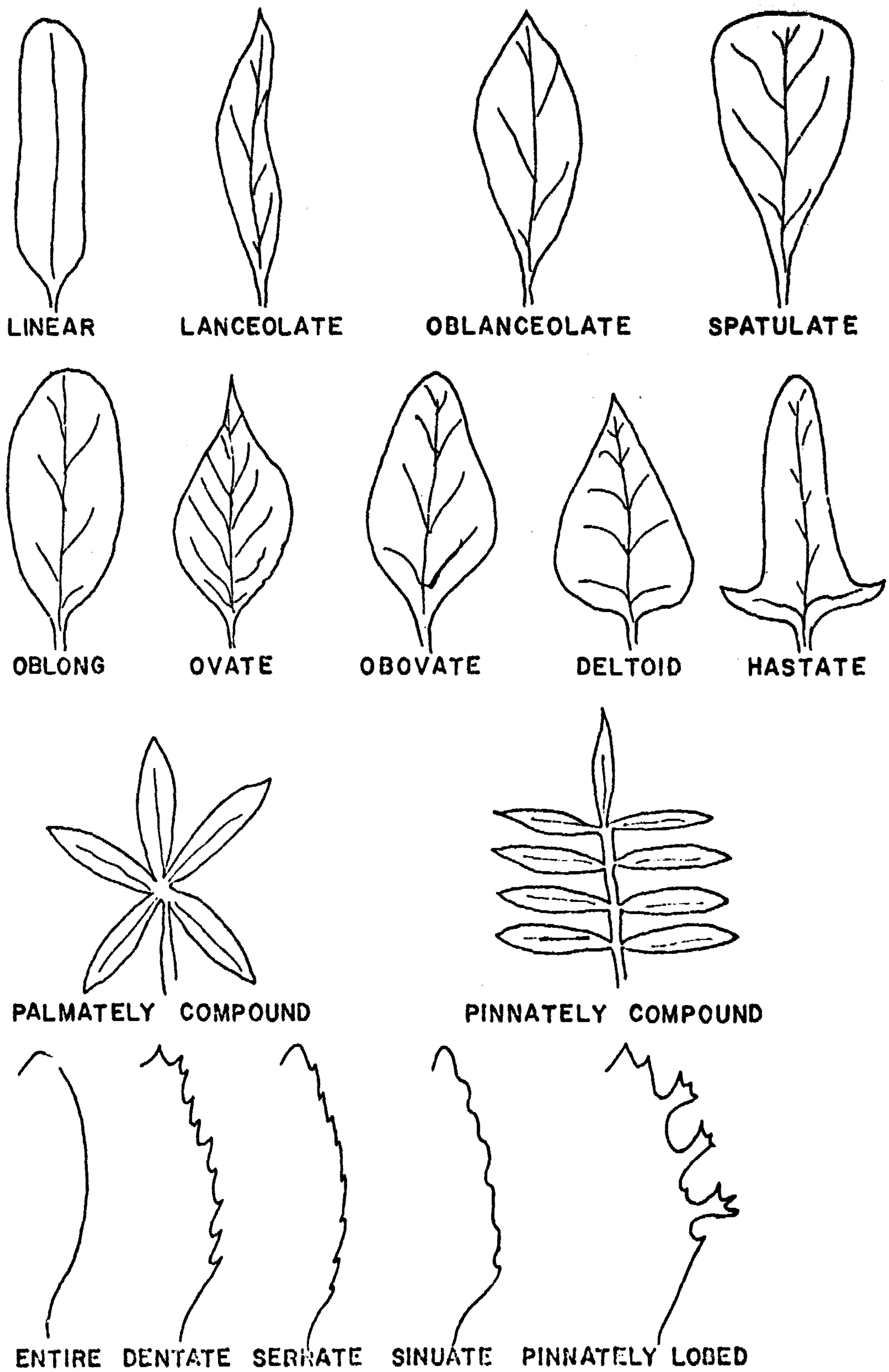
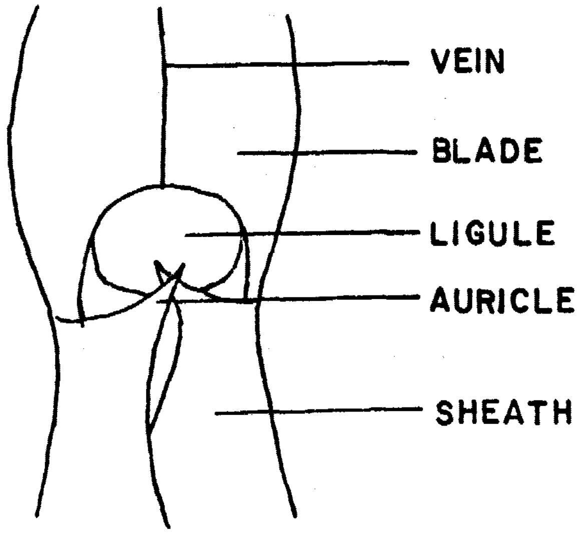
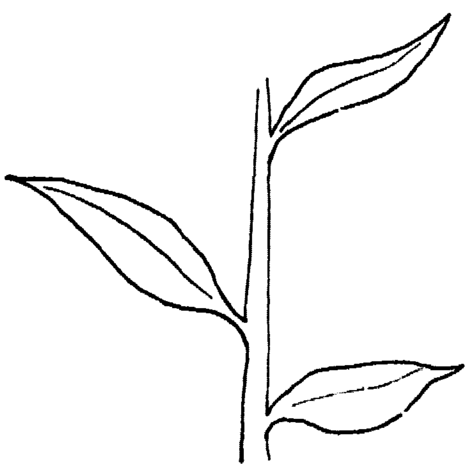


PLATE II

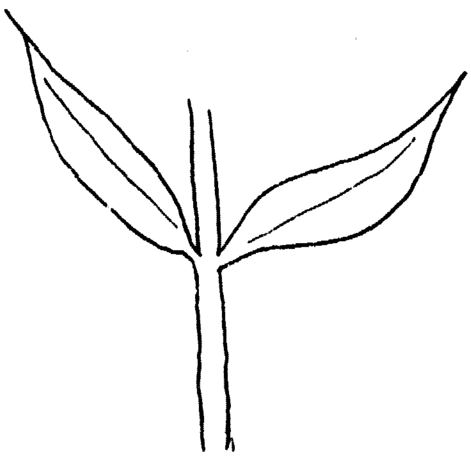
JUNCTION OF BLADE AND SHEATH IN GRASSES



BRANCHING TYPES



ALTERNATE



OPPOSITE

PLATE III WETLAND GRASS SPECIES

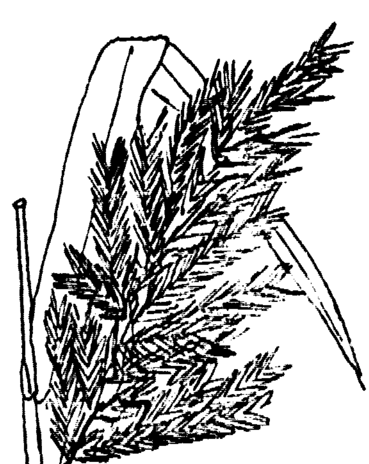
SPARTINA ALTERNIFLORA

SPARTINA CYNOSUROIDES

SPARTINA PATENS

DISTICHLIS SPICATA

PANICUM VIRGATUM



PHRAGMITES COMMUNIS

10. Cyperacae (Sedges) - Solid often triangular stems; fibrous roots, leaves in three ranks when present; sheath closed at the top; a spike or cluster at the top of the stem; flowers lack petals and sepals; fruit an achene. Only two species known in the marshes.

A. <u>Scirpus americanus</u>. Three-square - Rhizomes are stout and hard, dark brown in color. The upper sheath is concaved, also bears a longated linear, sharp pointed blade. Many spiklets in sessile clusters, and reddish-brown in color. Grows in the brackish to fresh water borders of the marsh.

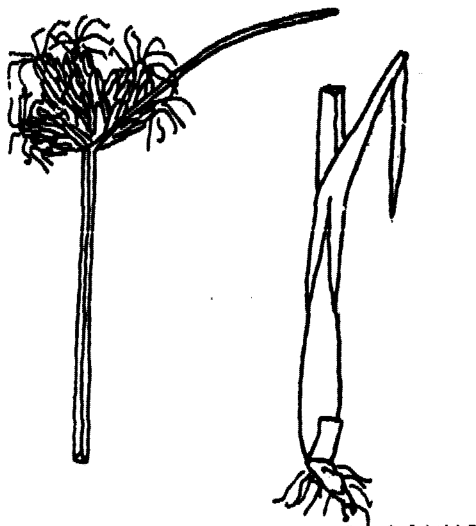


Fig 13. *SCIRPUS AMERICANUS*

B. <u>Scirpus torreyi</u>. Torrey's Rush - Rhizomes are flaccid and brown. Upper part of the sheath shows splitting; triangular leaves that are channels with obliquely rounded tips; spiklets in sessile clusters. Plant of the brackish to fresh water margins of ponds and marshes.

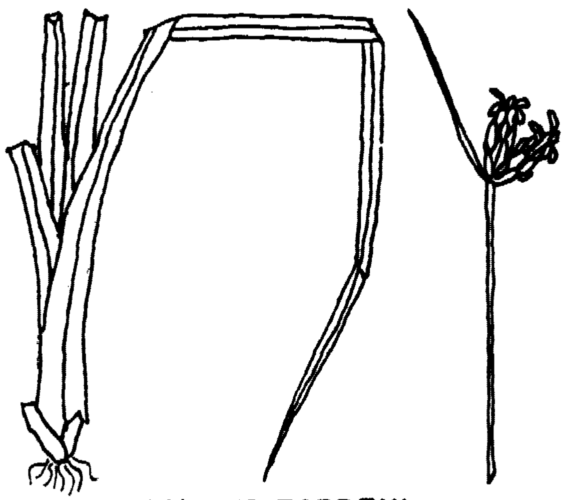


Fig 14. *SCIRPUS TORREYI*

11. Juncaceae (Rushes) - Pithy or hollow stems; unbranched; leaves narrowly lanceolate or filliform, in basal clumps or represented by sheaths only; clustered small greenish or brownish flowers; fruit a capsule.

A. <u>Juncus gerardi</u>. Black Grass - A wiry erect herb that resembles grasses or rushes. Rhizomes are slender and grow horizontally. The leaf sheath extends approximately 1/3 of the way up the stem. The leaf blades are stiff, ascending and slightly flattened. The stem ends in a cyme of brown flowers. Achenes protrude from floral envelopes in late summer to give the marsh a dark brown appearance. Grows in practically pure stands at the upper, landward edge of the marsh.

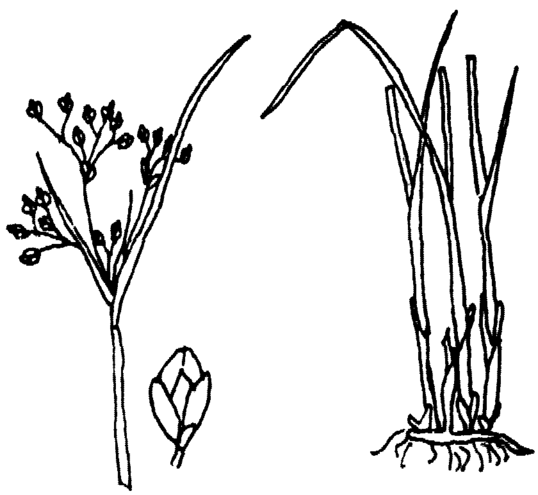


Fig 15. *JUNCUS GERARDI*

12. Linear slender leaves; cylindrical tips are rounded . . . . . Suaeda

    A. Short plants with branches radiating from the base, buds are around 2 mm wide . . . S. maritima
    Sea Blite

    A. Erect plants; seeds range from 1.2 mm to 1.5 mm wide. . S. Linearis
    Sea Blite

Fig 16. SUAEDA MARITIMA

Fig 17. SUAEDA LINEARIS

12. Broad leaves; not cylindrical or reduced to scales. 13

13. Opposite branching is obvious but found only at the base; leaves and scales are opposite 14

13. Alternate branching and leaves . . 15

14. Fleshy, jointed stems; leaves are in fact tiny scales at each node; flowers are found in hollows of the thick upper nodes, which form a spike. . . Salicornia

    A. Perenial plants; depressed, stout woody stems which fork into the ground; there is a long branched trailing stem, flower spikes are found at the tip of the ascending branches; forms extensive perenial mattes . . . . . . S. virginica
    Perenial Glasswort

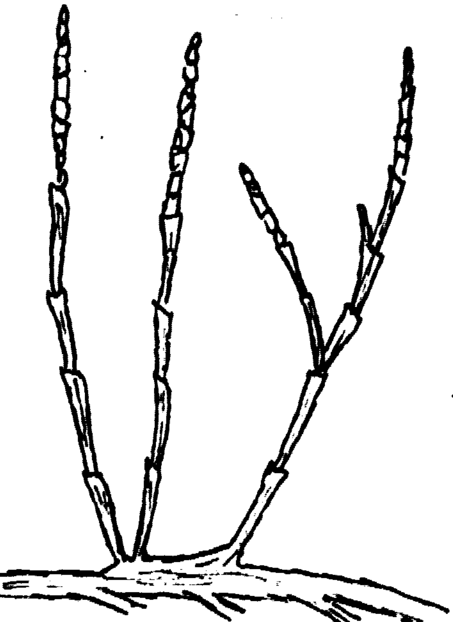


Fig 18. SALICORNIA VIRGINICA

    B. Annual plants with a small root system; erect; scales are mucronate, pointed and conspicuous; located at the nodes of the stem, flower spike is thicker than it is long . . . . S. bigelovii
    Dwarf Glasswort

    C. Annual plants with a small root system, blunt scales at the nodes; not visible when dried; flowering spike joints are longer than they are thick, turns red in fall . . . . S. europa
    Samphire

Fig 19. SALICORNIA BIGELOVII

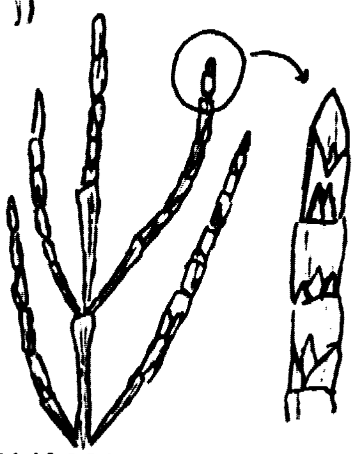


Fig 20. SALICORNIA EUROPA

Fig 21. *ATRIPLEX PATULA*

14. Plants with stems not as above; leaves are not reduced or in close tiers; leaves are arrow shaped; straggling, weedy species; opposite branching found only at the base; green flowers . . . . . . <u>Atriplex patula var hastata</u>
Orach

15. Leaves form a basal rosette. . . . 16

Fig 22. *PLANTAGO OLIGANTHOS*

15. Leaves do not form a basal rosette; the leaves can be various shapes on an erect stem 17

16. Leaves are linear - lanceolate; alternate in a rosette at the base; leaves equal to or exceed the length of the flower stalk; flower spike remotely flowered at the rosette . . . . . <u>Plantago oliganthos</u>
Seaside Plantain

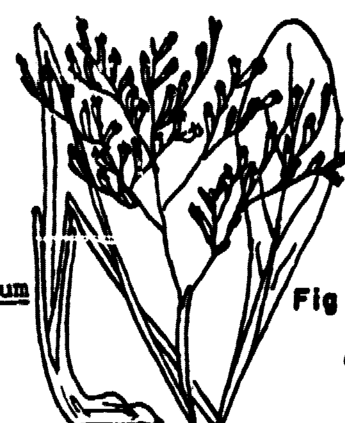


Fig 23. *LIMONIUM CAROLINIANUM*

16. Plant with alternating leaves and branches; leaves are spatulate with entire margins; often with reddish tips; erect flowering stalk that arises from the basal rosette; flowers are lavender in color on a branched leafless stem . . . . . . <u>Limonium carolinianum</u>
Sea Lavender

17. Pinnately lobed leaves; filliform, about 5 cm long; delicate, fibrous roots; small white flowers in terminal umbels . . . . . . <u>Ptilimnium capillaceum</u>
Mock Bishop's Weed

Fig 24. *PTILIMNIUM CAPILLACEUM*

17. Leaves not filliform 18

18. Serrated leaves, ovate to lanceolate, or obovate in shape; slightly pubescent underneath; flat-topped clusters of pink or purple flowers . . . . <u>Pluchea purpurascens var succulenta</u>
Salt Marsh Fleabane

18. Leaves entire, no pubescence on the underside, linear lanceolate, oblanceolate or spatulate 19

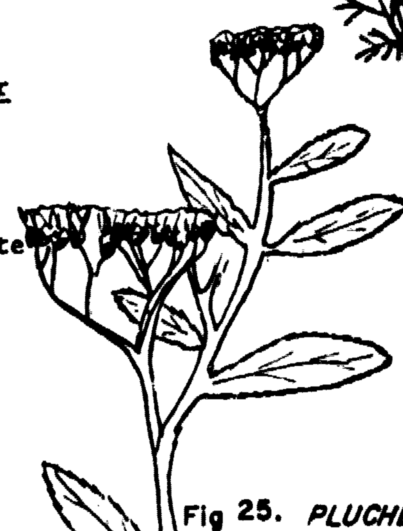


Fig 25. *PLUCHEA*

19. Veins in leaves are parallel . . . 20

19. Leaf veins are not parallel. . . . 21

20. Lanceolate, erect leaves, greyish green in color and are 6-23 mm wide. Stiff stem with a sausagelike brown head of minute, tightly packed, pistillate flowers. Above this is a spike of paler staminate flowers which disappears in late fall. The staminate spike touches the pistillate part. . . <u>Typha latifolia</u>
Broad-leaf Cattail

20. Similar to <u>Typna latifolia</u> except leaves are greener and only 3-8 mm in width. Also the staminate spike is separated from the pistillate part . . <u>Typha angustifolia</u>
Narrow-leaf Cattail

21. Large coarse plants; basal leaves which are oblanceolate or spatulate, range 1 to 4 cm in length; stem leaves are lanceolate; has yellow flowers in late summer and fall . . . . . <u>Solidago sempervirens</u>
Seaside Goldenrod

21. Small delicate plants with narrow linear leaves; small pink flowers on pedicels which originate from the axils of the upper leaves . . . . <u>Aster tenuifolius</u>
Salt Marsh Aster

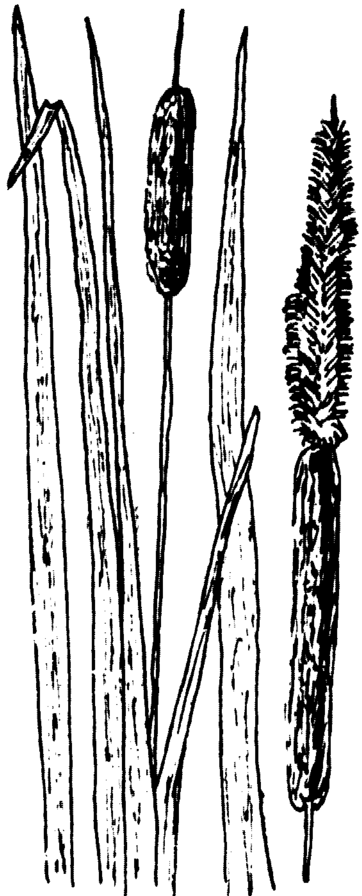


Fig 26. *TYPHA LATIFOLIA*

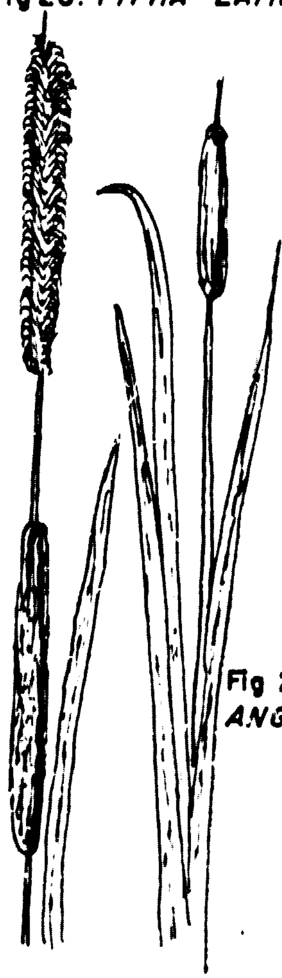
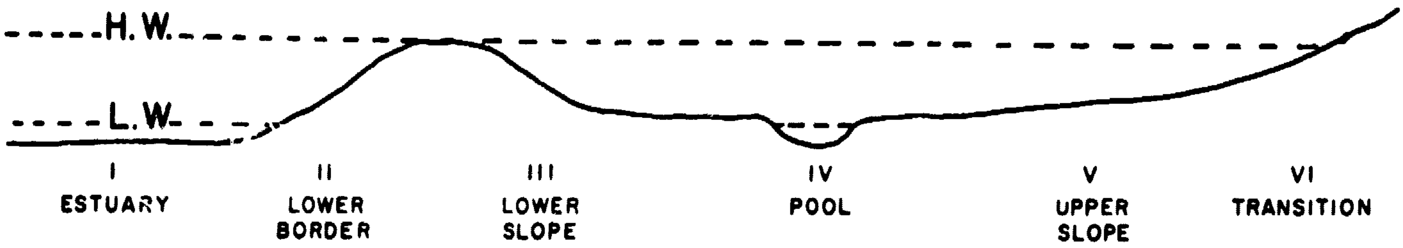


Fig 27. *TYPHA ANGUSTIFOLIA*

Fig 28. *SOLIDAGO SEMPERVIRENS*

Fig 29. *ASTER TENUIFOLIUS*

TIDAL MARSH DISTRIBUTION ZONES



Zone I. Estuary. The bottom may be sand, mud, cobbles, or any combination of the three. Covered with water but may be bordered by a flat which is exposed at low tides.

Zone II. Lower Border. Edge of the marsh, also found along creeks and ditches. Tides flood the area twice a day. Few species grow in this area. Spartina alterniflora zone.

Zone III. Lower Slope. This area is subject to the higher tides. Spartina patens zone.

Zone IV. Pool. The water in the pool varies according to the tidal influx. During the summer the salinity may reach 60 parts per thousand or more.

Zone V. Upper Slope. Area subject to extremely high tides and storm water. Juncus Gerardi zone.

Zone VI. Transition. Subject to storm tides only. The upland vegetation takes over and is mixed with marsh vegetation.

The dominant species for each zone in the above diagram are listed below. In most marshes the number of species increases from Zone I to VI.

Zone I.
- Ruppia maritima
- Zostera marina

Zone II.
- Aster tenuifolius
- Limonium carolinianum
- Pluchea purpurascens
- Salicornia bigelovii
- S. europaea
- S. virginica
- Spartina alterniflora*
- Suaeda maritima
- S. linearis

Zone III. <u>Aster tenufolius</u>
<u>Distinhlus spicata</u>
<u>Iva frutescens</u>
<u>Limonium carolinianum</u>
<u>Phragmites communis</u>
<u>Plantago oliganthos</u>
<u>Pluchea purpurascens</u>
<u>Ptilumnium capillaceum</u>
<u>Salicornia bigelovii</u>
<u>S. europaea</u>
<u>S. virginica</u>
<u>Solidago sempervirens</u>
<u>Spartina alterniflora</u>
<u>S. patens</u>*
<u>Suaeda linearis</u>
<u>S. maritima</u>

Zone IV. <u>Potamogerton pectinatus</u>
<u>Ruppia maritima</u>

Zone V. <u>Atriplex patula</u>
<u>Baccharis halmifolia</u>
<u>Distichlus spicata</u>
<u>Iva frutescens</u>
<u>Juncus gerardi</u>*
<u>Phragmites communis</u>
<u>Ptilimnium capillaceum</u>
<u>Solidago sempervirens</u>
<u>Suaeda linearis</u>
<u>S. maritima</u>

Zone VI. <u>Atriplex patula</u>
<u>Baccharis halmifolia</u>
<u>Hibiscus palustris</u>
<u>Panicum virgatum</u>
<u>Phragmites communis</u>
<u>Scirpus amoricanus</u>
<u>S. torreyi</u>
<u>Solidago sempervirens</u>

*Dominant species of that zone.

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