AN INVESTIGATION OF CERTAIN WATERFOWL FOOD PLANTS AND A BOTANICAL SURVEY OF BACK BAY NATIONAL WILDLIFE REFUGE, PRINCESS ANNE COUNTY, VIRGINIA

by

Edward B. Chamberlain, Jr.

Major Thesis Submitted to the Faculty

of

The Virginia Polytechnic Institute

Department of Biology

In Partial Fulfillment of the Requirements

For the Degree

of

Master of Science

in

Wildlife Conservation

APPROVED:

Dean of the College

APPROVED:

Head of Department
of Biology

APPROVED:

Dean of Agriculture

APPROVED:

Supervisor

March, 1948

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

FIGURES AND TABLES

Page

FIGURES

TABLES

TABLES (Cont'd)

FOREWORD

The work described in this paper was originated and brought to its present state only through the aid of a number of interested persons, but few of whom can be mentioned here. Every bit of such assistance is deeply appreciated. The Wildlife Mananement Institute by its very liberal grant made the entire project possible. The U. S. Fish and Wildlife Service allowed the work to be done on its refuge and supplied base maps. Mr. C. O. Handley, then leader of the Unit, was of considerable help in initiating the study. Dr. H. S. Mosby, present Station Director, has given much excellent advice, spent much time in working out various problems, and kindly taken several photographs. Mr. A. B. Massey, Botanist at the Station, who directly supervised the present study, has given more help than can be described here. Work under him has been both worthwhile and pleasant. Fellow-students W. P. Blackwell, G. A. Gehrken, C. H. Peery, III, C. H. Shaffer, and J. C. Sweet gave much help and fine companionship. Mrs. Nancy Huffman and Mrs. Kathryn Prouty, Station secretaries, have always been extremely helpful. The data on soils are due to the kindness of Dr. E. M. Dunton, Jr. of the Virginia Truck Experiment Station near Norfolk, who tested this material. Finally, the greatest

thanks are owed the Back Bay Refuge Manager, Mr. J. E. Perkins, and his wife, for their all-important contributions - interest, tolerance, many valuable suggestions and ideas, good company and continual help in all matters.

INTRODUCTION

The Back Bay area has long been recognized as one of the more important wintering grounds for waterfowl in the eastern states. As such, it is important to the Commonwealth of Virginia, the Fish and Wildlife Service, and to numerous private interests. Considerable sums of money are invested in hunting clubs, marshes, and equipment, and the income derived by providing various services to hunters is very important to the local people.

Prior to 1918 the growth of submerged aquatic waterfowl food plants in Back Bay apparently was usually unexcelled anywhere in the East. But between 1918 and 1926 these plants died out to such an extent that vast areas were practically barren (Bourn, 1932). Conditions seem to have fluctuated in the past 16 years, never approaching the pre-1918 level, but usually better than those of 1926-1932.

The purposes of the present investigation are four-fold. The first, a botanical survey of the Back Bay National Wildlife Refuge, in addition to its importance *per se*, is essential to successful waterfowl management in that it shows what plants are present. The second objective is to determine the abundance and distribution of the more important waterfowl food plants. This information is necessary to other phases of the problem, and is valuable in determining the trend of conditions in the area, which in turn affect management measures. The third purpose is to try to determine the factor or factors now limiting the growth of submerged waterfowl food plants in Back Bay, and responsible for the fact that the present productivity is considerably less than the potential. The fourth, and final aim is to recommend such management practices as seem feasible under conditions now extant.

DESCRIPTION OF AREA

1. General Description.

The area of marshes and open water known as Back Bay is located in Princess Anne County in the extreme southeast corner of Virginia, approximately between 36° 41' and 36° 45' north latitude and between 75° 53' and 76° 00' west longitude. It is the most northern of the series of inland waters which includes Currituck, Pamlico, and Albemarle Sounds in North Carolina. The south limit of Back Bay is roughly the Virginia-North Carolina boundary line. It is about eleven miles long in the north-south axis, five miles wide at the south end, and two miles wide at the north, which gives it an area of some 50 square miles. Back Bay is separated from the ocean only by a narrow barrier beach, but there is no direct connection with the sea north of Oregon Inlet in North Carolina, some 70 miles to the south.

Physiographically, Princess Anne County lies in the Atlantic Coastal Plain, and in that section of Virginia spoken of as Tidewater. The land is very nearly a level plain, though it actually consists of two terraces. Both are of marine origin, no fluvial deposits having been recognized within the county. The Princess Anne Terrace, on which Back Bay is located, is generally considered to range in elevation from sea level to an altitude of about 15 feet, though sand dunes of greater height than this can be found. The base of this terrace is below sea level, but the whole terrace is not considered to be more than 15 to 20 feet thick. It is supposed to have formed in the Quarternary Period of the Cenozoic Era.

Since no part of the county is more than eight miles from a point which lies at sea level, most of the natural drainageways are comparatively short. However, some large areas have no natural surface drainage, so incomplete is the system. The drainage in the northern part of the county is into Chesapeake Bay, and in the southern part into Currituck Sound, through Back Bay, North Landing River, or Northwest River. In addition, a small area some ten miles north of Back Bay drains into the Atlantic Ocean through Rudy Inlet, a very small inlet just south of the town of Virginia Beach. That the land is sinking apparently is borne out by the fact that remains of trees and foundations of earlier Coast Guard Stations can be seen on what is now the front beach, well below high tide mark.

2. Soils and Water Areas.

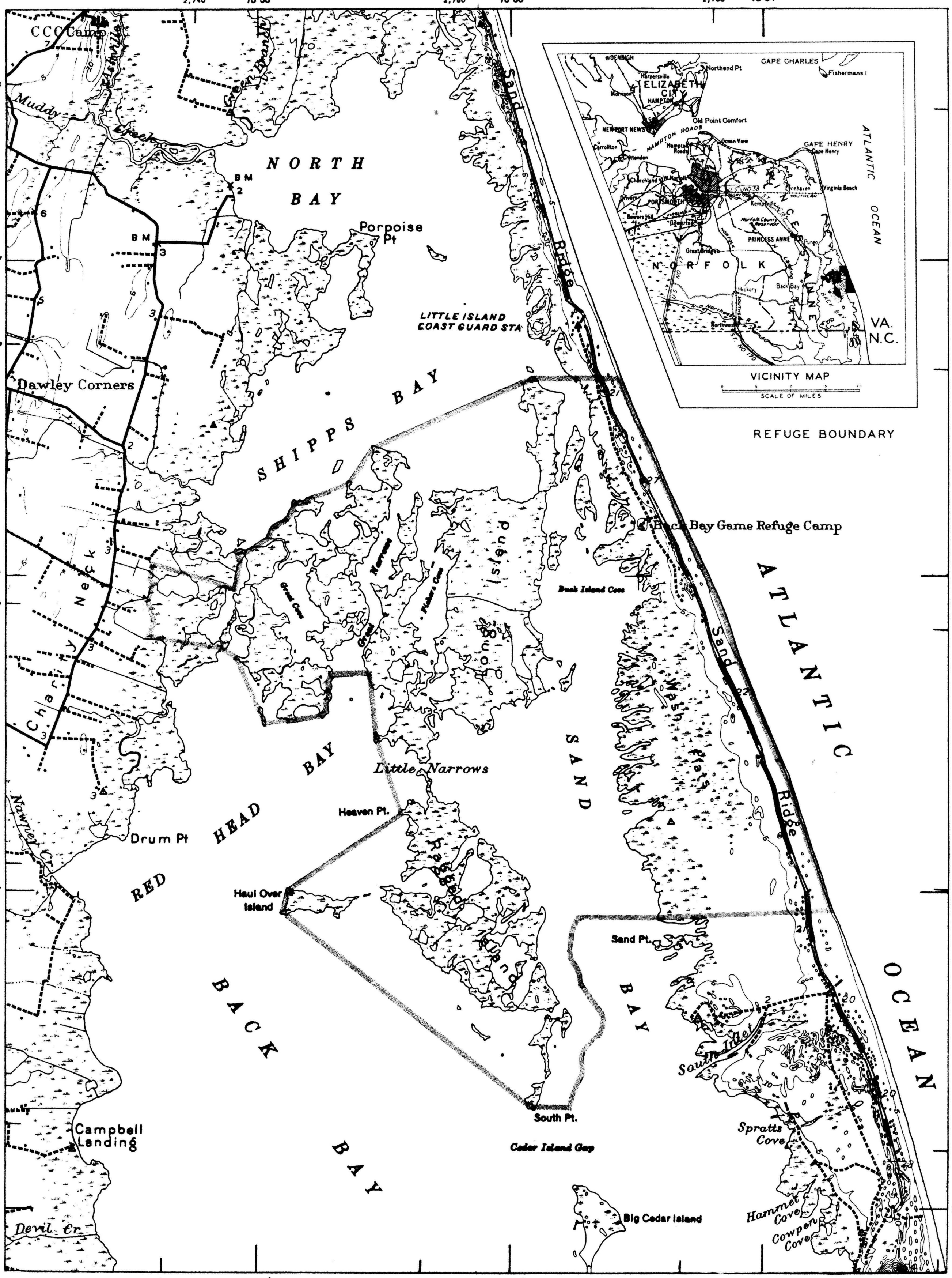
Within the county as a whole, the soils have been mapped as

24 types and phases in four groups according to drainage conditions, and ten separations classed as miscellaneous land types (Simmons and Shulkcum, 1945). Of these units; seven occur within the Refuge boundaries. Only two of the seven are definite soil types, the other five being rather classifications of material. Moyock fine sandy loam occurs on a small area at the south end of Long Island, while Sassafras fine sandy loam was found through the central and northern parts of Long Island, on Ragged Island, and about the immediate vicinity of Refuge headquarters. On the barrier beach between the ocean and the Bay are found the five miscellaneous land types, Arzell sand (primarily a quicksand), mobile and stabilized dunes, coastal beach, and marsh. Marsh also occurs extensively over other sections of the Refuge. Indeed, it comprises 10.2% of the total area of the county (Simmons and Shulkcum, 1945), and some 35% of the Back Bay area.

The Back Bay National Wildlife Refuge is a roughly triangular area of about 12,000 acres. As Figure 1 shows, it is located somewhat north of the central part of the Back Bay area, and extends from the front beach across the Bay to the west shore. The frontage along the Atlantic Ocean is a little over four miles, while that on the west shore is very short, only

BACK BAY NATIONAL WILDLIFE REFUGE

U. S. DEPARTMENT OF THE INTERIOR | PRINCESS ANNE COUNTY, VIRGINIA | FISH AND WILDLIFE SERVICE



COMPILED IN THE DIVISION OF LANDS
BASE BY U.S G.S.

CHICAGO, ILLINOIS 7273   MAY 1946

Figure 1. General and Location Map of Refuge

Scale: 0 – 20 – 40 – 80 – 120 – 160 CHAINS; 0 – ¼ – ½ – 1 – 1½ – 2 MILES

CONTOUR INTERVAL 5 FEET DATUM IS MEAN SEA LEVEL

MEAN DECLINATION 1940

B2 BAC 69

about one-half mile. The portion of the Refuge located on the barrier beach consists, as mentioned above, of coastal beach, both types of dunes, a limited amount of Arzell sand, and marsh. The coastal beach, of course, fronts on and parallels the ocean. Immediately behind this are the mobile dunes, another rather narrow zone which usually does not exceed 75 yards in width. Between the dunes and the Bay occurs an area of marsh, low stabilized dunes, and a limited amount of Arzell sand. This area, as before stated, is a little over four miles in length, and varies from about one-quarter mile wide at the north end to slightly over one mile wide at the south. The marsh is irregularly inundated, depending on water level in the Bay and on rainfall. A very low, natural levee exists along the Bay edge of this marsh. The stabilized dunes are low, one to four feet or so. In addition to herbaceous species, trees and shrubs are supported in a stabilized dune area of one-half by one-quarter mile near the south boundary of the Refuge. Also, near the south boundary, between the sand dunes and the Bay, is an area of practically barren, sandy, "salt flats." Within the Refuge, these so-called Wash Flats are about one and a quarter mile long and from one-quarter to three-quarters of a mile wide. Long and Ragged Islands, the two largest on the Refuge, are mainly marsh, but have some highland, consisting of the Moyock and Sassafras fine sandy loams. Scattered through the remainder of the Refuge are extensive marsh islands. The water area, some 7500 acres or about 62% of the Refuge, averages three to four feet in depth, though a few spots ten feet deep were found. Considerable areas less than three feet deep occur.

Actually, the water areas within the Refuge boundaries are not owned by the Federal government as the marsh and highland are. These latter areas were purchased by the Federal government from the Ragged Island Club, Inc. (812.00 acres) and the Princess Anne Club (3,776.76 acres), both private shooting clubs, in 1937. The Refuge was established by Executive Order No. 7907 on June 6, 1938. The water areas, however, were not given into Federal ownership. Chapter 388, of the Laws of the State of Virginia, approved March 31, 1938, merely transfers from the Commonwealth of Virginia to the United States all rights, authority, and control concerning wildlife, except fish and oysters, on the designated areas.

3. Climate.

The climate of Princess Anne County is sufficiently mild to be considered of the Austroriparian Zone, and is in the only part of the State in which this zone is found. The summers are long, but very hot days are few. Winters are mild, with little below-freezing weather. At the Cape Henry station of the U. S. Weather Bureau, which is the closest to the Refuge and supplied all climatological data, the average frost-free season is 245 days (March 20th to November 20th). Rainfall is moderate and well distributed. At least some wind is generally to be expected, and velocities of 30 mph are not at all uncommon. The normal monthly, seasonal, and annual temperature and precipitation at Cape Henry are given in Table 1. The Cape Henry weather station is 17 miles north of Refuge Headquarters.

TABLE 1

NORMAL MONTHLY, SEASONAL, AND ANNUAL TEMPERATURE AND PRECIPITATION AT CAPE HENRY, VIRGINIA. ELEVATION, 16 FEET.

Month	Temperature			Precipitation			
	Mean °F	Absolute Max. °F	Absolute Min. °F	Mean Inches	Total, Dryest Year Inches	Total, Wettest Year Inches	Average Snowfall Inches
Dec.	43.7	78	7	3.44	1.35	5.28	1.5
Jan.	40.2	79	6	3.15	4.39	5.59	2.0
Feb.	41.2	84	5	3.31	1.29	1.06	2.3
Winter	41.7	84	5	9.90	7.03	11.93	5.8
March	46.6	90	12	3.87	1.02	6.29	1.3
April	54.6	97	26	3.30	.93	6.89	T*
May	64.2	98	41	3.57	3.30	2.88	0
Spring	55.1	98	12	10.74	5.25	16.06	1.3
June	72.9	102	48	3.96	3.14	4.61	0
July	77.5	102	55	5.37	2.57	6.48	0
Aug.	76.9	103	57	4.86	1.21	3.32	0
Summer	75.8	103	48	14.19	6.92	14.41	0
Sept.	71.8	99	47	2.86	.46	10.04	0
Oct.	62.1	92	35	3.01	2.73	6.79	0
Nov.	52.1	86	19	2.36	.83	5.44	T*
Fall	62.0	99	19	8.23	4.02	22.27	T*
Year	58.7	103 (Aug., 1881)	5 (Feb., 1889)	43.06	23.22 (In 1915)	64.67 (In 1877)	7.1

Records from U. S. Weather Bureau.
*Trace

Storms which could force ocean water across the barrier beach and into Back Bay are important because of the effect such ocean break-throughs into the Bay would have on the salinity. Winds of sufficient velocity to cause this would almost always result from a northeast gale, or a hurricane. Weather Bureau records show that between 1915 and 1945, nine hurricanes struck the area. This averages three and one-third years between storms. There is no reason to believe that this average has undergone any great change. Therefore, it is likely that in former times, some ocean water entered the Bay at least once every three years. And since northeast gales could also cause this, the average was probably nearer once in two years.

4. A. and C. Canal.

Several man-made structures have had considerable effect on conditions in Back Bay. The first of these is the Albemarle and Chesapeake Canal, a sea level canal connecting Norfolk harbor with the northwest end of Currituck Sound. It was completed about 1860 and operated until 1912 by a private company. During this period, the canal had a tidal guard lock at its northern end to equalize differences in water level caused by the presence of lunar tides in Norfolk harbor and their absence in Currituck

Sound. This lock prevented any great amount of water from flowing south from Norfolk. In 1912 the U. S. Government purchased the canal and made it a part of the Intracoastal Waterway System.

The tide guard lock was removed in 1918 and work begun on enlarging and deepening the canal. This was completed in 1922. After the lock was removed, water was observed to flow southward through the canal regardless of lunar tides at Norfolk for as long as 22 hours and 40 minutes, and with a velocity of two mph (Bourn, 1932). The conclusion has been made (Bourn, 1929 and 1932) that polluted, turbid water from Norfolk harbor, resulting from the opening and enlarging of the A. and C. Canal, was responsible for the great loss of submerged waterfowl food plants in Back Bay in the years 1918-1932. Any waters reaching upper Currituck Sound from Norfolk harbor would, of course, with a south wind flow into Back Bay. Such waters reach Back Bay via the natural channel, or via an artificial canal (Corey's Ditch, dug 1912-15) past Knotts' Island (Figure 2). Following complaints of this damage from owners of waterfowl shooting properties, the locks were replaced in June, 1932, and have since remained closed.

5. Sand Fence.

Along the line of natural dunes on the beach separating Bay

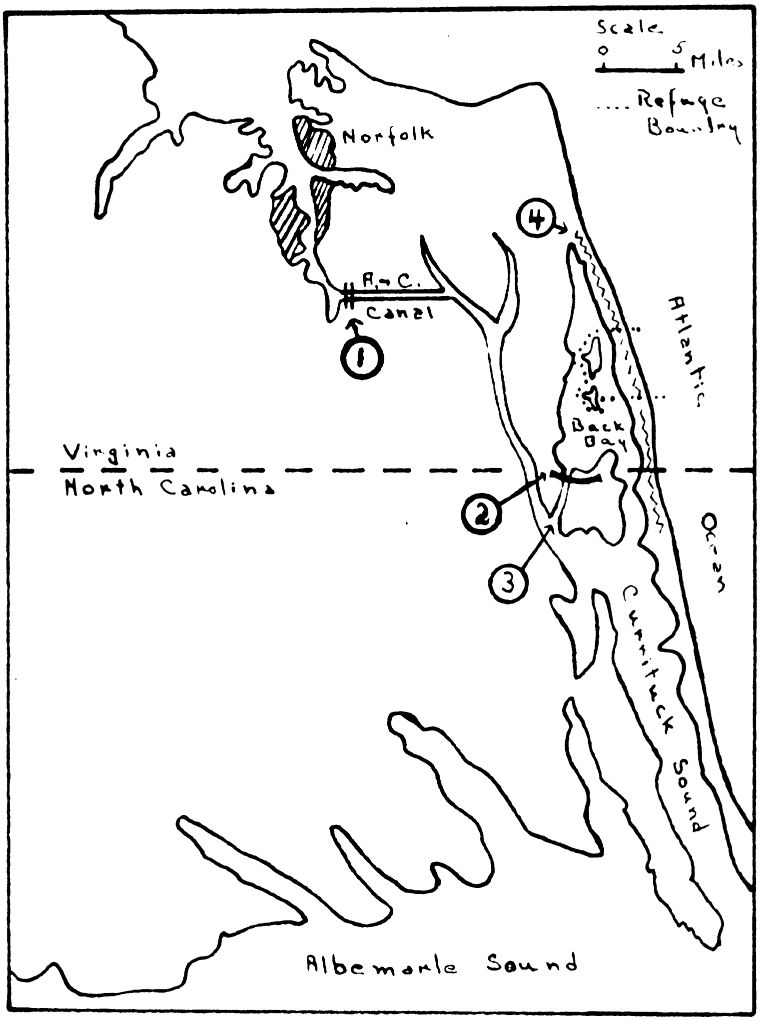


Figure 2. The Back Bay Region, Showing Relations of the A. & C. Canal with Locks (1), Knott's Island Causeway (2), Norfolk Harbor, Corey's Ditch (3), Back Bay, and Sand Fence (4).

and ocean, a sand fence was built between 1933 and 1935. This was done by erecting long fences of grass-work panels to catch and build up the drifting sands, and was designed to raise and make complete the barrier between Back Bay and the ocean. Prior to this, storm waters at times flowed across the beach and into Back Bay. Such an occurrence would naturally increase the salinity in the Bay, but apparently only temporarily. Freshness was maintained because these waters fairly promptly moved on into Currituck Sound through the channel between Knott's Island and the beach and across Great Marsh, between Knott's Island and the west shore. In the latter part of the last century, however, a causeway was built across this marsh which prevented the passage of water until a ditch was put in, about 1915. Local inhabitants who remember the times when ocean water crossed the beach into the Bay, claim that the submerged aquatic growths benefitted tremendously thereby. In this, Bourn (1932) concurred. Plants close to the break through would be killed, but the following year's growth was more luxuriant than before. The last time any salt water crossed the beach was in 1936 when a storm swept some through a low spot in the sand fence. This spot was later repaired, and since that time there has apparently been no salt water entering Back Bay directly from the ocean. The salinity of Bay water is now very low, averaging about 2.1% sea strength. This is in marked contrast to conditions in 1926-30, when extremes of 3.0% and 20% were reported (Bourn, 1932). After the hurricane of August, 1933, salinity rose from 12.5% to 32%, and after that of October, 1936, from 2.5% to 18.5% (Mosby, 1946).

REVIEW OF LITERATURE

A most comprehensive investigation of the problem of decline in the submerged aquatics of Back Bay was made by Dr. W. S. Bourn from 1926 through 1930, and the findings published in 1932 (Bourn, 1932). He made studies of the physical, chemical, and biological conditions of the water, sought varieties of plants resistant to existing conditions, and experimented with methods of replanting. Also, the history of conditions in the area is reviewed, the physiology of aquatic angiosperms dealt with at some length, and an extensive literature cited. Certain pertinent material from this report has already been mentioned, and further references will be made to it. The ecological investigations which Dr. Bourn made at that time led him to make a series of laboratory experiments to determine the factors limiting the growth of submerged angiosperms (Bourn 1934 and 1935). Another possible factor in the decline of aquatics was presented in a report on a fungus disease (Bourn and Jenkins, 1928). And at the Sixteenth American Game Conference, the situation to date was reviewed and certain corrective measures advocated (Bourn, 1929). The same author later made a report on general conditions in Back Bay (Bourn, 1945). A still more recent report (Mosby, 1946) is on an overall investigation of the waterfowl food plant status and problems on the Bay. These works seem to be the only reports which deal directly with the problem of decline in submerged aquatic waterfowl food plants in Back Bay. Others, mainly of interest from a historical point of view, will be found in the bibliography.

The plant life of the region has received considerable attention in aspects other than its importance to waterfowl. In 1898 Kearney made a botanical survey of Dismal Swamp and adjacent parts of North Carolina and Virginia (Kearney, 1901). Though he did not actually work in the Back Bay section, his work is of interest as one of the earlier studies of the vegetation of a large area, and for its treatment of the geology, soils, plant formations, notes on plant anatomy, catalogue of plants of the region, and especially for the section on the relation of plant growth to the character of the soil. A much more recent floral study, but again one which is outside of the Back Bay section, is a check list of species found on the State Park at Cape Henry (Egler, 1942). In addition to its annotated list, this work discusses geomorphology, climate, soils, life zone relationships, and plant communities. The greatest amount of botanical work in Princess Anne County, however, has been done by Dr. M. L. Fernald and reported upon in a series of articles in Rhodora (Fernald 1935; 1936; 1940; 1941; 1947; and Fernald and Griscom, 1935).

This work has been primarily taxonomic and has resulted in descriptions of many new varieties, several new species, and numerous range extensions. The phytogeographical discussions of the same author are of interest, as are his comments on conditions which he found on his trips to the Back Bay Refuge (Fernald, 1940). These will be considered later.

Aside from the literature mentioned here, which bear more or less directly on the problem at hand, there are numerous works which deal with related subjects. Some of these titles, at least, are listed in Appendix II.

BOTANICAL SURVEY

As stated in the introduction, a botanical survey of the Refuge has, in addition to its intrinsic value, much worth in considerations of waterfowl management. In areas such as this, which are used by the birds primarily as resting grounds and wintering range, waterfowl management consists almost wholly of vegetation management and water level control. It is desirable, therefore, to know what plants are present, and the relative abundance and distribution of the more important ones.

During this survey, which extended from May 1 to December 15, 1947, the aim was to cover the various associations weekly, in so far as possible, and to collect such plants on each occasion as were in condition for identification. As a result of this activity, about 330 species and varieties of 198 genera from 76 families were collected on the Refuge. These are presented as an annotated list in Appendix I. Names are based on the seventh edition of Gray's Manual, though more recent revisions have caused some deviation. Splitting to varieties has been avoided as completely as possible. In those few cases where the descriptions in Gray's Manual obviously do not fit, more recently described varieties, or rarely species, have been used.

1. Vegetative Associations of the Refuge.

Within the boundaries of the Refuge, seven associations can be separated on the basis of their vegetation. These are the aquatic, dune, low marsh, high marsh, sand woods, loam woods, and barren flats.

a. The Aquatic Association.

This association includes isolated ponds in the marsh, open Bay, and ponds and sloughs contiguous with the open Bay. Depth, therefore, varies from a few inches to ten feet. This latter extreme was found only in two very restricted spots, however, and the greatest depth over any area larger than a few hundred square yards is five and a half to six and a half feet. The overall average is three to four feet, and there are large areas less than three feet deep. Little zonation of species exists, the relatively few members of this association mingling fairly closely. However, *Lemma minor* and *Zannichellia palustris* are confined to the isolated ponds and to sloughs. The most important species, which are found in the open Bay and connecting ponds and sloughs, are Najas guadalupensis, Potamogeton pectinatus, P. perfoliatus, Ruppia maritima, Vallisneria americana, and Nitella sp. Type of bottom, in itself, does not seem to affect the distribution of these species. All, too, can be found in extremely shallow water, though the better growths are in depths of two to four feet. Practically none of these species grow where the depth is five and one-half feet or over. A few poorly developed, stunted Najas plants may be found at such depths, but nothing else. It is interesting to note that all the aquatics of the open Bay or of its contiguous ponds and sloughs are of the completely submerged type. No species whose leaves float on or reach above the surface, such as the Nymphaeaceae, were found.

The aquatic association is the largest in area of any association found on the Refuge, and at present that of greatest concern to the local people and to most other interested parties. The majority of plants found here are important waterfowl foods, and their decline from a former great abundance to their present state has caused a very real hurt locally. Many people living about the Bay depend for a large part of their income on guiding or otherwise serving hunters, and prosper in ratio to the amount of shooting available. Most of the hunting is from blinds in the Bay, with the diving ducks being the favored game species so that the submerged food plants are most important. The history of the decline of these plants has already been outlined, so that only a few of its points will be emphasized here. Natives who remember conditions prior to 1918 say that often the "grass," as all submerged aquatics are called, was thick enough to cause a boat trouble by fouling the propeller, and the boat wake could be traced as much as two days later. Birds (probably Semipalmated Plovers) are said to have walked about on the "grass" when it grew to the surface of the water. After 1918, however, conditions changed. It is stated (Bourn, 1932) that in 1926, two-thirds of the area were barren. More recently, conditions have been somewhat better, though the improvement has been fluctuating rather than steady. During the past three years there apparently has been some available food still remaining at the end of the winter. This might indicate that there was then enough food present, but it surely does not mean that a production nearer the potential would not be entirely desirable. Such an increase in food plants would meet the demands of any increase in the waterfowl population, distribute any birds present more evenly over the Bay, and minimize eat-outs. In October of 1946 a survey was made to determine and record the relative abundance and distribution of the submerged waterfowl food plants (Mosby, 1946). A similar survey and map were made during the present work, and though there was some difference in methods, for all practical purposes the results are comparable. In the 1946 survey a rake was used to take samples, and visual estimates of relative abundance made. In the present study, a scoop was used which picked up half square foot samples of the bottom, so that the density of the plants could be determined by counting. This latter method permitted comparison of different areas on a rather exact basis. The ratings shown in Table 2 were used in preparing the map (Figure 3), and by comparing this with the map for 1946 (Figure 4), it can be seen that the growth of submerged aquatic waterfowl food plants was more extensive in 1947 than in 1946. Here it may be pointed out that October is felt to be too late in the year for this kind of work. More accurate results and a truer picture could be obtained in September, for by the latter half of October most of the plants have begun to sink to the bottom, and many celery leaves have died and become detached. The increased turbidity of the water makes extensive, rapid surveys difficult. Occasionally, too, a late growth, as of *Nitella* this year, will tend to obscure the presence of other more valuable waterfowl foods, such as celery rhizomes and winter buds. In addition, by the second week in October, there is usually enough utilization by the birds to be significant.

TABLE 2

AREA RATING, SUBMERGED WATERFOWL FOOD PLANTS

Species	Area Rating by Number of Plants per Square Ft. [1]			
	Excellent (Red)[2]	Good (Purple)[2]	Fair (Yellow)[2]	Poor (Green)[2]
Potamogeton pectinatus	10 +	5 - 9	2 - 4	1
P. perfoliatus	18 +	10 - 17	4 - 9	1 - 3
Najas guadalupensis	175 +	90 - 174	20 - 89	1 - 19
Vallisneria americana	20 +	12 - 19	4 - 11	1 - 3
Ruppia maritima	10 +	6 - 9	3 - 5	1 - 2

(1) In this scheme, leaf clusters, as of Vallisneria americana, and separate stems, as of Najas guadalupensis, are counted as plants.
Area has rating of most abundant species, if one is dominant. When no one species is dominant, then if three most abundant are in the same class, area has next higher rating than these three species hold singly provided a fourth species is present. If all species present rate as poor, area is rated as poor.

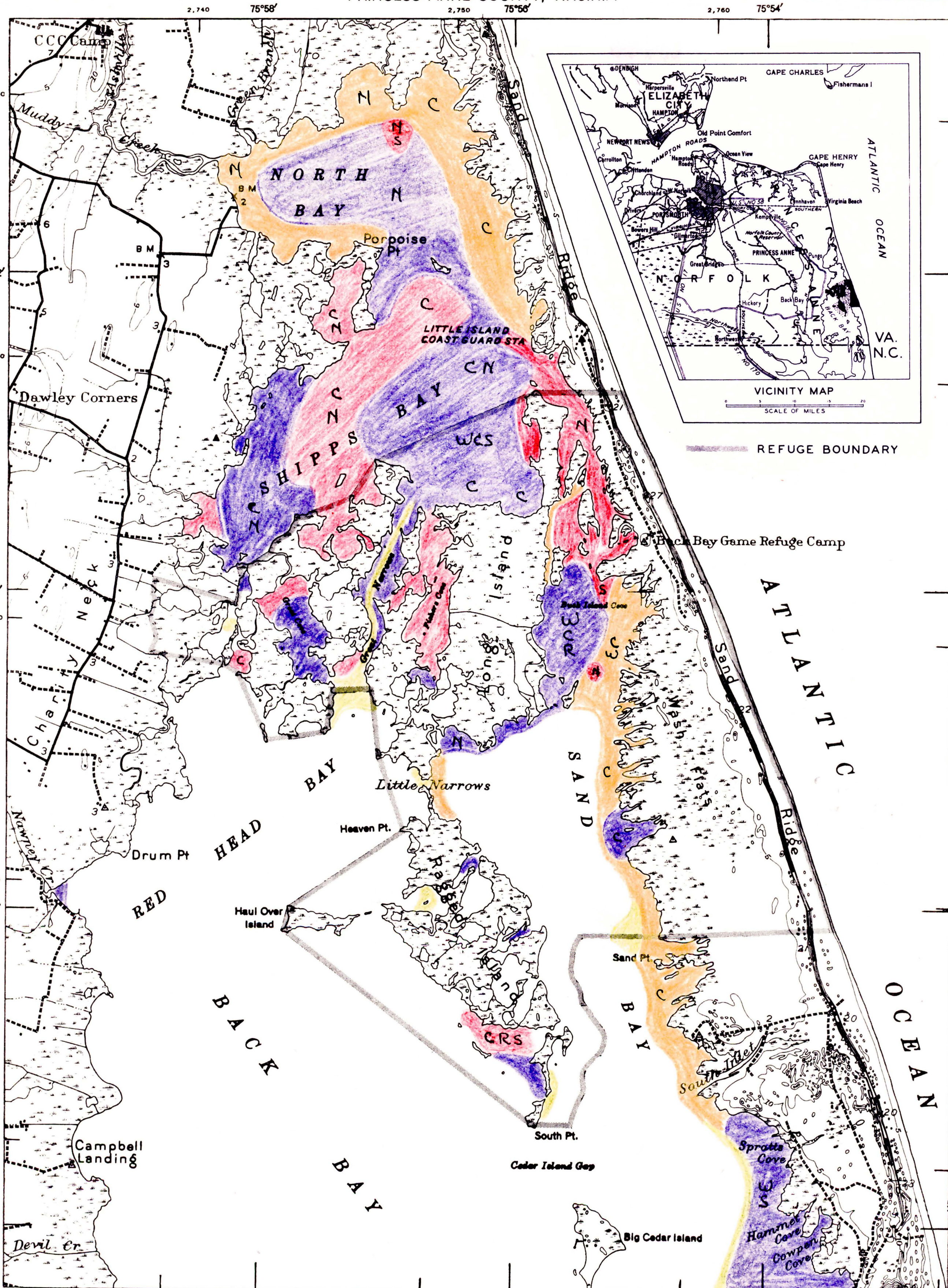
(2) Refers to color plotted on Figure 3.

BACK BAY NATIONAL WILDLIFE REFUGE

U. S. DEPARTMENT OF THE INTERIOR

PRINCESS ANNE COUNTY, VIRGINIA

FISH AND WILDLIFE SERVICE



COMPILED IN THE DIVISION OF LANDS
BASE BY U.S G.S.

Figure 3. Survey of Submerged Food Plants, Oct.1947

CHICAGO, ILLINOIS 7273 MAY 1946

Scale 0 20 40 80 120 160 CHAINS; 0 ¼ ½ 1 1½ 2 MILES

CONTOUR INTERVAL 5 FEET DATUM IS MEAN SEA LEVEL

MEAN DECLINATION 1940

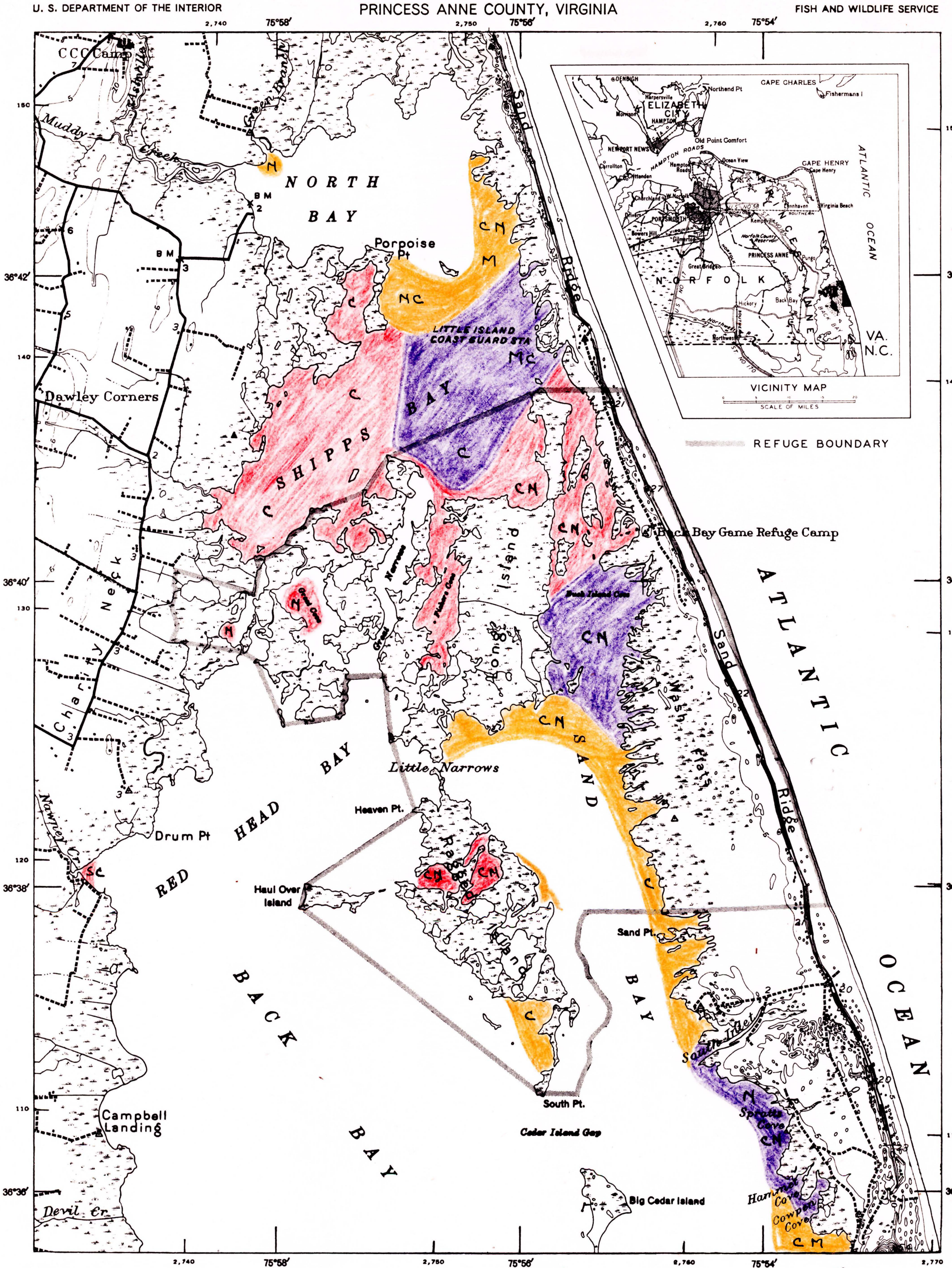
B2 BAC 69

BACK BAY NATIONAL WILDLIFE REFUGE

U. S. DEPARTMENT OF THE INTERIOR

PRINCESS ANNE COUNTY, VIRGINIA

FISH AND WILDLIFE SERVICE



COMPILED IN THE DIVISION OF LANDS
BASE BY U.S G.S.

Figure 4. Survey of Submerged Food Plants, Oct.1946

Scale 0 20 40 80 120 160 CHAINS
0 ¼ ½ 1 1½ 2 MILES

CONTOUR INTERVAL 5 FEET DATUM IS MEAN SEA LEVEL

MEAN DECLINATION 1940

CHICAGO, ILLINOIS 7273

MAY 1946

B2 BAC 69

The most abundant species in this aquatic association was formerly Potamogeton pectinatus (Bourn, 1932), after which ranked Najas flexilis (guadalupensis?), Vallisneria americana, Potamogeton perfoliatus, and Ruppia maritima. But in 1946, Vallisneria americana was first, followed in order by Najas flexilis (guadalupensis?), Ruppia maritima, Chara and Nitella spp., and Potamogeton pectinatus. In 1947, however, Najas guadalupensis was easily the most abundant, with Vallisneria americana second, Potamogeton pectinatus and Ruppia maritima about equal thirds, Nitella sp. fourth and Potamogeton perfoliatus fifth. The decrease of Potamogeton pectinatus may well be due to the decrease in salinity since construction of the sand fence, and the present position of Najas guadalupensis due to the fact that it is more tolerant of turbid water than are the other species.

The progress of growth shown by celery (Vallisneria americana) was followed more closely than was that of any other member of the aquatic association. In early May, leaves were only two to four inches long and the clusters were found in densities up to 12 per square foot. By mid-May, leaves were up to ten inches long, and densities up to 24 per square foot. At the first of June, leaves 20 inches long could be found, and some areas had 30 plants (actually leaf clusters) per square foot. In early July, the better areas still averaged 25 plants per square foot, with leaves up to 26 inches long. Conditions continued quite favorable for growth of celery and by the middle of the month a few spots had as many as 58 plants per square foot with leaves 30 inches long. Also during July, the density of Najas guadalupensis in one area increased from an average of six to 200 plants per square foot, and celery appeared in several previously barren localities. By August some celery leaves were as much as 42 inches long, but the density of even the best areas leveled off at about 30 plants per square foot. Throughout the summer, older leaves are lost and new, young leaf clusters and plants are observed. These spring from either seeds or rhizomes, primarily the latter. Growth continued through most of September and irregularly in October. During the last two weeks of November, celery leaves over 24 inches long were not found, some areas had only half as many plants as in the summer, and leaves were dying back.

Pistillate flowers of celery first appeared on the surface of the water June 17, but staminate flowers and pollen did not show up until August 2. After this, pollen was fairly abundant through the end of the month and small amounts were noticed occasionally during September. The last pollen was seen October 2, and the last pistillate flowers seen at the water surface October 9. Because of the great difference in the time of appearance, a sample of pistillate flowers was examined in late August to estimate the extent of fertilization. Apparently, slightly over 95% were fertilized. An examination of 25 fruits showed a variation in size from 130 by 4 mm. to 25 by 2 mm., and an average of 100 by 3 mm. The seeds averaged 2 by 0.5 mm., cylindric but tapered from the base with longitudinal striations. They are embedded in a clear viscous jelly, creamy white in color, becoming brown with age. From this examination, it appears that the seeding of celery was satisfactory during the past summer.

b. The Dune Association.

This term is here used to designate the vegetation found on those dunes which form a narrow belt parallel with the front beach and between it and the low marsh. These dunes are the site, and form a part, of the sand fence. Generally, their width does not exceed 75 yards, nor their height 25 feet above the marsh lying behind them. Uniola paniculata, Ammophila breviligulata, Panicum amarum, P. amarulum, Cenchrus tribuloides, Cakile edentula, Oenothera humifusa, Diodia teres and Iva imbricata are the principle species of the dunes. Of these, Uniola paniculata, Cakile edentula and Iva imbricata are commonly found on the seaward slopes or crests of the dunes, while Cenchrus tribuloides, Oenothera humifusa, and Diodia teres usually occur on the reverse slopes. Ammophila breviligulata, Panicum amarum, and P. amarulum seem equally at home on either slope and on the crests. In all cases, the vegetation occurs in open formation, so that large sand surfaces are visible between plants or clumps. Wind erosion works constantly on the dunes, and their shifts in size and location are frequent and rapid. The members of this association are generally regarded as unimportant to wildlife, but on Back Bay Refuge both Canada Geese and Bob-white were observed to feed on the seeds of Panicum amarulum.

c. Barren Flats Association.

Near the south boundary of the Refuge, between the sand dunes and the Bay, is a practically barren, sandy area called Wash Flats. Presumably, this represents land swept clear when ocean water last flowed across the barrier beach. Within the Refuge the flats are about one and a quarter mile long, and from one-quarter to three quarters of a mile wide. Below the Refuge line, their area is of similar extent. Between the flats and the dunes is a belt of low marsh, and between flats and Bay is a narrow strip of high marsh. When water level is high in the Bay, or following heavy rains, the flats may be under water, from one or two inches at the east side to eight or ten at the west. At no time do they become entirely dry, and free soil water can be reached at depths of one-half to three feet. This water is quite saline, running from 13.7% to 38.5% sea strength. Composite soil samples show the pH to average 7.55 at the surface, 7.95 at four inches, 8.18 at eight inches, and 7.65 at 12 inches. Available magnesium is considered high (17.5 - 22.5 ppm), calcium low (312.5 - 475 ppm), phosphorus low (0.75 - 1.50 ppm) and potassium low (25 - 45 ppm) at the surface, otherwise medium (225-450 ppm). Dr. E. M. Dunton, Jr., Soil Technologist at the Virginia Truck Experiment Station has stated (personal correspondence, 1947), "In view of the rather high pH and conductivity of these soils and the rather low tests for phosphorus and calcium, I believe that the concentration of the solution must be due to sodium chloride. The conductivity readings show a rather high concentration of salts in this soil, the highest concentration being in the 8" and 12" depth and the lowest concentration at the surface."

Vegetation on the flats is sparse to absent. Along the east side, bordering the low marsh, is a narrow, disrupted belt of Salicornia mucronata. On the west side are broad areas sparsely covered with Eleocharis parvula. A few scattered plants of Spartina alterniflora occur on both sides as do some patches of Distichlis spicata. Otherwise, the only vegetation on the flats is an algal coat which covers most of the ground surface. But scattered about on the flats are old, low, stabilized dunes which are well vegetated. These are discussed in the following section. In their present condition the Wash Flats are of value to waterfowl only as resting space.

d. Sand Woods Association.

The common factor among the several different types of vegetation which will be discussed in this section is that all are situated on old, stabilized dunes. Some of these are low, only ten or twelve inches high, while others reach three or four feet above the general level. Isolated dunes are scattered irregularly through the low marsh and on Wash Flats. When low, these dunes generally are covered by Spartina patens. Species commonly found on the higher dunes are Quercus virginiana, Myrica cerifera, M. carolinensis, Baccharis halimifolia, Diospyros virginiana, Panicum amarulum, Hudsonia tomentosa, Lechea maritima, Hieracium gronovii, and Senecio tomentosa.

The best development of this association is found in an area of about one-half by one-quarter mile, next to the Bay, at the south boundary of the Refuge. In this section, the dunes are old and rather well leveled off. Quercus virginiana and Pinus taeda are the principal species, both reaching tree size. In lower, damp spots are Acer rubrum, Salix nigra and Myrica cerifera. Rhus toxicodendron and R. copallina are frequent, as is Rubus andrewsianus. Among those species which were found only in this section of the Refuge are Gelsemium sempervirens, Vaccinium marianum, Amelanchier oblongifolia and a single speciman of Pinus virginiana. As far as could be observed, this association is of no value to waterfowl except that the low isolated dunes are used as roosting places by geese.

e. Low Marsh Association.

This association occurs as a band, varying in width from a hundred yards to perhaps half a mile, immediately behind the zone of mobile dunes. It blends, in various places, into the high marsh, dune woods, and barren flats associations. The term low marsh is used because most of its member species do not reach heights of over three feet, and because it has much of its ground surface covered with a few inches of water at irregular intervals. This is due to heavy rainfalls, since no areas of this type were noted to be inundated directly by high water in the Bay. However, a high level in the Bay may be a factor in that it would tend to slow up the run-off. A great number of plant species occurs in this association, since the soils here included vary widely in water content, texture, and organic content. The more abundant plants are Scirpus americanus, Spartina patens, Juncus scirpoides, Cyperus haspan, C. ferax, Andropogon glomeratus, Eleocharis olivaceae, E. ovata, E.palustris, Hydrocotyle umbellata, Diodia virginiana, Rhexia mariana, Pluchea camphorata, and Lycopus sessilifolius.

So far as wildlife is concerned, this association is one of the more valuable on the Refuge. Both Snow and Canada Geese feed here regularly and extensively. The lower stems and rhizomes of Scirpus americanus are apparently the most sought after food, but several other species are also fed on considerably. The geese feed in flocks, working outward from any small opening in the marsh when there is an inch or two of water over the ground surface. By working their feet up and down, the birds "puddle" out rhizomes, roots, and lower stems. Ducks, especially Pintails, often feed along with the geese, taking fruit and seed as well as bits left by the geese. As Figures 5 through 8 show, an area may be almost devegetated by such feeding. But on the Refuge, at least, recovery during the following growing season seems to be complete, and such denuded "eat-out" areas normally are entirely revegetated.

f. High Marsh Association.

Like the previous association, the name of this one is based on the height of its more abundant members. Plants characteristic of this association grow, on the whole, more than three feet tall. The soil surface is not always under water, but is inundated more frequently and for longer periods than is the low marsh since high marsh areas may be subject to flooding when the Bay water level is high. Here the commoner species are *Spartina cynosuroides*, *Scirpus robustus*, *S. olneyi*, *Typha angustifolia*, *T. truxillensis*, and *Juncus roemerianus*. This last plant makes its best and most extensive growth between the low marsh and the Bay on the barrier beach. The others, while

Figure 5. Low Marsh Prior to Feeding by Geese.

Figure 6. Eat-Out in Low Marsh Due to Feeding by Snow Geese.

Figure 7. Eat-Out in Low Marsh Due to Feeding by Canada Geese.

Figure 8. Detailed View, Goose Eat-Out in Low Marsh.

abundant in this same section, reach their peak in the marshes of Long and Ragged Islands and all over the numerous other islands on the Refuge. <u>Spartina cynosuroides</u> is most partial to the outer section of a marsh, while the other plants occur in more or less mixed stands over the inner portions. One or another will sometimes form fairly pure stands, however. On the whole, this association is extremely valuable to wildlife. The muskrat is largely confined to this type of marsh and the adjacent water. <u>Typa</u> spp. and <u>Scirpus</u> spp. make up a large part of its food (Dozier, 1947; Krummes, 1940; Stearns and Goodwin, 1941), and its houses are built of these and the other common species of the association. <u>Scirpus robustus</u> and <u>S. olneyi</u>, as well as many of the less abundant species, are valuable waterfowl food plants (Martin & Uhler, 1939; McAtee, 1939). The value of the association in this respect, however, depends on how well the birds can reach these foods. In solid stands these plants grow too tall and thick to be accessible to the birds. Hence, it is highly desirable to have this type of marsh interrupted and broken up by ponds and pot-holes to permit waterfowl to utilize such areas in feeding. The feeding and burrowing activities of muskrats are important in making such openings in the marsh. On the Refuge, a marsh burning program is followed which makes it possible for the birds to get into the marsh. The removal by burning of the dense stand of vegetation especially favors geese which feed on rhizomes and rootstocks.

g. Loam Woods Association.

This, the most restricted association, is found on Long Island, and to a very slight degree, Ragged Island. It is here, and around Refuge headquarters, that the only true soil types on the Refuge, Sassafras and Moyock fine sandy loams, have been mapped (Simmons and Shulkcum, 1945). Here the characteristic species are trees. The most common species are Pinus taeda, Celtis mississippiensis, Diospyros virginiana, Sassafras albidum, Morus rubra, Ilex opaca and Crataegus crus-galli. Smilax glauca, S. bona-nox, Lonicera japonica, Tecoma radicans, Vitis cinerea, and rarely Berchemia scandens and Zanthoxylum clava-herculis occur with them. A large part of the land formerly occupied by this association on Long Island has long been cleared, and now is cultivated to provide food for Canada Geese. Consequently, numerous weed species are now found about these field edges.

2. Relation to Other Floras.

The phytogeography and relationships between this and other floras have been discussed at length by Kearney (1901) and Fernald (1937 and 1940). They will be but briefly recapitulated here, since the actual area covered in this investigation is relatively very small. It has already been said that Princess Anne County is in the Austroriparian Zone. It may be further pointed out that here in Virginia occurs the northern extremity of this zone, that within the Commonwealth this zone is quite narrow, and that it "... does not greatly exceed the bounds of the Dismal Swamp region" (Kearney, 1901). Southward, the Austroriparian Zone constantly widens, so that it includes about one-third of North Carolina and one-half of South Carolina, in both cases comprising the eastern portions of the two states. While some species of plants usually considered Austroriparian range north of the mouth of Chesapeake Bay, the more predominant ones reach their northern limit in southeast Virginia. Kearney lists 33 such species. Of these, the following eleven occur on Back Bay Refuge:

<u>Erianthus giganteus</u>	<u>Zanthoxylum clava-herculis</u>
<u>Sacciolepis striata</u>	<u>Berchemia scandens</u>
<u>Uniola paniculata</u>	<u>Cornus stricta</u>

Cyperus haspan | *Gelsemium sempervirens*

Fimbristylis spadicea

Quercus virginiana

Eupatorium capillifolium

The seven plants in the left column above are not confined to the Austroriparian Zone, but extend south into the Tropical, thus emphasizing the kinship of the Refuge flora to southern rather than northern floras. However, since this is at the north border of a Zone, it would be expected that some northern forms also would find their southern limit here. Of nineteen such species listed by Kearney, only three, *Ammophila breviligulata*, *Lechea maritima*, and *Hudsonia tomentosa*, were found on the Refuge, again pointing out the essentially southern character of its flora. Of the nine species Kearney cites as being found in southeastern Virginia and in the Tropical Zone of both hemispheres, four, *Cyperus haspan*, *Hydrocotyle umbellata*, *Centella asiatica*, and *Bacopa monniera*, grow on the Refuge. Of fifty species common to the New World Tropics and to Virginia, the following nineteen were found on the Refuge:

Triglochin striata

Sacciolepis striata

Samolus floribundus

Gelsemium sempervirens

Uniola paniculata
Eleocharis ochreata
Fimbristylis spadicea
Quercus virginiana
Lepidium virginicum
Parthenocissus quinquefolia
Oenothera laciniata
Proserpinaca palustris
Linaria canadensis
Oldenlandia uniflora
Ambrosia artemisiifolia
Eupatorium capillifolium
Erigeron canadense
Pluchea camphorata
Gnaphlium purpureum

It must be pointed out that Fernald (1940) lists Triglochin striata as also being found in New Zealand, Australia, and South Africa.

On the other hand, of the thirty-one species occurring in southeast Virginia and in the North Temperate Zone of Europe and Asia, as listed by Kearney (1901), only the following eight were found on the Refuge.

Osmunda regalis
Lycopodium inundatum
Typha angustifolia
Spergularia marina
Ludvigia palustris
Bidens cernua
Potentilla monspeliensis

This again emphasizes the southern quality of the Back Bay flora, and points to an equatorial origin for its characteristic elements.

However, as Fernald (1940) has pointed out, there are several species present in the Coastal Plain which are boreal rather than tropical in nature. These possibly spread outward from the Appalachian Upland as it became elevated in late Cretaceous time. Yet, as regards the Back Bay flora, he agrees (Fernald, 1940: 507) that ".... the species which characterize the fresh to but slightly brackish shores and pools about Back Bay are largely plants of highly restricted and localized occurrence, and they belong for the most part to genera or species with the characteristically severed geographic occurrence of all pantropical and subantarctic groups." To explain this distribution, Fernald postulates a condition along the entire east coast similar to that obtaining in Back Bay, Pamlico, Albemarle, and Currituck Sounds today. That is, an extensive series of landlocked sounds with fresh to slightly brackish water, along the shores of which the plants in question could spread. This state existed when the continental shelf was elevated as a nearly continuous outside ridge, and ended with the sinking of the shelf in post-Miocene or post-Pliocene time. As Fernald presents it, the evidence supporting this theory sounds good. But it must be admitted that one of the species he considers as restricted to river-marshes (Sagittaria subulata) was found on Back Bay during the present survey, and that an outstandingly subantarctic species (Lilaeopsis carolinensis) which he found on the Refuge was not located during the past year. These details do not detract from the theory, however.

ECOLOGICAL INVESTIGATION

The decline in abundance of the submerged aquatic waterfowl food plants on Back Bay has already been outlined, the probable causes suggested, and the importance of the situation mentioned. In the Introduction, it was stated that one of the present objectives was to seek the factor or factors now limiting the growth of these food plants in the Bay, and responsible for the fact that the actual production is so much below the potential. Working through the comparatively short period of one growing season, it was felt that best results could be obtained by comparing areas of good and poor growth on the basis of several factors which might affect the growth of submerged aquatics. In this way, the critical factor or factors might be isolated.

The first step, then, in this investigation was to locate the areas of growth within the boundaries of the Refuge and compare each with the others. This comparison was made on the number of plants per square foot, as outlined in the section describing the aquatic association. The sampler scoop (Figure 9) operates like a set of oyster tongs. The jaws of the sheet metal bucket are nine inches wide and are chained to open only eight inches, so that at each grab a one-half square foot section of

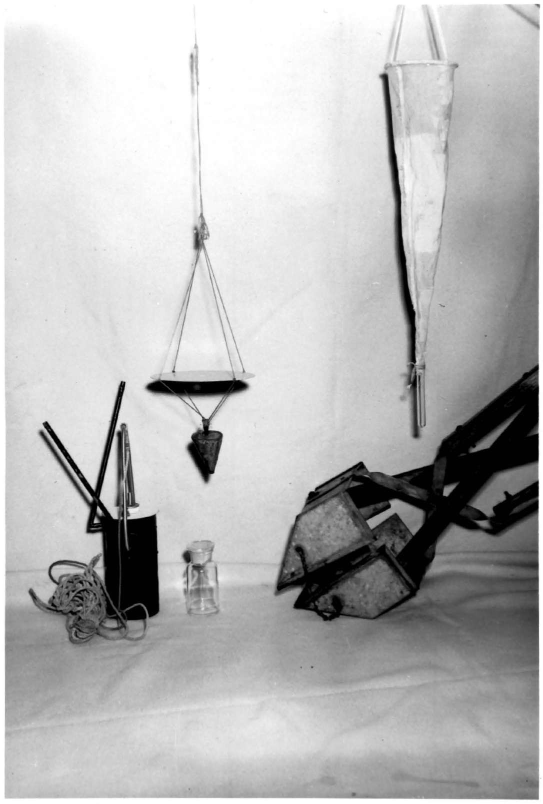


Figure 9. Equipment Used in Ecological Investigation. Top Row: Secchi Disc and Plankton Net. Lower Row: Water Collector, Water Bottle, and Bottom Sampler. The sheet metal bucket of this sampler has jaws nine inches wide, chained to open eight inches. The oak handles are eight feet long. Photograph courtesy Dr. H. S. Mosby.

bottom is picked up. This sample is dropped into a sieve rigged over the side of the boat at about water level (Figure 10) and the plants counted. This method and equipment proved to be entirely satisfactory.

During the first month of field work (May, 1947) all the water areas of the Refuge were sampled in this way and the various growth areas located. One hundred and one stations were established. At these stations, the plant growth was determined, the depth recorded, Secchi disc readings taken, type of bottom noted, wave action estimated, and the locations indicated on work maps. Later, forty-nine other stations were surveyed in the same way, though thirty of them were off the Refuge. These were investigated primarily to check the Refuge against the outside areas. All the plants were small during May, but on the whole the areas of better growth could be fairly well distinguished from those of poor or no growth. However, a few areas made fair to excellent growths later in the summer after appearing as poor in May. Ten test stations were set up in early June on the basis of the May survey, five in good and five in poor areas. Five others were later added to take care of the areas which showed late growths. All these test stations were designated by letters, and the location of each station is indicated on

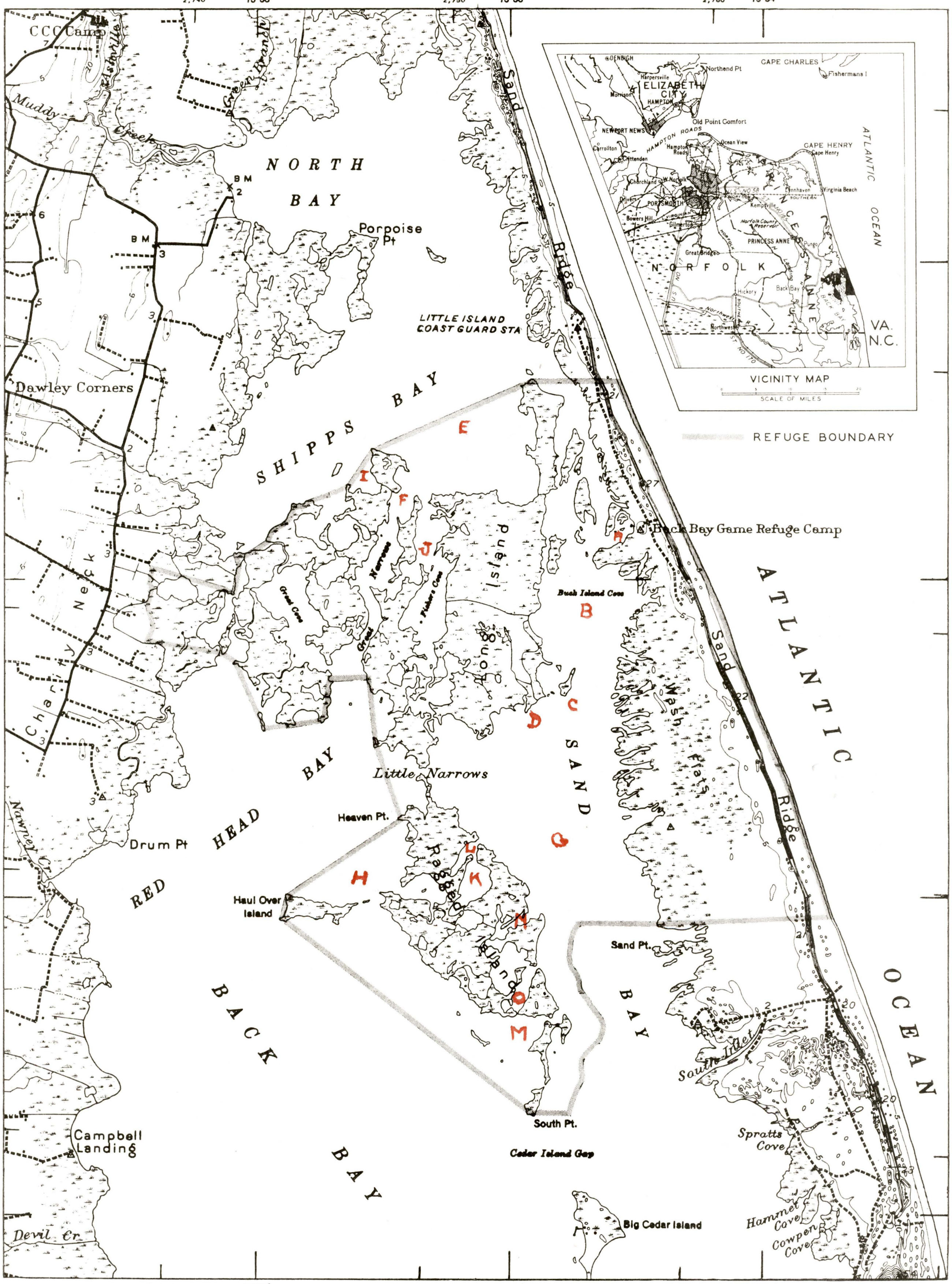
Figure 10. Bottom Sampler and Sieve in Use.

BACK BAY NATIONAL WILDLIFE REFUGE

U. S. DEPARTMENT OF THE INTERIOR

PRINCESS ANNE COUNTY, VIRGINIA

FISH AND WILDLIFE SERVICE



COMPILED IN THE DIVISION OF LANDS
BASE BY U.S G.S.

Figure 11. Test Station Locations

Scale 0 20 40 80 120 160 CHAINS
0 ¼ ½ 1 1½ 2 MILES

CONTOUR INTERVAL 5 FEET DATUM IS MEAN SEA LEVEL

CHICAGO, ILLINOIS MAY 1946
7273

MEAN DECLINATION 1940

B2 BAC 69

Figure 11 by its title letter. For each station, the average depth, type of bottom, and seasonal summary of growth are shown in Table 3. From the time each station was set up until the opening of the waterfowl shooting season (December 8), weekly tests were run to give points for comparison. These tests and results will be discussed in the following sections.

TABLE 3

AVERAGE DEPTH, TYPE OF BOTTOM, AND GROWTH AT TEST STATIONS

STATION	AVERAGE DEPTH	TYPE BOTTOM(1)	GROWTH(2)-NO. PLANTS PER SQUARE FOOT			
			May	July	August	October
A	3'1"	SM	5N	6N 12W	275N 20C	200N 8C
B	3'4"	SM	24C;5S 46N;1R	18C;30N 30W		23C;55W 65N;3R;2S
C	4'7"	SM	46N 14C	6C 50N		1C 55N
D	4'4"	BSi	24N	17N 10C		13C 70N
E	3'4"	S	14C 4N;1S	15C;4R 3W;4N		16C;50W 38M
F	7'3"	BSi	None	None	None	None
G	6'2"	BM	1N	None	None	1N
H	5'2"	BSi	None	None	None	1N
I	4'	SM	40N;5S 26C	28C 40N		35C;15W 100N
J	2'10"	BSi		13C 8N	28C	38C;60M 10N
K	2'5"	BSi			None	None
L	2'9"	SM			6C	10C 65N
M	3'5"	SM			20C;4S 60N	10C;9S 55N
N	2'2"	SM			12C	10C 200N
O	1'9"	BSi	None		None	None

(1) Bottom Symbols: S-Sandy; BM-Black Mud; SM-Sandy Mud; BSi-Soft Black Silt

(2) Growth Symbols: C-celery(Vallisneria americana); S-Sago(Potamogeton pectinatus); R-Redhead(P. perfoliatus); N-Najas(Najas guadalupensis); W-Widgeon Grass (Ruppia maritima); M-Muskgrass(Nitella sp.)

1. Water Relations.

The following water properties which might affect the growth of submerged aquatics were considered in this study: salinity, dissolved oxygen content, free carbon dioxide content, hydrogen-ion concentration, temperature, depth, and turbidity. All water samples were taken in 250 cc. ground glass stoppered bottles with a specially designed deep water collector at approximately one foot above the bottom. Tests for salinity, dissolved oxygen, free carbon dioxide, and pH were run in the laboratory, usually within two hours after the sample was taken.

a. Salinity.

Tests for salinity were made with a LaMotte Chemical Products Co. set designed for boiler water analysis. The method employs titration with silver nitrate in the presence of potassium chromate indicator. Dilution of the sample with distilled water was necessary, something of a bother, but as a consequence the end point was rather fine. All results are given as per centages of sea strength, using 35000 ppm total chlorides as normal sea strength. Throughout

TABLE 4

SALINITY AT TEST STATIONS
All Figures are Per Cent Sea Strength

WEEKLY TESTS		STATIONS														
		A*	B*	C	D	E*	F	G-	H-	I*	J*	K-	L-	M	N	O-
June	1	2.5	2.2	2.0	2.0	1.6	1.6	2.2	2.3	1.7						
	2	2.3	2.3	2.2	2.4	2.0	1.8	2.1	1.9	1.8						
	3	2.2	2.2	2.2	2.1	1.8	1.8	2.1	2.1	1.8						
	4	2.2	2.2	2.1	2.1	2.0	1.9	2.3	2.3	2.2						
July	5	2.7	2.4	2.4	2.5	2.1	2.1	2.3	2.2	2.0						
	6	2.2	2.2	2.1	2.1	1.9	2.1	2.1	2.1	2.0						
	7	2.3	2.2	2.2	2.2	2.1	2.1	2.4	2.2	2.1						
	8	2.4	2.4	2.3	2.2	1.8	1.9	2.3	2.1	1.9						
	9	2.3	2.2	2.2	2.2	1.9	1.8	2.2	2.2	1.8	2.2				2.1	
Aug.	10	2.3	2.2	2.2	2.2	1.9	1.8	2.2	2.1	1.9	1.9	2.1	2.1	2.0	2.2	2.1
	11	2.3	2.3	2.3	2.2	1.9	1.9	2.3	2.2	1.9	1.8	2.3	2.3	2.2	2.2	2.0
	12	2.3	2.3	2.5	2.4	1.9	2.2	2.3	2.2	2.0	1.9	2.3	2.3	2.2	2.3	2.4
	13	2.5	2.4	2.3	2.5	2.2	2.1	2.3	2.2	2.2	2.3	2.2	2.2	2.2	2.3	2.3
Sept.	14	2.3	2.4	2.4	2.3	2.2	2.2	2.3	2.2	2.1	2.2	2.2	2.3	2.2	2.2	2.2
	15	2.1	2.1	2.1	2.1	2.0	1.9	2.1	2.2	1.9	2.2	2.0	2.1	2.2	2.0	2.2
	16	2.1	2.1	2.1	2.2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	17	2.2	2.1	2.1	2.1	1.9	2.1	2.1	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.9
	18	2.0	2.0	2.0	2.1	2.1	2.1	2.0	2.1	2.0	1.9	2.0	2.0	2.1	2.0	2.1

TABLE 4 (Cont'd)

WEEKLY TESTS		STATIONS														
		A*	B*	C	D	E*	F	G–	H–	I*	J*	K–	L–	M	N	O–
Oct.	19	2.1	2.0	2.1	2.1	2.1	2.0	2.0	2.1	2.0	2.0	2.0	2.0	2.1	2.1	2.1
	20	2.1	2.1	2.0	2.0	1.9	2.0	2.0	2.0	2.0	2.0	2.1	2.1	1.9	2.2	2.1
	21	2.3	2.2	2.3	2.3	2.1	2.0	2.1	2.1	2.1	2.2	2.2	2.2	2.0	2.1	2.1
	22	2.3	2.2	2.1	2.2	2.1	2.2	2.1	2.1	2.1	2.2	2.2	2.1	2.1	2.1	2.2
Nov.	23	2.1	2.1	2.1	2.2	2.0	2.1	2.1	2.0	2.1	2.1	2.0	2.0	2.1	2.1	2.0
	24	2.0	2.1	2.1	2.0	2.0	2.0	2.0	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0
	25	2.0	2.0	2.0	2.0	2.1	2.1	2.0	2.0	2.0	2.0	1.9	2.0	2.1	2.0	2.0
	26	1.7	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.9	1.9	1.9
Dec.	27	1.8	1.9	1.9	1.9	1.9	1.8	1.9	2.0	1.8	1.8	1.9	1.9	1.9	1.9	1.9
Max.		2.7	2.4	2.4	2.5	2.2	2.2	2.4	2.3	2.2	2.3	2.3	2.3	2.2	2.3	2.4
Min.		1.7	1.8	1.9	1.9	1.6	1.6	1.9	1.9	1.7	1.8	1.8	1.8	1.9	1.9	1.9
Aver.		2.2	2.2	2.2	2.2	2.0	2.0	2.1	2.1	2.0	2.0	2.1	2.1	2.1	2.1	2.1

*Stations of good growth.
–Stations of poor growth.

the period, salinities at all the test stations were quite uniform and fluctuated but little, as can be seen in Table 4. No correlation can be found between salinity and regions of good and poor growth. The range of salinities, 1.6% to 2.7%, is entirely within the tolerances of the plants in question (Bourn 1932, 1934, and 1935). The obvious source of salt water in the Bay is the sounds to the south, which eventually communicate with the ocean through Oregon Inlet in North Carolina. For example, salinities of 4.1% at the north end of Knott's Island Channel, 7.5% in Currituck Sound, and 21.4% in Albemarle Sound were found during the summer. In agreement with this, the higher salinities in Back Bay were found to result from periods of south winds and/or low rainfall, the lower salinities from north winds and/or high rainfall. The possibility of seepage of ocean water through the barrier beach is generally regarded as nil, but this source of salinity is at least suggested by the already mentioned high salinities of the Wash Flats free soil water (13.7% to 38.5%), by the restriction of the strongly halophytic plants to the barrier beach marshes and flats, and by the fact that waters of sloughs extending into the barrier beach generally had slightly higher salinities than did the open Bay. It may also be interesting to note that the water of a deep well at Refuge headquarters tested 4.5% sea strength. It is to be repeated, however, that in so far as the growth of submerged aquatics was concerned, salinity in itself could not be considered a critical factor. Its connection with turbidity will be considered in discussing that factor.

b. Dissolved Oxygen Content.

The dissolved oxygen content was determined by the Rideal-Stewart Modification of the Winkler Method (Theroux, Eldridge and Mallman, 1943) using a LaMotte test set. Results of the weekly tests at all test stations are shown in Table 5. Also shown are the maximum, minimum and average figures, with the per cent saturation for the average, at each station. This latter value is determined after correcting for the average temperature at each station. Compared with Bourn's (1932) results, these waters have a considerably increased dissolved oxygen content. During one month only did his per cent saturation reach 80, for all others it averaged about 60. This might indicate that the closed A. and C. Canal locks (See Figure 2) effectively prevent pollution of Back Bay by Norfolk harbor waters, since the dissolved oxygen content is considered as reflecting the degree of pollution. All results of the present tests show that Back

TABLE 5

DISSOLVED OXYGEN CONTENT AT TEST STATIONS
All Figures are Parts Per Million

WEEKLY TESTS	STATIONS A*	B*	C	D	E*	F	G-	H-	I*	J*	K-	L-	M	N	O-
June 1	7.2	9.0	7.4	7.2	8.2	7.1	7.6	6.7	6.8						
2	7.8	7.6	8.0	7.2	7.2	6.6	6.3	7.2							
3	7.0	7.4	7.1	7.1	7.3	7.0	6.2	7.0	7.5						
4															
July 5															
6	7.0	7.1	6.8	6.5	5.8	5.8	7.6	7.6	5.3						
7	7.9	7.1	7.3	6.6	7.4	7.2	5.9	6.8	7.3						
8	6.6	6.9	6.6	7.1	6.3	7.2	6.1	6.2	7.4	6.2					
9															
Aug. 10															
11															
12							6.4	6.2			5.8	5.8	7.1	6.6	6.4
13	5.1	6.3	6.4	6.7	7.2	6.6	5.8	5.7	7.2		5.4	6.2	5.4	6.8	5.2
Sept. 14	6.2	7.8	6.8	7.1	7.6	6.2	5.5	5.8	6.4	7.6	5.6	6.2	5.6	6.0	5.7
15	5.2	6.2	5.2	6.1	6.0	6.0	6.3	6.2	5.8	6.8	5.4	6.2	3.2	4.8	3.2
16	6.8	6.4	6.5	4.9	6.2	6.8	5.3	5.0	6.8	5.8	5.7	5.8	6.2	6.0	6.0
17	7.8	8.0	7.2	7.2	9.6	7.6	6.6	6.8	8.8	7.9	7.0	7.4	7.1	6.3	7.0
18	7.6	7.6	8.2	7.6	8.0	7.8	7.2	7.4	8.4	9.8	8.4	8.6	9.2	8.3	7.8

TABLE 5 (Cont'd)

WEEKLY TESTS		STATIONS A*	B*	C	D	E*	F	G-	H-	I*	J*	K-	L-	M	N	O-
Oct.	19	7.4	7.3	7.6	7.0	8.0	7.2	7.2	6.8	7.7	7.8	7.0	7.2	7.7	6.8	6.9
	20	6.0	7.0	7.2	6.7	8.0	7.4	6.6	6.8	7.9	7.8	6.5	7.2	8.2	7.0	7.5
	21	8.0	8.0	8.4				8.0	8.0							
	22															
Nov.	23	7.7	8.5	7.8	8.4	8.4	7.6	8.4	8.0	8.1	7.6	8.0	7.6	8.2	7.9	8.4
	24	7.9	5.6	6.6	8.0	8.2	8.0	8.9	7.3	8.4	8.3	8.6	8.7	9.2	8.9	8.9
	25	9.7	10.6	9.6	10.4	8.5	9.7	9.4	8.8	8.6	8.6	9.4	9.0	9.0	9.0	9.0
	26	8.8	9.6	8.8	8.8	8.3	8.6	9.0	8.8	8.7	8.4	8.3	9.5	9.0	9.2	9.4
Dec.	27	10.6	11.2	10.9	10.8	10.0	9.3	8.7	9.6	9.8	10.7	10.2	10.8	10.7	10.0	9.4
Max.		10.6	11.2	10.9	10.8	10.0	9.3	9.4	9.6	9.8	10.7	10.2	10.8	10.7	10.0	9.4
Min.		5.1	5.6	6.4	4.9	5.8	5.8	5.3	5.0	5.3	5.8	5.4	5.8	3.2	4.8	3.2
Aver.		7.4	7.8	7.5	7.4	7.7	7.3	7.1	7.0	7.6	7.9	7.2	7.6	7.6	7.4	7.2
% Sat.		85	87	87	84	88	82	81	80	86	86	78	83	84	82	79

*Stations of good growth.
-Stations of poor growth.
% Sat.: % Saturation after correction for temperature.

Bay is not now suffering from any pollution, and further that the three to five ppm of dissolved oxygen required by warm water game fish (Ellis, Westfall, and Ellis, 1946) are present in all waters. Keeping in mind the decreasing solubility of oxygen in water as temperature increases, examination of Table 5 shows that waters with a good growth of submerged aquatics generally had a higher oxygen content than did those with a poor growth, especially during the summer and early fall. This condition, though correlated with a difference in the amount of aquatic growth, is rather a case of effect than of cause. The higher oxygen content (most readily seen in the average and per cent saturation figures) of areas of good growth is due to the vegetation, and is not a cause of it. This is so because the plants in photosynthesis release oxygen to the water, raising its content above that of areas having no plants. In any event, all stations, good and poor, had dissolved oxygen contents entirely adequate for plant needs. Therefore, it may be concluded that dissolved oxygen content is not a limiting factor with submerged aquatics in the Back Bay Refuge.

c. Free Carbon Dioxide Content.

The free carbon dioxide test was essentially that of the American Public Health Association (Theroux, Eldridge, and Mallman, 1943), though performed with LaMotte equipment. Results of weekly tests, maximum, minimum and average values for each test station are shown in Table 6. In general, these tests show less free carbon dioxide than did those of Bourn (1932), who gives contents of two to ten ppm for North Bay and four to thirty ppm for Back Bay and Currituck Sound. This shift is doubtless due to the present conditions of increased vegetation and greatly decreased industrial and municipal pollution. As is the case with the dissolved oxygen content, the free carbon dioxide content almost always varied with the amount of vegetation present in the water. However, variations in the dissolved carbon dioxide content are the result rather than the cause of the observed good and poor plant growth. Areas in which plants were numerous and actively photosynthetic usually gave a negative test for free carbon dioxide since it is continually used up by the plants. Thus, in Table 6, most stations in areas of good growth show more zeros than do those in areas of poor growth. While a somewhat higher carbon dioxide content may be beneficial

TABLE 6

FREE CARBON DIOXIDE CONTENT AT TEST STATIONS
All Figures are Parts Per Million

WEEKLY TESTS		STATIONS														
		A*	B*	C	D	E*	F	G–	H–	I*	J*	K–	L–	M	N	O–
June	1	4	3	4	2	3	3	2	2	3						
	2	4	2	4	2	2	4	3	4							
	3	4	2	2	2	2	2	2	2	2						
	4	2	2		1	1	2	2	1	1						
July	5	0	2	1	2	2	1	1	2	1						
	6	3	2	1	3	1	2	1	1	1						
	7	0	1	3	3	1	2	1	1	2						
	8	0	0	0	2	0	0	1	3	0						
	9	0	0	0	0	0	1	1	1	0	3			2		
Aug.	10	0	0	0.5	0	1	1	1	1	0	0	1.5	0	3	0	0
	11	0	0	2	0	0	0	0	0	0	0	1.5	0	0	2	0
	12	0	0	0.5	0	0	0	2	2	0	0	2	0	0	1	2
	13	0	0	0	0	0	2.5	0	2.5	0	0	3	2	4	4	2
Sept.	14	0	0	0	0	0	0	0.5	1	0	0	4	0.5	2	2	2
	15	2	0	0	1	2	1	1	1	0.5	0	2.5	1	1	4	0
	16	1.5	0	0	0	0.5	1	0	1.5	0	0	2	1.5	5	2	3.5
	17	0	0	1.5	1.5	2	4	1	1.5	2	0.5	2	2.5	1	2	3
	18	0	1	0	0.5	1.5	4	2	2	2	0	2.5	2	1	2	1

TABLE 6 (Cont'd)

WEEKLY TESTS		STATIONS														
		A*	B*	C	D	E*	F	G-	H-	I*	J*	K-	L-	M	N	O-
Oct.	19	2	0.5	1.5	1.5	1.5	2.5	2	1.5	1.5	1	1.5	2	2	1	1
	20	2	1.5	1.5	1	1.5	2.5	1.5	2	2	0	2	1.5	2	2	0
	21	2	0.5	0	0	0	0	0	0	0	0	1	2	1	4	1
	22	0.5	0	1	1.5	1	2	1.5	1.5	1.5	0	2	0.5	1	2	1.5
Nov.	23	1	2.1	1	1.5	1	1.5	1.5	1	1.5	2	1.5	1.5	1	1.5	1
	24	1.5	1.5	2	1.5	2	2	2	2	1	2	3	2	2.5	2.5	2
	25	3	3	4	2	2.5	4	2	2	2.5	2.5	5	4	5	4	4
	26	2	2	3	2	3	3	2	2	4.5	3.5	4	3	3.5	3.5	3.5
Dec.	27	2.5	2.5	3	3	2	3	3	2.5	4	2	2	2	3	3	2
Max.		4	3	4	3	3	4	3	4	4.5	3.5	5	4	5	4	4
Min.		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Aver.		1.4	1.1	1.4	1.3	1.2	1.9	1.4	1.6	1.3	0.9	2.4	1.6	2.1	2.4	1.6

*Stations of good growth.
-Stations of poor growth.

to the plants, the values as shown in Table 6 are about what is to be expected in natural, unpolluted waters (Bourn, 1932 and Whipple, 1927). Hence, it does not seem that the free carbon dioxide content of the water is in itself responsible for the present distribution and condition of submerged waterfowl food plants on Back Bay.

d. Hydrogen-Ion Concentration.

All hydrogen-ion tests were colorimetric, using a LaMotte block comparator and indicator solutions of chlorphenol red (pH 5.2-6.8), bromthymol blue (pH 6.0-7.6), phenol red (pH 6.8-8.4) and thymol blue (pH 8.0-9.6). Results of all weekly tests, the maximum, minimum, and average pH values at all test stations are shown in Table 7. It can be seen that all stations were usually alkaline, and the pH values were generally higher in areas of good growth, especially during periods of active photosynthesis. This is true because the plants use free carbon dioxide from the water which if present would cause an acid condition. Therefore, while the pH value is related to the amount and condition of submerged aquatic growth, it is an indirect relationship, depending on the amount of free carbon dioxide present and on certain other factors of water quality. The worth of a series

TABLE 7

HYDROGEN-ION CONCENTRATION AT TEST STATIONS
All Figures are pH Values

WEEKLY TESTS		STATIONS														
		A*	B*	C	D	E*	F	G-	H-	I*	J*	K-	L-	M	N	O-
June	1	7.6	7.9	7.5	7.4	7.5	7.5	7.5	7.4	7.5						
	2	7.6	7.9	7.4	7.5	7.9	7.5	7.4	7.4	7.4						
	3	7.5	7.8	8.0	7.8	7.8	7.5	7.4	7.3	7.7						
	4	8.1	7.5	7.5	7.8	8.2	7.4	7.8	7.8	8.2						
July	5	8.4	8.0	7.8	8.3	7.9	8.0	7.7	7.7	7.9						
	6	7.8	8.0	7.4	7.6	7.4	7.3	7.8	7.7	7.4						
	7	8.4	8.2	7.8	7.8	8.2	8.0	7.7	7.4	8.0						
	8	8.4	8.3	8.3	7.6	8.4	8.4	7.8	7.4	8.4						
	9	8.4	8.4	8.4	8.4	8.4	8.2	8.2	7.8	8.4					7.3	
Aug.	10	8.4	8.4	8.1	8.4	8.2	7.8	7.4	7.6	8.3	8.4	7.4	8.3	8.4	7.6	8.4
	11	8.7	8.4	8.2	8.4	8.7	8.7	8.3	8.3	8.7	8.4	7.6	8.3	8.7	8.7	7.6
	12	8.7	8.7	8.2	8.4	8.7	8.4	7.8	7.7	8.7	8.7	7.6	8.4	7.5	8.4	7.7
	13	8.7	8.9	8.6	8.7	8.4	7.2	8.4	7.4	8.4	8.7	7.2	7.4	7.3	7.0	7.1
Sept.	14	8.7	8.9	8.6	8.7	8.4	8.4	8.0	7.7	8.3	8.9	7.2	8.0	7.6	7.8	7.6
	15	7.5	8.4	8.3	7.7	7.5	7.8	7.7	7.6	8.0	8.3	7.4	7.8	8.3	7.4	7.2
	16	7.2	8.3	8.7	8.3	7.9	7.8	8.3	7.8	8.3	8.7	7.4	7.5	7.1	7.0	7.4
	17	8.4	8.6	8.0	8.0	7.8	7.0	7.4	7.3	7.4	8.0	7.3	7.2	7.0	7.6	7.4
	18	8.7	7.8	8.5	8.3	7.4	7.1	7.4	7.6	7.4	8.6	7.1	7.2	7.6	8.0	7.2

TABLE 7 (Cont'd)

WEEKLY TESTS		STATIONS														
		A*	B*	C	D	E*	F	G-	H-	I*	J*	K-	L-	M	N	O-
Oct.	19	7.3	8.0	7.8	8.0	7.6	7.1	7.7	7.6	7.3	7.6	7.2	7.3	7.7	7.3	7.6
	20	7.4	7.6	7.4	7.4	7.4	7.0	7.3	7.2	7.4	8.6	7.3	7.4	8.3	7.4	7.4
	21	8.0	8.2	8.6	8.4	8.7	8.3	8.6	8.6	8.3	8.5	7.4	7.2	7.5	7.5	7.0
	22	7.9	8.3	7.8	7.6	7.8	7.6	7.6	7.5	7.6	8.3	7.4	7.9	7.4	7.4	7.3
Nov.	23	7.7	7.2	8.0	7.8	7.4	7.3	7.6	7.6	7.3	7.3	7.3	7.4	7.6	7.4	7.8
	24	7.2	7.3	7.0	7.2	7.6	7.3	7.3	7.3	7.4	7.1	7.0	7.2	7.2	7.1	7.1
	25	6.8	6.8	7.0	7.2	7.2	6.8	7.1	7.1	7.0	7.0	6.6	6.8	7.0	6.8	7.0
	26	7.0	7.0	6.8	7.2	7.1	7.1	7.1	7.3	6.8	7.1	7.1	7.0	7.0	7.0	7.1
Dec.	27	6.8	7.0	6.8	7.1	7.0	7.2	7.1	7.0	6.9	7.0	7.0	7.1	7.1	7.0	7.1
Max.		8.7	8.9	8.7	8.7	8.7	8.7	8.6	8.6	8.7	8.9	7.6	8.4	8.7	8.7	8.4
Min.		6.8	6.8	6.8	7.1	7.0	6.8	7.1	7.0	6.8	7.0	6.6	6.8	7.0	6.8	7.0
Aver.		7.9	8.0	7.9	7.9	7.9	7.6	7.7	7.5	7.8	8.1	7.3	7.5	7.6	7.5	7.4

*Stations of good growth.
-Stations of poor growth.

of pH readings, then, is that they are symptomatic of water conditions. Practically all pH tests at the Back Bay stations during this study were within the range pH 6.0 to pH 8.7, so that none can be considered indicative of disturbed and unfavorable water conditions (Ellis, Westfall, and Ellis, 1946). The limiting factor of the Back Bay aquatic waterfowl food plants, then, apparently is not directly associated with any condition of pH values observed in this investigation.

e. Temperature.

Weekly water temperatures were taken just below the surface, and about one foot above the bottom at all test stations, and daily observations were read just below the surface at Refuge headquarters boathouse. The maximum water temperature recorded was 32°C, taken July 1st and 31st in midafternoon at headquarters station. On December 15, this same station was frozen over, the ice being one-half to three-quarters of an inch thick. For the period June 1 through December 7, the averages of all test stations fall in the range 21.5°C - 23°C. Through quite a length of time, then, the water temperatures are favorable to plant growth. This period probably actually begins in April, for when the present field work started May 1, some plants had already made a few inches of growth. During May, temperatures ranged from 17°C to 29°C and growth went along at a moderate rate. From the first week in June through the third week in September, temperatures above 30°C and below 25°C were rare, and this was the time of most growth of the submerged aquatics, with July and August the best two months. On September 22nd and 23rd the area was brushed by the northeast winds of a tropical hurricane. In 24 hours, both the mean air temperature and the average water temperature fell 7.3°C. From then through the end of October, water temperatures at all the test stations ranged from 15°C to 25°C, and growth of the submerged aquatics continued irregularly. During November and the first week in December, these temperatures varied from 17.2°C to 2.8°C, averaging about 12°C. Very little, if any, growth took place during this time. Indeed, it is during the latter part of October and in November that the plants disappear from the upper levels of the water because of both sinking and dying back. Of course, other factors are important in limiting this growth period, but temperature is doubtless operative.

On the whole, the range of temperatures encountered at Back Bay seems favorable to aquatic plant growth. Only on one or two occasions in water less than one foot deep was any "scorching" of plants seen. Differences between surface and bottom temperatures greater than 1.5°C were almost never found, unless there was a dense bed of submerged aquatics present. In one such situation, a difference of 3.2°C in two feet was noted. But since water temperatures over the whole area were generally uniform, they can hardly be held accountable for differences in the amount of aquatic plant growth.

f. Depth.

The depth at each test station was noted when the weekly tests were taken, and the morning and afternoon water levels as shown on a gauge set up at Refuge headquarters boathouse were recorded. It would be desirable to base these variations on mean sea level, but the altitude of a U. S. Coast and Geodedic Survey triangulation point at Refuge headquarters has not yet been determined. Still, the information on fluctuation given by this series of readings is extremely worthwhile. The maximum fluctuation of the period May 1 through December 15 was 29 inches. Monthly fluctuations varied from 6 3/4 inches (August) to 26½ inches (November) and averaged 17 3/4 inches. The greatest fluctuation in any twelve hour period was 8¼ inches. These variations are due primarily to changes in wind direction and velocity, southeast, south and southwest winds raising the level and their opposites lowering it. Now and again, however, there were slight changes in water level which did not correlate with wind action. These are probably due to the influence of lunar tides in the sounds to the south though such tides there are termed "negligible" in most tide tables.

Plants growing in the shallower areas were, of course, exposed during the times of very low water. Such periods, fortunately, seldom exceeded three or four days and occured during the cooler months. As a result, very little damage to the submerged aquatics could be seen. Still, such exposure is hardly beneficial since the better growths were found in depths of two to four feet, where the effects of fluctuation in water level are considerably minimized. Little growth was found in depths over five and one-half feet, but depth alone cannot be responsible for this since in other sections of the country the same species of plants as occur at Back Bay thrive in deeper water than this.

g. Turbidity.

Turbidity readings were taken weekly with a 20 cm. Secchi disc at each test station and daily at Refuge headquarters boathouse. These readings are the depth at which the disc becomes indiscernible, and permit the comparison of different turbidities, though there are several drawbacks to the method. Among these are the possibility of personal error, variations with varying light conditions, and the fact that the percentage of light transmitted is not determined. Still, it is the most common method in use and does give figures by which the turbidity of one area can be compared with that of another, the important thing in this investigation. It was found too, that the readings varied less than expected with varying conditions of cloudiness. Thus, on one occasion, a Secchi disc reading of 22 inches was taken with the sky heavily and completely clouded. Twenty minutes later the sun was shining brightly and the reading in the same spot was 23 inches.

Differences in turbidity from one area to another could clearly be seen, apparently due to several factors. Their relationships were not always obvious, but could usually be worked out. In the first place, the clearer waters were usually found over sandy or sandy mud bottoms. Also, the water was clearer when the Bay had little wave action. This indicates that the turbidity is due mainly to suspended matter stirred up by waves from the soft black silt bottom. Turbidity was also greater in areas of poor growth, as shown by Figure 12. This graph compares

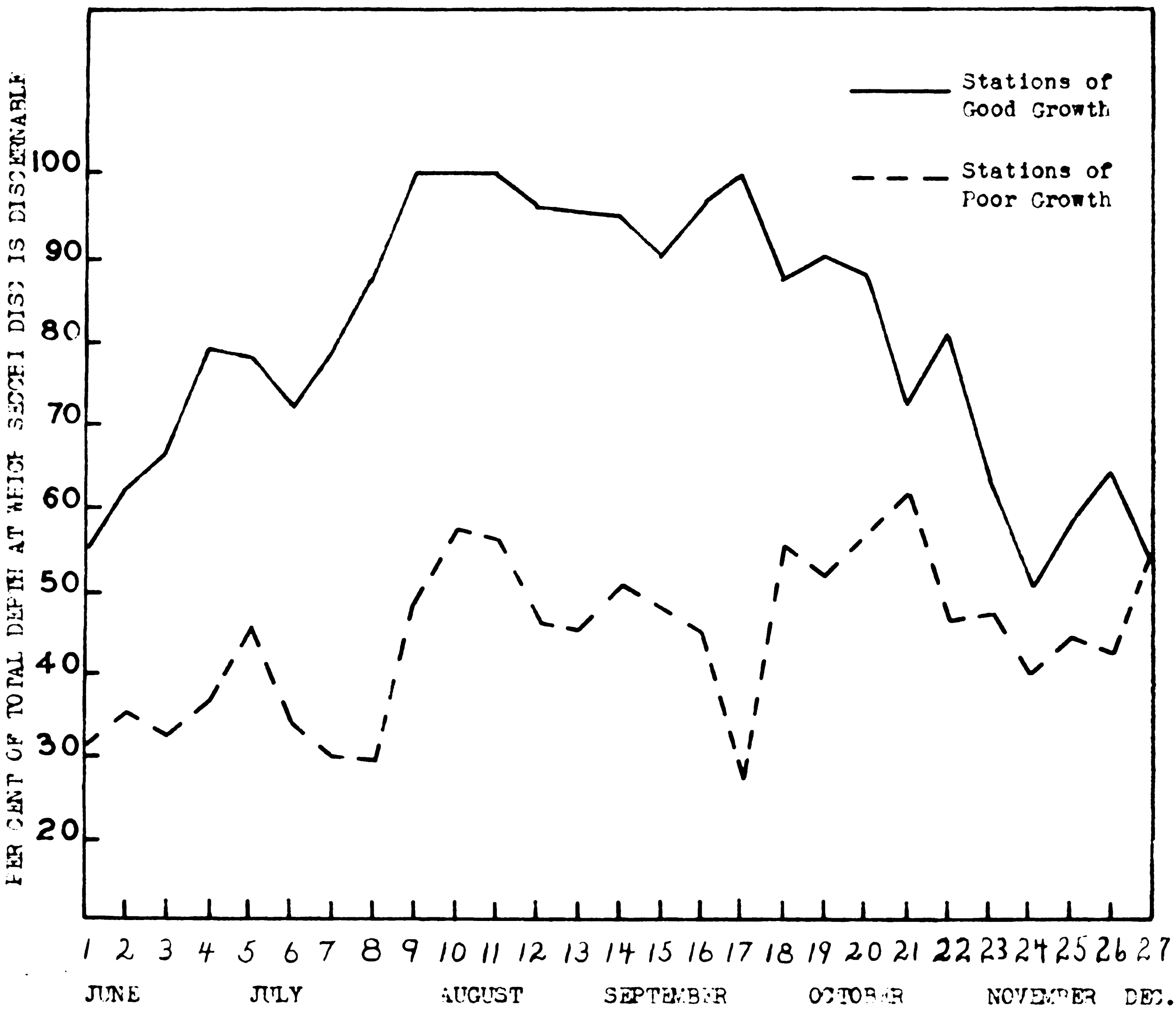


Figure 12. Average Weekly Turbidities at Stations in Areas of Good Growth and in Areas of Poor Growth.

the average turbidity of five good stations with that of five poor ones. Here the per centage of the total depth at which the Secchi disc disappeared rather than the actual reading in inches is used so that the values of deep and shallow stations will be proportional. As to the relationship between turbidity and the amount of submerged aquatic growth, it seems cause and effect are so closely linked that it is not always easy to say which is which. In the spring, areas which have sandy and sandy mud bottoms become less turbid earliest. Here the first aquatics appear at the beginning of the growing season. As these plants grow, they lessen turbidity by mechanically reducing the movement of water and by binding the bottom. As the season progresses, the amount of wind decreases, with a resultant decrease in wave action in all areas. This causes decreases in turbidity, and plants begin to grow on at least some silt bottoms. If the water is not over about three feet deep, these plants likewise so effectively reduce turbidity that the water becomes as clear as that over sandy bottoms. However, if the water is over about five and a half feet deep, the turbidity is never reduced enough for plant growth. For this reason, large sections of Sand Bay, Redhead Bay, and Back Bay proper have no submerged waterfowl food plants. Two examples will indicate the importance of turbidity to submerged aquatics. At the north end of Great Narrows, near Station F, within 50 feet the depth drops from two or three feet, where there is a good growth of celery and najas, to eight or nine feet, where there is no growth. No differences in water quality could be detected between the shallow and deep spots, and the Secchi disc readings were the same. The critical thing here was that sufficient light for plant growth could reach the bottom in the shallow water, but not in the deep. In the other case, it was noted that najas and celery grew densely all around an unused boathouse at Refuge headquarters, but stopped abruptly at the area which was shaded by the roof. Here the water was equally clear and deep both inside and outside the boathouse. It could only be the lack of light which prevented plants from growing inside the house. In this connection, it may be noted that Bourn (1932) found the average percentage transmission of total solar energy by the waters of the center of Back Bay to diminish from slightly over 15% at one foot below the surface to about 1.6% at six feet. Further, the minimum required for growth by Potamogeton pectinatus was determined to be between 2.5% and 3.5% total solar energy. It is obvious, then, that turbidity of the water restricts plant growth by preventing their receiving the necessary amount of light for photosynthesis, and that turbidity seem be the factor now limiting the growth of submerged waterfowl food plants in Back Bay. It was found by experiment that this turbidity could be reduced by adding enough clear ocean water to the Bay water to bring the latter up to about 9.5% sea strength. This will be discussed later in this paper.

On several occasions in July and August, there were noticeable fluctuations of turbidity in such areas as Buck Island Bay which did not tie in with wind or wave action, but seemed due to fluctuations in the quantity of plankton. No standard plankton net was available, but with a rather large meshed substitute, noticeably greater amounts of material could be collected in very turbid areas than in moderately turbid ones. But between these latter and the clear areas, little difference could be seen. However, in all cases the condition seemed to be more or less temporary, lasting for only a few days.

2. Climatic Relations.

Data on climate was kindly furnished by the Fort Story (Cape Henry) Station of the U. S. Weather Bureau in their Monthly Climatological Summaries (U. S. Weather Bureau, 1947). In addition, daily records were kept at the Refuge of morning and afternoon air temperatures, wind direction and approximate velocity and general state of the weather. The general climate of the region has already been discussed; here only such climatic factors as relate to the submerged aquatic waterfowl food plants will be considered.

Rainfall might affect these plants by influencing both the water level and the salinity in the Bay. In the case of the former, it was found that the effect of wind was more marked than was that of rainfall. Furthermore, as already pointed out, the fluctuation of water level was relatively unimportant. As to the other question, it was found that the periods of higher salinity (July, August and October) do correspond with periods of low rainfall. The mean precipitation for July was 3.01 inches, the normal 5.37 inches. August had received only 1.16 inches until the 28th when 4.70 inches fell in 24 hours. This brought the total to 5.86 inches. The normal is 4.86 inches. October, with only 0.75 inches, was the dryest since 1934. But since salinity itself has been shown not to be a critical factor with the submerged aquatics of Back Bay, rainfall must also be considered not critical.

Air temperatures were found to be reflected quite closely in water temperatures, which have already been discussed.

However, water temperatures did not go to the extremes which air temperatures did. During the summer, the maximum water temperature noted was 32°C, and the maximum air temperature recorded at Cape Henry was 36°C. On December 14th and 15th when one-half to three-quarters of an inch of ice formed in the sloughs and along the shore, the air temperature was -1.6°C. Thus, water temperatures were generally close to, but less extreme than, air temperatures. As a consequence, air temperature cannot be reckoned as of other than minor importance to the submerged aquatics.

Tropical hurricanes or "northeast" storms severe enough to put sea water into the Bay would doubtless have great effect on the submerged food plants. But since no such storms hit the area in the past year, no estimate of such effect can be made. One light hurricane brushed the area in September (wind velocity 42 mph), but caused only a temporary lowering of water level in the Bay. Salt spray brought in from the ocean by east winds perhaps contributes to the salinity of Bay water and affects the barrier beach vegetation as described by Wells and Shunk (1938). At Refuge headquarters it was noted that potted ferns were killed, apparently by salt spray, if placed on an open porch on the east side of the house. And in October, following two days of east wind ranging from 24 to 33 mph, leaves on the east side of the taller pines on Long Island appeared to be damaged by salt spray. The effect of such spray on the submerged aquatics would only be very, very slight, however.

The real importance of wind, which is an outstanding element of Back Bay weather, is its effect on water level and wave action in the Bay. The former has already been discussed. In considering the latter, it must be remembered that Back Bay has large areas of open, shallow water. Here considerable wave action results from comparatively light wind velocities. It is this wave action which roils the water, stirring up silt and other material from the bottom, causing the turbidity which seems primarily responsible for the present limited growth of submerged aquatic waterfowl food plants in Back Bay. Of course, there are some factors which restrict this wave action. The protection yielded to small water areas by surrounding marsh or trees is quite evident. Even a narrow strip of marsh gives a surprising amount of opposition to waves. A dense growth of submerged aquatics likewise is remarkably effective in inhibiting wave action. Where beds of sago, najas or celery reach the surface, the water remains calm though waves may be running all around these so-called "slicks."

3. Soil Relations.

Composite soil samples from the bottom at eight test stations were taken with the help of, and kindly tested by, Dr. E. M. Dunton, Jr. of the Virginia Truck Experiment Station near Norfolk. Results are shown in Table 8.

As can be seen, there is no correlation between the pH values of the substratum and the amount of growth. And there seems little direct correlation between the amount of growth and available nutrients, organic matter, or type bottom. However, it will be noted that no areas are without growth having a sandy substratum. This again indicates that turbidity is the limiting factor in the growth of the plants in question. In most cases where the bottom is salty, wave action keeps the water muddy. The resultant exclusion of light outweighs the benefits which should be derived from a substratum rich in nutrients. Here it may be pointed out that Najas flexilis and Potamogeton perfoliatus have been found (Bourn, 1932) to make their best growth in a soil substratum, but that they will grow well and remain green and healthy when rooted in quartz sand if supplied with adequate nutrient solution. Water samples from Station K (a station of poor plant growth with a soft black silt substratum) tested very slightly higher in both phosphorus and potassium

TABLE 8

NUTRIENTS, ORGANIC MATTER, pH, AND TYPE BOTTOM AT TEST STATIONS

	STATIONS						
	B*	E*	J*	M*	G-	H-	K-
pH	4.42	4.95	4.48	4.6	4.95	4.75	5.32
Organic Matter	2.3	0.60	4.9	3.50	3.50	3.70	7.45
Available Phosphorus	1.50-2.25	0 - 0.75	0.75-1.50	0.75-1.50	1.50-2.25	0.75-1.50	1.50-2.25
Available Potash	225.-450.	225.-450.	450. plus	450. plus	450. plus	450. plus	450. plus
Type Bottom	Sandy Mud	Sand	Soft Black Silt	Sandy Mud	Black Mud	Soft Black Silt	Soft Black Silt

*Stations in areas of good growth.
-Stations in areas of poor growth.
Figures for nutrients are ppm in soil, those for organic matter are percentages.

content than did samples from Station B (a station of good plant growth with a sandy mud substratum). This again emphasizes the importance of the texture of the substratum, and the importance of turbidity. Those areas which have a substratum that tends to promote clear water, even though low in nutrients, will have better growths than do those, higher in available nutrients, that encourage turbidity. Similarly, those areas of rich substratum which because of protected situation or shallow water are not too turbid for adequate plant photosynthesis produce the most luxuriant growths.

4. Animal Relations.

The effect on the submerged aquatic plants by waterfowl and fish, which are the animals most affecting them, is difficult to measure exactly. Yet, these effects are very real. Cahn (1929) describes a lake one\mile long by one-quarter to three-quarters of a mile wide which was completely devegetated by the "rooting" or feeding of rough fish, mainly carp (Cyprinus carpio). In Back Bay, carp are abundant enough to support a large scale fishery, and evidence of their damage to the waterfowl food plants can easily be seen. From the first of the season, uprooted plants, especially celery, were commonly found. Their effect in roiling the water could hardly be noticed in the open Bay, but in the shallow, sheltered ponds of Ragged Island the water was always extremely muddy. In these ponds carp were abundant. They were, perhaps, as abundant in the open Bay, but they and their work could be most easily seen in the restricted ponds. There seems no doubt that the presence of carp in Back Bay is a definite detriment to the submerged aquatics, because of both their uprooting and consuming plants and their contributing to the general turbidity.

As to the waterfowl, perhaps their effect on the submerged aquatics should be called utilization rather than damage since these plants are of interest primarily as foods for the birds. At times, though, this feeding does become unduly detrimental. Thus, in the summer of 1946 there were excellent growths of submerged food plants in certain ponds on Ragged Island. That fall and winter heavy concentrations of ducks (10,000 to 12,000 birds) fed in these areas. In the 1947 season, practically no plants grew here. This is believed due to a combination of factors. In the first place, the birds fed so heavily that very little propagative stock remained. Secondly, the areas have soft black silt bottoms, so that once the plants were gone, wave action and carp kept the water so turbid that revegetation could not be accomplished in one year.

Usually the birds follow a fairly regular pattern in feeding over the Bay, with the fortunate result that these eat-outs occur only irregularly. The first migrants arrive in September or even late August, but are not present in numbers till October. During that month fairly heavy concentrations build up. Ruddy ducks first concentrate on the east side of Shipp's Bay, later spreading south to Sand Bay. All other species of ducks then present and the Canada geese first concentrate along the east shore of Sand Bay, centered about Widgeon Point Island, and in the adjacent marsh and sloughs. This area provides food, sand bars for resting, and both exposed and sheltered water. By the end of the third week in October, about one-third of the submerged aquatics in this section had been eaten, so that the birds began spreading to Buck Island Bay, Deep Creek, Bryant's Cove, Fisher's Cove, and the Ragged Island ponds. Sand Bay was extensively used as a rest area. At the very end of October, both ducks and geese were feeding in Shipp's and North Bays, the latter off the Refuge. By moving about in this way, the birds worked over one of the better areas after another, but not to excess. By the end of November two-thirds of the food plants in Fisher's Cove had been taken, as had a like percentage of those in the east half of Shipp's Bay. At the same time, one-quarter to one-third of the food had been eaten in Buck Island Bay and North Bay. This led to further spreading so that by late November the birds were pretty well distributed. There were, of course, exceptions. Redheads and scaup fed largely in North Bay and rested in Sand Bay. Ring-necks also fed in North Bay, but rested in numbers in the ponds on Ragged Island. In their feeding, the birds took celery, najas, sago, widgeon grass and redhead grass. Of these, it appears that during 1947 najas was the most valuable submerged food plant on the Bay since it does not die back as early as celery, was the most abundant of the lot, and was taken most frequently by the ducks.

5. Miscellaneous Adverse Factors.

A brackish water hydroid, Cordylophora lacustris Allman, has been described (Bourn, 1932) as seriously affecting the submerged aquatics in the Bay. This hydroid is not parasitic, but damages the plant mechanically and by leaving on the plant a gelatinous material in which other harmful organisms live. Mosby (1946) considered it definitely detrimental, especially to sago. However, in 1947 hydroids seemed unimportant. None were found until the very end of July, when a few light infestations were found in the Ragged Island ponds and about the headquarters boathouse. Subsequently, other very light infestations were found in various other sections through the end of October.

Also described as severely detrimental to the submerged aquatics is a fungus, a strain of Rhizoctonia solani Kuhn (Bourn and Jenkins, 1928). This parasite is supposed to cause first dark lesions on the plant stem, especially at the point of attachment of a hydroid colony, or at the point of emergence from the substratum. The stem later decays and becomes detached. During May of the present study, slightly less than 10% of the celery plants sampled showed lesions similar to Bourn's symptoms of Rhizoctonia infection. But by the early part of June, this passed more or less completely, and most plants appeared normal and healthy. If this actually were a Rhizoctonia infection, its effects were negligible.

In the latter part of June, a red discoloration of the leaves and stems was noticed in celery and najas. This was found especially along the mid-veins and at the terminal ends of the branches. These red leaves appeared otherwise normal under the microscope. Following the red state, however, some of the leaves at least become yellow, lose turgor, and rot off. In July, about 51% of the celery examined had several yellowed leaves, and the red coloring was quite noticeable. By the end of August, and through September, a dull red or brownish color replaced the previous definite red. No satisfactory explanation has been developed for this coloration.

In June and July, 1945, there was a period of high water level in the Bay (Bourn, 1945) due to long continued south winds and heavy rainfall (18.98 inches in July). This water, standing for several weeks over the peaty swamp lands in the drainage area north of Back Bay, became very dark and also picked up much oil from oil-soaked bags of sawdust placed as mosquito controls in the maze of drainage ditches about military establishments in the area. When water levels in the Bay went down, this dark, oily water drained in. Almost all plants in North Bay were killed as it flowed through Great Narrows into Redhead Bay and south to Currituck Sound. In 1946, North Bay remained practically barren. In 1947, there was until the end of July only a light growth of celery and sago around the eastern end and a few najas plants in the west and along the south side. During August and September, however, these spread and grew so well that by October all the central part of North Bay had a good stand of najas and some excellent stands of sago. This shows the length of time required for re-vegetation, again emphasizes the importance of turbidity, and demonstrates the uncontemplated and disastrous results of some ditching and mosquito control programs.

DISCUSSION

The various factors considered in this investigation have been discussed individually. But to gain a better understanding of the situation, it is necessary to consider their relations with each other.

Salinity at present is not a critical factor in the growth of Back Bay aquatics, since its concentration is entirely within the tolerance range of the plants in question. This concentration is at the same time too low to have any great effect on turbidity. Were the salinity 8% to 9.5% instead of the present 2% sea strength it is thought that a marked clearing up of the water might occur. Such an increase would undoubtedly benefit the growth of sago, widgeon grass, and redhead grass, but would hinder najas and probably celery. In any case, as long as the sand fence remains, any change in the salinity of Back Bay seems unlikely, maintained as it is by a balance between rainfall, northerly and southerly winds.

Both dissolved oxygen content and free carbon dioxide content are about what would be expected in natural, unpolluted waters. This indicates that pollution is at present of no consequence in Back Bay. So far as the requirements of the plants are concerned, enough oxygen seems to be liberated in photosynthesis to meet all needs. Increased quantities of free carbon dioxide would aid the growth of the submerged aquatics, but this compound is almost always in short supply for this group of plants everywhere. The content of Back Bay waters seems about normal. No alkalinity or acidity of sufficient concentration to cause damage to the submerged aquatics was found. In fact, practically all pH values recorded were of such range as to indicate a normal, balanced state for the waters of Back Bay. Likewise, nothing detrimental could be seen in the water temperatures found at Back Bay.

The turbidity factor is more complex. All evidence and all indications point to turbidity as primarily responsible for the present limited growth of submerged aquatic waterfowl food plants in Back Bay. Turbidity of the water operates against the plants, of course, by preventing the required amounts of light from reaching them. The primary cause of this turbidity appears to be wave action engendered by wind. Throughout the period of field work it was observed that turbidity varied directly with the wave action in all areas of open water. The relationship between wind action and turbidity is further brought out by Figure 13. The graph clearly shows that when most of the winds

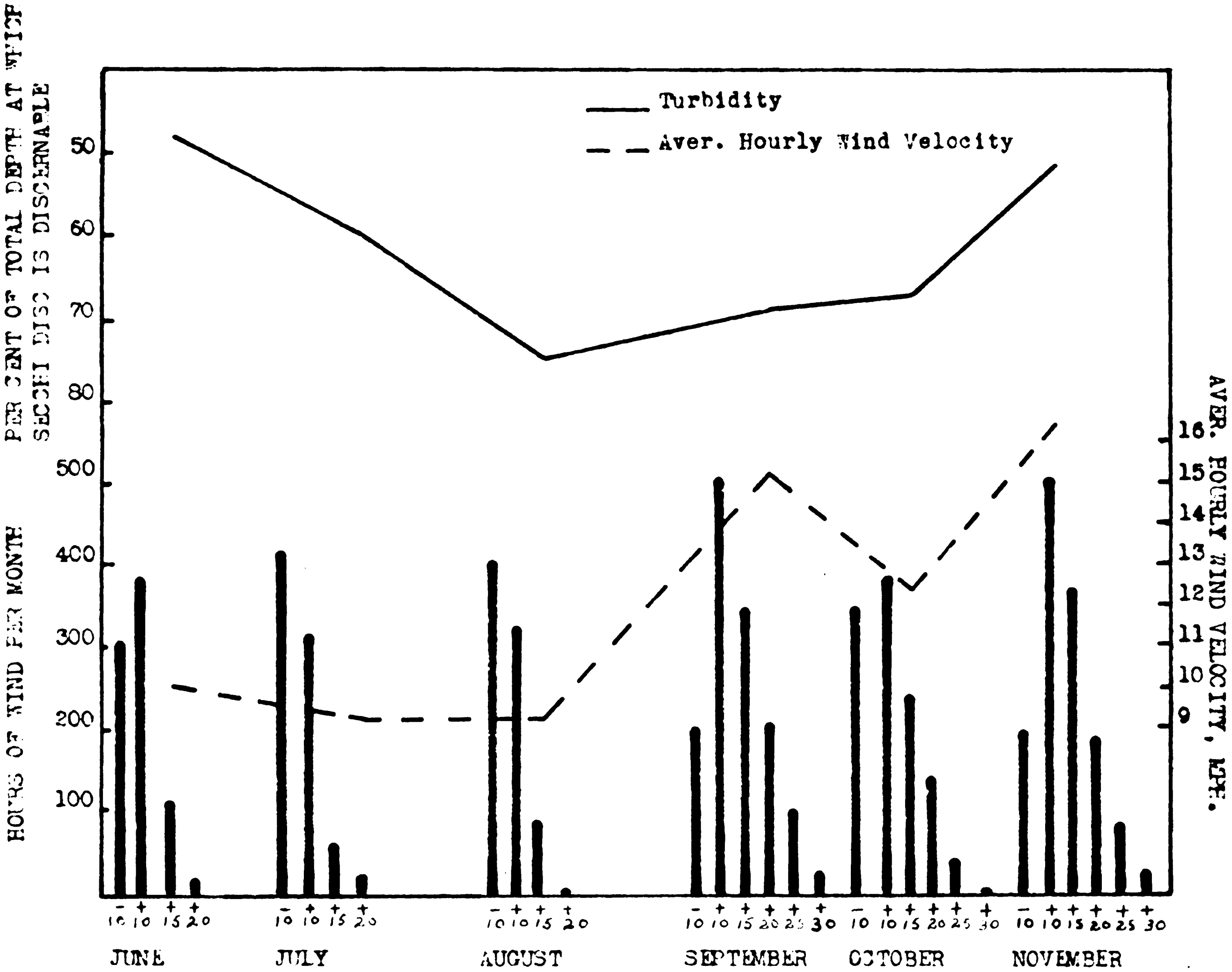


Figure 13. Average Turbidity and Wind Velocity.

are less than ten mph, and the average hourly velocity is lowest, the water becomes clearest. As the average hourly wind velocity increases, and most of the winds have velocities of ten mph and above, the water becomes more and more turbid.

But while wave action due to wind is the primary cause of this turbidity, other contributing factors must not be overlooked. The texture of the bottom is quite important. Water over sand or sandy mud is not made turbid by waves nearly so easily as is that over soft black silt bottoms. The vegetation itself both depends on and contributes heavily to clarity of the water. Its main effect is in reducing wave action, though its binding of the bottom is a close second.

Carp affect the submerged aquatics both directly by uprooting and consuming the plants and by contributing to water turbidity. Their actions, especially that of roiling the water, can be seen especially in the smaller, partially enclosed, shallow bodies of water such as the Ragged Island ponds. Since carp are abundant enough to support a sizable local fishing industry, they doubtless work over the open areas like Redhead and Sand Bays too, but being more dispersed are less noticeable. Considering the size of the area involved, it is believed that carp are definitely secondary to wind in causing turbidity.

Waterfowl, while feeding, do uproot and waste some plants, but usually seem to move to another feeding area before doing excessive damage. On occasion, however, the birds concentrate and apparently feed so heavily in certain restricted areas as to cause eat-outs. Revegetation is doubtless hindered in these cases by the actions of carp, but in any event at least two years seem required for recovery.

To sum up, the present condition of submerged aquatics in Back Bay appears to be the result of a lengthy interplay of factors. After the A. and C. Canal was opened and enlarged, the Bay was subjected to inflows of turbid, polluted, salty water. It is true that both before and after the opening of the Canal, the Bay received additions of salt water when the ocean crossed the barrier beach. But prior to such artificial changes as the causeway across Great Marsh, high salinities were not maintained in the Bay, and the plants apparently were benefitted by such temporary additions of sea water. But with the more or less constant increased salinity, pollution, disease, and turbid water the submerged aquatics declined badly in the years 1922-32. As the plants decreased, conditions for their growth and recovery became progressively worse. Plants had retarded roiling by wave action, but as the submerged aquatics decreased the wind caused waves which increased turbidity. This turbidity hindered further growth. Thus a vicious circle was started. Even after the closing of the A. & C. Canal locks in 1932, there could be no quick recovery. It was a question of slight progress some years, none others. It is thought that a gradual betterment of conditions can be expected, the concensus of local opinion being that the 1947 season was better than any of the last several. During the past few years at least, there apparently has been sufficient food to meet the needs of the waterfowl population. However, any marked increase in the population would doubtless find the present quantities of food inadequate. Even with no increase in the number of waterfowl, a greater production of submerged aquatic food plants would have two immediate good effects. First, it would tend to reduce such eat-outs as now occur, and second it would tend to distribute the birds more evenly over the area and so improve shooting.

MANAGEMENT RECOMMENDATIONS

The desirability of increasing the growth of submerged aquatic waterfowl food plants in Back Bay has been indicated. The factor presently limiting this growth has been shown to be turbidity. Any method of management for increasing the production of the submerged food plants must therefore reduce turbidity. To do this, its causes must either be eliminated or counteracted. But considering the causes in this case, it seems impossible to recommend any practical, feasible scheme. The turbidity is due mainly to wave action caused by wind. It is obviously not practical to control the wind, and in an area of this size no system of dams or breakwaters is thought to be feasible. The introduction of sea water to reduce the turbidity has frequently been suggested by owners of shooting properties and other hunters on the Bay. That sea water will do this, has been indicated by laboratory experiments. However, the difficulties of applying this method on a large scale prohibit its recommendation. In the first place, the salt content would have to be controlled to a rather fine degree over a great area. Secondly, the increase necessary to affect turbidity would definitely be detrimental to najas and probably so to celery, the two most abundant and valuable submerged food plants in the area. Thirdly, a system of pumping stations and pipe lines of forbidding expense would be required.

Carp are held to be a secondary cause of turbidity, and some management can be applied to them. It is not thought that they can ever be eliminated from the Bay, nor is that advocated. A local carp fishery already exists which is very important to the residents. They should be encouraged to keep the carp population at the minimum.

It would be desirable to prevent eat-outs by the waterfowl, perhaps by breaking up feeding concentrations which are great enough to be detrimental. But generally speaking, methods to accomplish this are unsatisfactory. Night feeding can sometimes be limited by the use of revolving search lights or beacons, and daytime feeding by continual disturbance or noise. None of these are infallable, however, and all more or less expensive or time consuming.

No other management practices to encourage the growth of submerged aquatics can be suggested, except that pollution and inflows of oil similar to that of 1945 should always be prevented. The management of marsh species of food plants, however, offers more possibilities. If is felt that were any money to be put into waterfowl food plant management on Back Bay, it could be more profitably spent in this phase. The botanical survey of the Refuge showed twenty-four recognized waterfowl food plants (Martin and Uhler, 1939; McAtee, 1939) occuring in the marsh. These are listed in Table 9, and their relative importance indicated. Some 35% of the Back Bay area is composed of marsh, and a goodly part of this could be managed. So far as the Refuge is concerned, that marsh most susceptible to management lies on the barrier beach between headquarters and the south boundry. Its main deficiency at the present time is that it is too dry for good food plant production and utilization, being only irregularly inundated. However, if a low dike were built along the line of natural levee at the Bay edge of the marsh, tied in with the sand fence at the north and south ends, and water control structures put in at several of the sloughs, a large acreage of worthwhile marsh would result from relatively little diking. Water from high levels in the Bay and from run-off could be held, and the usual practices with controlled water levels followed. Similar measures would be effective in other sites of the barrier beach marsh. As for the marshes of the islands in the Bay, any improvement is largely a question of controlling the more

TABLE 9

WATERFOWL FOOD PLANTS OCCURING
IN THE MARSHES OF BACK BAY REFUGE

SPECIES	RELATIVE ABUNDANCE	VALUE*
Sagittaria falcata	Frequent	Slight
S. subulata	Uncommon	Slight
Distichlis spicata	Common	Locally fair
Spartina alterniflora	Infrequent	Locally fair
Leersia oryzoides	Infrequent	Fair
Paspalum boscianum	Frequent	Locally fair to good
Echinochloa walteri	Infrequent	Excellent
Setaria lutescens	Uncommon	Slight
Eleocharis spp.	Common	Fair to good
Scirpus americanus	Abundant	Good
S. olneyi	Frequent	Slight to good
S. robustus	Abundant	Good to excellent
S. validus	Infrequent	Slight to fair
Rynchospora corniculata	Infrequent	Slight
Pontederia cordata	Infrequent	Slight
Myrica spp.	Common	Slight
Polygonum hydropiperoides	Infrequent	Good
P. pennsylvanicum	Frequent	Good to excellent
P. punctatum	Frequent	Good to excellent

TABLE 9 (Cont'd)

SPECIES	RELATIVE ABUNDANCE	VALUE*
Salicornia mucronata	Frequent	Locally fair to good
Proserpinaca palustris	Infrequent	Slight
Hydrocotyle umbellata	Abundant	Slight; locally fair
Bacopa monnieria	Frequent	Fair
Bidens spp.	Infrequent	Slight

*From Martin and Uhler, 1939.

undesirable species and opening up the marsh, perhaps by burning, blasting, and manipulation of the muskrat population.

Several benefits would result from any such marsh improvement. The feeding pressure on the submerged food plants would be reduced, thereby bettering conditions for further growth of these plants. More waterfowl could be supported by the area, and they could be well distributed. In this connection it should be pointed out that even the diving ducks, which are held in highest esteem and are most sought after by hunters on the Bay, derive some 18.7% of their diet from marsh food plants, as against 28.9% from submerged aquatics (Cottam, 1939; Martin and Uhler, 1939). Therefore, it is not abandoning the diving ducks to suggest marsh improvement. Considering, then, the extreme difficulties of applying practical management measures to the submerged food plants, and the greater possibilities offered by more feasable marsh management practices, it is recommended that any waterfowl food plant management in Back Bay be first applied to the marsh species.

CONCLUSIONS

1. The vegetation characteristic of the Back Bay area is largely Austroripariam. On the Back Bay National Wildlife Refuge about 330 species and varieties of 198 genera from 76 families were found.
2. Of these plants, five are important submerged aquatic waterfowl foods and twenty-four are emergent or marsh food species.
3. The present production of submerged waterfowl food plants is much below the potential for the area, though somewhat greater than in past years.
4. The factor now most responsible for this limited growth is turbidity of the water.
5. The chief cause of turbidity is wave action due to wind. The action of carp is a secondary cause.
6. In view of the extreme difficulties and expenses of controlling turbidity, no management practices can be recommended for increasing the growth of submerged aquatics other than continued prevention of pollution and maintainence of as low a carp population as possible.
7. Marsh management, on the other hand, is thought to offer good possibilities for benefitting waterfowl conditions on

the area. Therefore, it is believed that any management efforts to improve waterfowl food plant conditions on Back Bay can be more profitably applied to marsh and emergent species than to submerged aquatic species.

APPENDIX I

ANNOTATED CATALOG OF PLANTS COLLECTED ON BACK BAY NATIONAL WILDLIFE REFUGE PRINCESS ANNE COUNTY, VIRGINIA

May - December, 1947

THALLOPHYTA

CHARACEAE

Chara vulgaris. Infrequent - submerged. Shipp's Bay.
13-5*

Nitella hyalina. Abundant - submerged. Fisher's Cove.
11-3

EMBRYOPHYTA

BRYOPHYTA

MUSCI

Sphagnum sp. Uncommon, low damp spots. Marsh south of head-
1-7
quarters.

PTERIDOPHYTA

POLYPODIACEAE

Asplenium platyneuron (L.) Oakes. Uncommon - woods. Long Island.
4-19

Asplenium platyneuron (L.) Oakes f. serratum (E. S. Miller) Hoffm.
15-3
Frequent - dry soil, in woods, Long Island.

*Specimen number. These specimens are deposited in the Virginia Cooperative Wildlife Station herbarium.

Woodwardia virginica (L.) J. Sm. Infrequent - open areas.
2-13
Marsh north of headquarters.

OSMUNDACEAE

Osmunda regalis L. Uncommon - medium dry soil. Marsh north of
2-23
headquarters.

LYCOPODIACEAE

Lycopodium inundatum L. var. adpressum Chapm. Frequent - damp
20-17, 22-10
soil. Marsh north of headquarters.

SPERMATOPHYTA

PINACEAE

Pinus taeda L. Frequent - dry soil. Woods south of Black
2-29
Island Slough and on Long Island.

Pinus virginiana Mill. Very rare - dry sandy soil. Woods south
19-1
of Black Island Slough.

TYPHACEAE

Typha angustifolia L. Abundant - wet soil and emergent. All
5-7
marshes.

Typha latifolia L. Frequent - wet soil and emergent. East side,
10-16
Long Island.

Typha truxillensis HBK. Frequent - wet soil and emergent. All
11-7,11-8,12-4
marshes.

NAJADACEAE

Najas guadalupensis (Spreng) Morong. Abundant - open water,
9-5,11-1,15-11
submerged. Deep Creek, Buck Island Bay, Shipp's Bay.

Potamogeton pectinatus L. Common - submerged. Shipp's Bay,
30-2,8-14,6-28,15-14,5-2,3-3
Buck Island Bay.

Potamogeton perfoliatus L. Frequent - submerged. Buck Island Bay.
15-13

Potamogeton pusillus L. Infrequent - submerged - mud bottom,
12-6,3-2
shallow water. Marsh south of headquarters.

Potamogeton richardsonii (Benn.) Rydb. Frequent - submerged.
3-5,9-9
Buck Island Bay.

Potamogeton zosteriformis Fernald. Infrequent - small ditch in
6-9
marsh - submerged. Long Island.

Ruppia maritima L. Common - open water, submerged. Shipp's Bay.

9-6, 15-12

Zannichellia palustris L. Frequent - submerged, ponds and
9-7,12-7,5-18
sloughs. Ragged Island, Marsh north of headquarters.

JUNCAGINACEAE

Triglochin striata R & P. Infrequent - emergent - 3" water.
12-24
Marsh south of headquarters.

ALISMACEAE

Sagittaria falcata Pursh. Frequent - wet soil and emergent.
10-14
East side, Long Island.

Sagittaria graminea Michx. Uncommon - submerged. Marsh north
9-10
of headquarters.

Sagittaria subulata (L.) Buchenau. Uncommon - wet sand. Black
18-1
Island Slough.

HYDROCHARITACEAE

Vallisneria americana Michx. Common - submerged. Shipp's Bay,
30-1, 27-3, 9-2, 9-1, 9-4, 16-2, 16-1, 15-12, 5-1, 3-1, 18-6,1-15
Fisher's Cove.

GRAMINEAE

Agrostis hiemalis (Walt) B.S.P. Uncommon - medium dry soil.
4-3
Marsh south of headquarters.

Ammophila breviligulata Fernald. Abundant - dry dunes. Front
22-3
beach.

Andropogon glomeratus (Walt) B.S.P. Frequent - damp soil. Marsh
24-1
south of headquarters.

Andropogon virginicus L. Abundant - dry to damp soil. Marsh
24-13,25-6
south of headquarters.

Avena sativa L. Cultivated for geese, escaped. Long Island.
4-30

Bromus secalinus L. Frequent along woods edge, dry soil. Long
10-4,4-31
Island.

Cenchrus tribuloides L. Frequent - dry sand and dunes. Front beach.
19-11

Cynodon dactylon (L.) Pers. Common - dry soil. Headquarters yard.
10-7

Digitaria ischaemum (Schreb.) Muhl. Common on lawn - dry soil.
24-2
Headquarters yard.

Digitaria sanguinalis (L) Scop. Infrequent - dry soil. Head-
24-3,17-28
quarters yard.

Distichlis spicata (L.) Greene. Common - wet soil and emergent.
19-8,14-20
Wash Flats.

Echinochloa walteri (Pursh) Heller. Infrequent - damp soil.
20-2,24-4
Marsh north of headquarters.

Elymus riparius Wiegand. Common - dry soil, woods edge. Long
15-4
Island.

Elymus virginicus L. Infrequent - dry soil - woods edge. Long
10-9,12-31
Island.

Eragrostis spectabilis (Pursh) Staud. Frequent - dry sand. Marsh
19-18
south of headquarters.

Erianthus giganteus (Walt.) Muhl. Frequent - damp soil. Marsh
22-1
south of headquarters.

Festuca octoflora Walt. Uncommon - damp soil. Marsh south of
4-9
headquarters.

Holcus lanatus L. Frequent about headquarters - dry soil.
6-27

Hordeum pusillus Nutt. Frequent - dry soil, woods edge. Long
4-28
Island.

Leersia oryzoides (L.) Swartz. Infrequent - wet soil. Width of
25-13
leaf and retrorse scabrousness intermediate w/L.
hexandra. South of Black Island Slough.

Panicum agrostoides Nash. Infrequent - damp soil. Marsh north
20-3
of headquarters.

Panicum amarulum Hitche and Chase. Common - beach dunes. Front
2-36
beach.

Panicum amarum Ell. Common - dry sand. Front beach.
19-13

Panicum anceps Michx. Frequent - damp soil, woods edge, Long
23-5
Island.

Panicum capillare L. Common - damp to dry soil. Marsh south
27-1
of headquarters.

Panicum ciliatum Ell. Frequent - dry sand. Marsh north of
14-17
headquarters.

Panicum condensum Nash. Infrequent - damp soil. Marsh south
22-7
of headquarters.

Panicum microcarpon Muhl. Frequent - damp woods. Long Island.
23-8

Panicum roanokense Ashe. Abundant - damp soil. Marsh south of
25-4
headquarters.

Panicum scoparium Lam. Frequent - damp soil. South of Black
25-5,18-4,8-1
Island Slough.

Panicum virgatum L. Abundant - damp soil. Marsh south of head-
11-6,12-36,12-10,18-5
quarters.

Panicum webberianum Nash. Frequent - dry sand. Marsh north of
14-18
headquarters.

Paspalum boscianum Flugge. Frequent - damp soil. Marsh north
22-9
of headquarters.

Paspalum dilatatum Poir. Infrequent - dry soil. Headquarters yard.
10-10

Phragmites communis Trin. Scarce - wet soil and emergent. Ragged
15-16
Island.

Poa pratensis L. Common about Hq. - dry soil.
3-6

Polypogon monspeliensis (L.) Desf. Common - wet soil and emergent.
17-2,6-14,14-9,6-5,4-5
Marsh south of headquarters.

Sacciolepis striata (L.) Nash. Infrequent - damp soil. Marsh
20-16
north of headquarters.

Setaria geniculata (Lam.) Beauv. Common - damp soil. Marsh
25-2
south of headquarters.

Setaria lutescens (Weigel) F. T. Hubb. Uncommon - damp soil.
17-1,15-5
Long Island.

Sorghum halepense (L.) Pers. Infrequent - dry soil. Long Island.
12-35

Spartina alterniflora Lois. Infrequent - edges of Wash Flats.
25-8
Similar to S. cynosuroides (L.) Roth. var. polystachya (Michx) Beal. See Rhodora 49 (580): 113-Fernald. Differs in having smooth leaf margins.

Spartina cynosuroides (L.) Roth. Abundant - wet soil. All marshes.
23-19

Spartina patens (Ait.) Muhl. Abundant - dry to damp soil. Marshes
10-2
north and south of headquarters.

Sphenopholis obtusata (Michx) Scribn. Common - dry to damp soil.
4-6,3-7
Headquarters yard.

Triodia flava (L.) Smyth. Frequent - dry field edge. Long Island.
23-10, 21-4

Uniola paniculata L. Common - dry dunes. Front beach.
19-12

CYPERACEAE

Carex suberecta (Olney) Britton. Uncommon - dry soil. Headquarters yard.
6-4,4-1

Carex vulpinoidea Michx. Infrequent - dry soil. Long Island.
12-41

Cyperus ferax Rich. Abundant - damp soil. Marsh south of head-
20-9,12-1
quarters.

Cyperus grayii Torr. Common - dry sand. Beach north of head-
20-13,26-5
quarters.

Cyperus haspan L. Common - damp soil. Marsh north of headquarters.
20-7

Cyperus houghtonii Torr. Infrequent - wet soil. Marsh south of
12-23
headquarters.

Cyperus lancastriensis Porter. Infrequent - wet soil. Long
19-9
Island, southeast end.

Cyperus rivularis Kunth. Infrequent - damp soil. Marsh north
20-25
of headquarters.

Cyperus strigosus L. Frequent - damp soil. Marsh north of
19-10,20-8,24-8,24-6
headquarters.

Dichromena colorata (L.) Hitchc. Frequent - damp soil. Marsh
7-13,12-15
south of headquarters.

Eleocharis acicularis (L.) R. & S. Frequent - wet soil and
19-3,1-12
emergent. Long Island, southeast end.

Eleocharis ochreata (Nees) Steud. Common - wet soil. Marsh
17-12
south of headquarters.

Eleocharis olivacea Torr. Abundant - wet soil. Marsh south of
12-29
headquarters.

Eleocharis ovata (Roth.) R. & S. Frequent - wet soil, emergent
2-28,1-4
in water 2" to 3" deep. Marsh south of headquarters.

Eleocharis palustris (L.) R. & S. Common - wet soil. Long Island,
19-7,6-15
southeast end.

Eleocharis parvula (R. & S.) Link. Common - shallow pools, muddy
18-3,3-4
shores. Black Island Slough.

Eleocharis quadrangulata (Michx) R. & S. Infrequent - emergent,
12-21
3" water. Marsh south of headquarters.

Eleocharis tuberculosa (Michx) R. & S. Common - wet soil. Marsh
17-17
south of headquarters.

Fimbristylis puberula (Michx) Vahl. Frequent - dry sand. Marsh
19-16
south of headquarters.

Fimbristylis spadicea (L.) Vahl. Infrequent - damp soil. Fernald
19-4,17-27,14-10,12-26
(Rhodora 37: p. 397) calls this F. castanea. Marsh
north and south of headquarters.

Fuirena squarrosa Michx. Frequent - wet soil. Marsh north of
20-5,25-7
headquarters.

Rynchospora corniculata (Lam.) Gray. Infrequent - wet soil.
6-10
Marsh north of headquarters.

Scirpus americanus Pers. Abundant - damp soil. Marsh north and
2-15,6-25,1-2
south of headquarters.

Scirpus olneyi Gray. Frequent - wet soil and emergent. Ragged
2-14
Island.

Scirpus robustus Pursh. Abundant - wet soil and emergent. All
17-11,7-16,6-18
marshes.

Scirpus validus Vahl. Infrequent - wet soil. Marsh south of
2-21,12-5
headquarters.

LEMNACEAE

Lemna minor L. Abundant on pools in marsh. Ragged Island.
5-19

XYRIDACEAE

Xyris caroliniana Walt. Infrequent - damp soil. Marsh north of
20-4
headquarters.

COMMELINACEAE

Commelina virginica L. Infrequent - damp soil. Headquarters yard.
20-27

PONTEDERIACEAE

Pontederia cordata L. Infrequent - wet soil and emergent. Long
9-3,8-13
Island.

JUNCACEAE

Juncus acuminatus Michx. Common - slightly damp soil. Marsh
6-12,7-3,7-4,11-15
south of headquarters.

Juncus aristulatus Michx. Abundant - damp soil. Marsh north of
8-9
headquarters.

Juncus balticus Willd., var. littoralis Engelm. Frequent - damp
6-13
soil, wood edge. Long Island.

Juncus brevicaudatus (Engelm) Fernald. Abundant - slightly damp
2-16,2-35
soil. Marsh south of headquarters.

Juncus dichotomus Ell. Common - damp soil. Long Island.
6-20

Juncus effusus L. Frequent - woods edge - only slightly damp.
4-10
Long Island.

Juncus gerardi Loisel. Uncommon - damp sandy soil. Marsh south
4-7
of headquarters.

Juncus greenei Oakes & Tuckerm. Common - damp soil. Marsh south
11-13
of headquarters.

Juncus maritimus Lam. Very extensive - damp ground and emergent,
2-12
1 to 2" of water. Marsh south of headquarters.

Juncus nodosus L. Abundant - dry soil. Marsh south of headquarters.
7-6

Juncus robustus (Engelm.) Coville. Infrequent - damp soil. Marsh
2-33
south of headquarters.

Juncus roemerianus Scheele. Abundant - wet soil. Marsh north
2-2,6-16,1-9,1-6
and south of headquarters.

Juncus scirpoides Lam. Abundant - damp soil. Marsh north of
20-14,7-9
headquarters.

Juncus setaceus Rostle. Common - damp soil. Marsh south of
2-30,17-8,11-12,4-33
headquarters.

LILIACEAE

Allium vineale L. Common - lawn and field edges. Headquarters yard.
4-14,7-2

Nothoscordum bivalve (L.) Britton. Uncommon - woods, slightly
4-18
damp soil. Long Island.

Smilax bona-nox L. Frequent - edges of woods, medium dry soil.
31-4,4-26
Long Island.

Smilax glauca Walt. Frequent, edges of woods, medium dry soil.
31-3,4-25
Long Island.

Smilax laurifolia L. Infrequent - dry soil. Marsh south of
29-1
headquarters.

Smilax pseudo-china L. Uncommon - old dunes. Marsh south of
2-34
headquarters.

Smilax walteri Pursh. Frequent - woods, dry soil. Long Island.
28-7

IRIDACEAE

Sisyrinchium gramineum Curtis. Frequent - medium damp spots.
2-4
Marsh north of headquarters.

ORCHIDACEAE

Calopogon pulchellus (Sw.) R. Br. Infrequent - slightly damp
7-20
open area. Marsh south of headquarters.

Pogonia ophioglossoides (L.) Ker. Infrequent - slightly damp,
7-21
open area. Marsh south of headquarters.

Spiranthes cernua (L.) Richard. Infrequent - slight damp soil.
7-7
Marsh south of headquarters.

Spiranthes odorata (Nutt.) Lindl. Rare - wet soil. Marsh north
24-11
of headquarters.

SALICACEAE

Salix longipes var. Wardii. (Bebb) Schneider. Scarce - damp
17-13
soil. Long Island.

Salix nigra Marsh. Infrequent - damp woods edge. Long Island.
2-1, 12-39

MYRICACEAE

Myrica cerifera L. Common dry soil. North and south of headquarters.
2-17

Myrica carolinensis Mill. Infrequent - dry soil. North and south
6-26
of headquarters.

FAGACEAE

Quercus nigra L. Infrequent - dry soil. Ragged Island.
5-11

Quercus phellos L. Infrequent - dry soil. Ragged Island.
5-15

Quercus virginiana Mill. Frequent - low stabilized dunes. South
2-26
of Black Island Slough.

URTICACEAE

Broussonetia papyrifera (L.) Vent. Common about house on Ragged
5-13
Island - dry soil.

Celtis mississippiensis Bosc. Common - dry soil. Long Island.
15-1, 4-39

Celtis occidentalis L. var. crassifolia (Lam.) Gray. Few plants,
6-11
dry soil. Long Island.

Maclura pomifera (Raf.) Schneider. Rare - damp soil - possible
17-10
escape. Headquarters yard.

Morus rubra L. Frequent - slightly damp woods. Long Island.
28-6, 5-10

Ulmus fulva Michx. Infrequent - slightly damp soil in woods.
28-5
Long Island.

POLYGONACEAE

Polygonum hydropiperoides Michx. Infrequent - wet soil. Marsh
12-30
south of headquarters.

Polygonum pennsylvanicum L. Frequent - damp soil. Marsh south
11-14
of headquarters.

Polygonum persicaria L. Frequent - dry soil. Long Island.
12-34

Polygonum prolificum (Small) Robinson. Frequent - damp soil.
50-4, 21-8
Wash Flats Marsh.

Polygonum punctatum Ell. Frequent - damp soil. Marsh south of
30-5,10-15,11-16
headquarters.

Polygonum sagittatum L. Infrequent - wet soil. Marsh south of
20-15,12-14
headquarters.

Rumex acetosella L. Sparse growth - low dunes. Marsh south of
1-10
headquarters.

Rumex conglomeratus Murr. Common - wet soil and emergent. Ragged
6-17,5-6
Island.

Rumex hastatulus Baldw. Infrequent - dry sandy soil, low dunes.
1-14
Marsh south of headquarters.

Rumex verticillatus L. Common - wet soil. Marsh north of head-
9-8
quarters.

CHENOPODIACEAE

Salicornia mucronata Bigel. Frequent - damp soil. Wash Flats.
21-11,11-2

PHYTOLACCACEAE

Phytolacca decandra L. Common - dry soil, near house, Ragged Island.
5-16

AIZOACEAE

Mollugo verticillata L. Infrequent - damp soil. Wash Flats.
19-15

Sesuvium maritimum (Walt) BSP. Common - "salt" flats. Wash Flats.
14-11

CARYOPHYLLACEAE

Cerastium viscosum L. Common - Headquarters yard - medium dry soil.
2-8

Spergularia marina (L.) Griseb. Infrequent - bare, sandy area.
7-15,14-12,1-13
Wash Flats.

Stellaria media (L.) Cyrill. Infrequent - open field, damp soil.
31-2
Long Island.

LAURACEAE

Sassafras albidum (Nutt.) Nees. Common - woods. Long Island.
4-27

CRUCIFERAE

Cakile edentula (Bigel.) Hook. Common - dry sand dunes. Front beach.
13-3

Erysimum officinale L. Uncommon - field edges. Long Island.
4-13

Lepidium virginicum L. Common - headquarters yard - dry soil.
2-6

DROSERACEAE

Drosera longifolia L. Frequent - slightly damp soil. Marsh south
7-8
of headquarters.

ROSACEAE

Agrimonia parviflora Ait. Infrequent - damp woods. Long Island.
23-6

Amelanchier oblongifolia (T&G) Roem. Rare - moist woods. South
30-4
of Black Island Slough.

Crataegus crus-galli L. Frequent - field and woods edges - dry
23-11,4-12,4-37
soil. Long Island.

Duchesnea indica (Andr.) Focke. Frequent along woods edges -
4-21
medium dry. Long Island.

Geum canadense Jacq. Scarce - dry soil. Headquarters yard.
15-18

Potentilla monspeliensis L. Uncommon - dry soil. Headquarters yard.
13-8, 17-21

Prunus sp. (cultigen). Few trees around Ragged Island house -
5-9
dry soil.

Prunus persica (L.) Stokes. Few trees about Ragged Island house,
5-12
dry soil.

Prunus serotina Ehrh. Infrequent - medium dry soil. Long Island.
2-18

Pyrus malus L. Few plants about house on Ragged Island - dry soil.
6-23

Rosa palustris Marsh. Infrequent - damp soil. Marsh south of
21-1, 7-17,12-9
headquarters.

Rubus andrewsianus Blanchard. Common in dry woods and open
4-17
sandy areas. Marsh south of headquarters.

LEGUMINOSAE

Cassia fasciculata Michx. Abundant - damp soil. Long Island,
14-7,6-21
marsh north and south of headquarters.

Cassia nictitans L. Common - dry soil. Marsh south of headquarters.
17-7

Desmodium canescens (L.) DC. Infrequent - damp soil. Marsh north
20-20,19-6
of headquarters.

Desmodium paniculatum (L.) DC. Frequent - dry soil. Ragged Island.
19-2

Galactia regularis (L.) BSP. Uncommon - damp soil. Marsh south
17-5
of headquarters.

Galáctia volubilis (L.) Britton. Common - dry soil. Marsh
12-19
south of headquarters.

Lespedeza capitata Michx. Infrequent - dry soil. Marsh south
25-3
of headquarters.

Medicago sativa L. Scarce - dry soil, headquarters yard.
5-3

Melilotus alba Desr. Scarce - dry soil about headquarters.
15-15

Melilotus officinalis (L.) Lam. Infrequent - dry soil. Head-
6-3
quarters yard.

Strophostyles helvola (L.) Britton. Common - damp soil. Marsh
20-1,17-4
south of headquarters.

Strophostyles umbellata (Muhl) Britton. Frequent - dry soil.
14-3
Marsh north of headquarters.

Trifolium incarnatum L. Rare - field edge - possible escape.
4-11
Long Island.

Trifolium repens L. Common - medium dry soil. Headquarters yard.
2-5

Vicia angustifolia (L.) Richard. Few plants about headquarters,
2-7
medium dry soil.

Vicia villosa. Infrequent - dry soil of field edges - escape -
12-32,4-34
cultivated as cover crop. Long Island.

LINACEAE

Linum floridanum (Planch) Trel. Common - damp soil. Marsh north
8-8
of headquarters.

Linum medium (Planch) Britton. Common - dry to damp soil. Marsh
12-28,12-16,7-19
south of headquarters.

OXALIDACEAE

Oxalis stricta L. Common - medium dry soil. Headquarters yard.
2-11

Oxalis violacea L. Few plants about headquarters yard. Dry soil,
4-41
escape.

GERANIACEAE

Geranium carolinianum L. Common - headquarters yard - medium dry
2-9
soil. Fruit measure 1-1.5 cm.,somewhat smaller than typical.

RUTACEAE

Zanthoxylum clava-herculis L. Infrequent - dry soil. Ragged
21-5,20-18
Island.

POLYGALACEAE

Polygala sanguinea L. Abundant - damp soil. Marsh south of
12-8
headquarters.

EUPHORBIACEAE

Euphorbia polygonifolia L. Infrequent - sand dunes. Front Beach.
14-15

ANACARDIACEAE

Rhus copallina L. Common - medium dry soil. Marsh south of
2-27
headquarters.

Rhus toxicodendron L. Frequent - medium dry soil, in shade.
2-24
South of Black Island Slough.

AQUIFOLIACEAE

Ilex opaca Ait. Common - damp woods. Long Island.
4-23

ACERACEAE

Acer rubrum L. Infrequent - damp soil, Long Island and woods
2-32
south of Black Island Slough.

RHAMNACEAE

Berchemia scandens (Hill) Trel. Few plants - thick woods on
6-7
Long Island.

VITACEAE

Ampelopsis arborea (L.) Koehne. Common - slightly damp to dry
4-38
soil. Long Island.

Parthenocissus quinquefolia (L.) Greene. Common - edges, medium
2-19,6-22
dry soil. Long Island.

Vitis cinerea Engelm. Frequent - dry soil. Ragged Island.
21-6,2-38

Vitis riparia Michx. Infrequent - damp soil. Long Island.
19-5

MALVACEAE

Hibiscus moscheutos L. Infrequent - wet soil and emergent.
13-4
Long Island, east side.

Hibiscus oculiroseus Britton. Common - wet soil. Marsh south
14-21,12-17
of headquarters.

Kosteletzkya virginica (L.) Presl. Frequent - damp soil. Marsh
23-18,18-2
south of headquarters.

Malva rotundifolia L. Infrequent - dry soil. Headquarters yard.
13-1

HYPERICACEAE

Ascyrum hypericoides L. Infrequent - dry sand. Marsh north of
20-11
headquarters.

Hypericum gentianoides (L.) BSP. Common - dry soil. Long Island.
24-9, 12-40

Hypericum virgatum Lam. Infrequent - damp soil. Marsh north of
14-14
headquarters.

Hypericum virginicum L. Uncommon - wet soil. Marsh south of
17-16
headquarters.

CISTACEAE

Hudsonia tomentosa Nutt. Uncommon - dry sand. Marsh south of
2-31
headquarters.

Lechea maritima Leggett. Frequent - dry soil. Marsh south of
21-9,25-11
headquarters.

VIOLACEAE

Viola lanceolata L. Common - damp black loam, in open areas.
1-8
Marsh south of headquarters.

PASSIFLORACEAE

Passiflora incarnata L. Dry sandy soil - frequent. Headquarters yard.
10-17

LYTHRACEAE

Lythrum lineare L. Common - damp soil. Marsh south of headquarters.
14-1

MELASTOMACEAE

Rhexia mariana L. var. purpurea Michx. Common - damp soil.
14-4,12-18,12-38
Marsh south of headquarters.

Rhexia virginica L. Uncommon - damp soil. Marsh south of
11-9
headquarters.

ONAGRACEAE

Ludvigia alternifolia L. Common - damp soil. Marsh south of
24-7,8-6,12-2
headquarters.

Ludvigia palustris (L.) Ell. Frequent - damp soil - Wash Flats Marsh.
21-10

Oenothera humifusa Nutt. Common - dry soil and sand. Front beach.
10-6, 7-10

Oenothera laciniata Hill. Common-dry soil about headquarters.
2-3

Oenothera muricata L. Frequent - dry soil. Marsh north of
17-19,14-8,23-12
headquarters.

HALORAGIDACEAE

Proserpinaca palustris L. Infrequent - emergent - pond in woods
30-6
south of Black Island Slough.

UMBELLIFERAE

Centella asiatica (L.) Urban. Common - damp soil. Marsh north
8-3
of headquarters.

Daucus carota L. Uncommon - dry soil. Headquarters yard.
13-7

Foeniculum vulgare Hill. Infrequent - dry woods edge. Long Island.
12-37

Hydrocotyle umbellata L. Abundant - damp soil. Marsh north of headquarters.
8-4

Ptilimnium capillaceum (Michx) Raf. Common - damp soil. Marsh south of headquarters.
15-9,17-9,11-10,14-2

CORNACEAE

Cornus stricta Lam. Few plants - marsh-field border on Long Island.
6-6

Nyssa sylvatica Marsh. Frequent - damp woods. Long Island.
4-24

ERICACEAE

Vaccinium marianum Wats. Infrequent - medium dry soil. South of Black Island Slough.
25-14

PRIMULACEAE

Anagallis arvensis L. Common - dry soil. Long Island.
12-33

Samolus floribundus HBK. Common - damp soil. Long Island.
10-11

EBENACEAE

Diospyros virginiana L. Common - woods and field edges. Long Island.
4-36

LOGANIACEAE

Gelsemium sempervirens (L.) Ait. Frequent - medium dry woods.
30-3
South of Black Island Slough.

GENTIANACEAE

Sabatia angularis (L.) Pursh. Uncommon - damp soil. Long Island.
15-2

Sabatia stellaris Pursh. Common - damp soil. Marsh south of
17-3,26-2
headquarters.

APOCYNACEAE

Apocynum cannabinum L. Abundant - damp soil. Marsh north of
8-10
headquarters.

ASCLEPIADACEAE

Asclepias incarnata L. Infrequent - field edges - this plant has
23-16
stem pubesent, follicle sparingly so. Same character
of var. pulchra. Long Island.

Asclepias incarnata L. var. pulchra (Ehrh.) Pers. Frequent-damp soil.
14-19
Marsh north of headquarters.

CONVOLVULACEAE

Convolvulus sepium L. var. pubescens (Gray) Fernald. Common
4-40
along woods and field edges and about headquarters.

Cuscuta sp. Frequent - damp soil - on low plants. Marsh south
12-11
of headquarters.

Ipomoea purpurea (L.) Roth. Frequent - dry soil. Long Island.
23-2

VERBENACEAE

Lippia nodiflora (L.) Michx. Abundant - damp soil. Infrequent-
7-14,15-10
dry soil. Headquarters yard.

Verbena scabra Vahl. Frequent - dry soil. Headquarters yard.
17-20

Verbena urticifolia L. var. leiocarpa Perry & Fernald. Frequent-
10-13,7-1
dry soil. Headquarters yard.

LABIATAE

Lycopus sessilifolius Gray. Common - wet soil. Marsh south of
17-14
headquarters.

Prunella vulgaris L. Uncommon - dry soil. Headquarters yard.
13-6

Teucrium canadense L. var littorale (Bickness) Fernald. Frequent-
11-11
damp sand. Marsh south of headquarters.

SOLANACEAE

Datura tatula L. Infrequent - open field - dry soil. Long Island.
31-1

Solanum carolinense L. Frequent - dry soil - some flowers w/six
6-2,7-12
carolla lobes and six stamens. Headquarters yard.

SCROPHULARIACEAE

Bacopa monnieria (L.) Wettst. var. cuneifolia (Michx) Fernald.
12-22,17-18
Frequent - wet soil. Marsh south of headquarters.

Gerardia purpurea L. Frequent - field edges. Long Island.
23-13, 26-1

Linaria canadensis (L.) Dumont. Sparse - dry sand. Marsh south
1-11
of headquarters.

Pentstemon laevigatus Ait. Infrequent - dry soil. Headquarters yard.
6-1

Verbascum blattaria L. Frequent - about headquarters yard - dry soil.
4-44

Verbascum blattaria L. var albiflorum Ktze. Frequent-about head-
4-43
quarters yard - dry soil.

Verbascum thapsus L. Uncommon - dry soil. Headquarters yard.
10-5,13-2

BIGNONIACEAE

Tecoma radicans (L.) Juss. Frequent - woods and along edges.
6-8,8-12
Long Island.

PLANTAGINACEAE

Plantago virginica L. Common - headquarters yard - medium dry soil.
2-10

RUBIACEAE

Diodia teres Walt. Infrequent - dry sand. Marsh south of headquarters.
12-25

Diodia teres Walt. var. hystricina Fernald & Griscom. Frequent-
20-26,14-16
dry sandy soil - flowers purple to purplish white.

Marsh south of headquarters.

Diodia virginiana L. Common - wet soil. Marsh south of headquarters.
14-5,12-12

Galium claytoni Michx. Common in marsh - wet soil. Marsh north
5-5,8-5
of headquarters.

Oldenlandia uniflora L. Common - damp soil. Marsh north of
20-10
headquarters.

CAPRIFOLIACEAE

Lonicera japonica Thumb. Common along edges. Long Island.
4-20

Lonicera sempervirens L. Frequent - damp woods edges. Long Island.
4-22, 5-17

Sambucus canadensis L. Common about yard - Ragged Island - dry
5-14
soil.

CURCURBITACEAE

Melothria pendula L. Frequent - dry soil - Ragged Island.
21-7

CAMPANULACEAE

Specularia perfoliata (L.) ADC. Common - field borders - dry
4-32
soil. Long Island.

COMPOSITAE

Achillea millefolium L. Common - dry soil. Long Island.
17-6, 11-5, 10-1, 4-42

Ambrosia artemisiifolia L. Common - dry soil. Long Island.
23-3, 23-15, 21-3

Anaphalis margaritacea (L.) B & H. Infrequent - dry soil.
10-8
Headquarters yard.

Anthemis cotula L. Common - dry soil. Long Island.
15-8, 10-3, 4-16

Artemisia caudata Michx. Infrequent - sandy soil. Marsh north
20-24
of headquarters.

Aster ericoides L. Frequent - field edges. Long Island.
23-14

Aster novi-belgii L. Rare - damp soil. Marsh north of headquarters.
26-4

Aster subulatus Michx, var. euroanster Fernald & Griscom. Common-
24-12
damp soil. Marsh north of headquarters.

Aster surculosus Michx. Infrequent - dry to damp marsh edges.
28-3
Long Island.

Aster tenuifolius L. Common - medium dry soil. Marsh north of
22-11
headquarters.

Baccharis halimifolia L. Common - damp soil. Marsh south of
6-24,25-9
headquarters.

Bidens cernua L. Infrequent - wet soil. Marsh south of headquarters.
25-12,27-2

Bidens connata Muhl. Common - woods - slightly damp. Long Island.
28-4

Bidens coronata (L.) Fisch. Frequent - damp soil, in woods.
23-4
Long Island.

Bidens frondosa L. Infrequent - dry field. Long Island.
23-17

Chrysopsis graminifolia (Michx.) Nutt. Frequent - dry soil.
25-1
Marsh south of headquarters.

Elephantopus carolinianus Willd. Infrequent - damp woods.
23-7,21-2
Long Island.

Erigeron bonariensis L. Common - dry soil. Long Island.
15-6

Erigeron canadensis L. Abundant - dry soil. Long Island.
23-1,17-26

Erigeron divaricatus Michx. Common - dry sand. Marsh south of
19-17
headquarters.

Erigeron ramoeus (Walt.) BSP. Common - dry soil. Marsh south
12-3
of headquarters.

Erigeron vernus (L.) T & G. Uncommon - open, sandy, dry soil.
4-8
Marsh south of headquarters.

Eupatorium aromaticum L. Common - damp soil. Marsh north of
20-21
headquarters.

Eupatorium capillifolium (Lam.) Small. Common - dry soil.
24-10
Long Island.

Eupatorium coelestinum L. Infrequent - damp soil. Marsh north
20-22
of headquarters.

Eupatorium hyssopifolium L. Infrequent - dry soil. Marsh north
24-5
of headquarters.

Eupatorium purpureum L. Infrequent - damp soil. Marsh north of
20-23
headquarters.

Gnaphalium polycephalum Michx. Frequent - dry soil. Marsh
22-13,28-1
north of headquarters.

Gnaphalium purpureum L. Common fairly dry areas. Headquarters yard.
2-20

Hieracium gronovii L. Common - dry soil. Marsh south of headquarters.
17-15, 12-20

Hypochaeris radicata L. Common - dry soil. Marsh south of
7-11
headquarters.

Iva frutescens L. Frequent - damp soil. Marsh north of
20-19
headquarters.

Iva imbricata Walt. Infrequent - dry sand. Front beach.
19-14

Krigia amplexicaulis Nutt. Frequent - damp soil. Marsh north of
14-6,17-22
headquarters.

Krigia virginica (L.) Willd. Infrequent - dry soil. Marsh south
1-3
of headquarters.

Lactuca canadensis L. Common - dry soil. Marsh south of head-
22-2
quarters.

Lactuca villosa Jacq. Common - field edge. Long Island.
4-15

Mikania scandens (L.) Willd. Common - wet soil and emergent.
14-13,5-4
All marshes.

Pluchea camphorata (L.) DC. Abundant - damp soil. Marsh south
20-6
of headquarters.

Pluchea foetida (L.) DC. Infrequent - damp soil. Marsh south of
17-25
headquarters.

Polymnia uvedalia L. Infrequent - dry soil - woods edge.
15-7
Long Island.

Pyrrhopappus carolinianus (Walt.) DC. Few about headquarters
7-22,7-18
yard - dry soil.

Senecio tomentosus Michx. Common - dry sandy areas. Marsh
1-1,2-22
south of headquarters.

Solidago altissima L. Frequent - dry field border. Long Island.
23-9

Solidago erecta Pursh. Frequent - dry soil, woods edges.
28-2
Long Island.

Solidago graminifolia (L.) Salisb. Frequent - pine woods.
28-8
Long Island.

Solidago puberula Nutt. Frequent - dry soil. Marsh north of
20-12
headquarters.

Solidago sempervirens L. Common - dry to slightly moist soil.
22-4,26-3
Marsh north of headquarters.

Solidago tenuifolia Pursh. Abundant - dry soil. Marsh north of
22-12
headquarters.

Vernonia noveboracensis Willd. Common - damp soil. Marsh south
17-24
of headquarters.

APPENDIX II

LITERATURE CITED

Bourn, W. S.

1929. The Destruction of Aquatic Duck Food Plants in Back Bay and Currituck Sound. Trans. 16th Am. Game Confer., pp. 46-54.

1932. Ecological and Physiological Studies on Certain Aquatic Angiosperms Contrib. from Boyce Thompson Institute, Vol. 4 (4), pp. 425-496.

1934. Sea-Water Tolerance of Vallisneria Spiralis L. and Potamogeton Foliosus Raf. Contrib. from Boyce Thompson Institute, Vol. 6 (3), pp. 303-308.

1935. Sea-Water Tolerance of Ruppia Maritima L. Contrib. from Boyce Thompson Institute, Vol. 7 (3), pp. 249-255.

1945. Report on Aquatic Plant Conditions in Back Bay and Currituck Sound, Virginia and North Carolina, Season 1945. Typed Report, USFWS.

Bourn, W. S. and Jenkins, Bernice

1928. Rhizoctonia Disease on Certain Aquatic Plants. Bot. Gaz. Vol. 85, (4), pp. 413-426.

Cahn, A. R.

1929. The Effect of Carp on a Small Lake: The Carp as a Dominant. Ecology Vol. 10 (3), pp. 271-274.

Cottom, C.

1939. Food Habits of North American Diving Ducks. Tech. Bull. No. 643, Bureau Biol. Survey, USDA.

Dozier, H. L.

1947. Salinity as a Factor in Atlantic Coast Tidewater Muskrat Production. Trans. 12th N. A. Wildlife Confer. pp. 398-420.

Dunton, E. M., Jr.

1947. Personal Correspondence.

Egler, F. E.
1942. Check List of Plants of the Seashore State Park, Cape Henry, Virginia. N. Y. State College of Forestry, Syracuse, N. Y.

Ellis, M. M., Westfall, B. A. and Ellis, M. B.
1946. Determination of Water Quality. Research Report 9, USDI, FWS, Govt. Printing Office, Washington, D. C.

Fernald, M. L.
1935. Midsummer Vascular Plants of Southeastern Virginia. Rhodora, Vol. 37, pp. 378-413 and 423-454.

1936. Plants of the Outer Coastal Plain of Virginia. Rhodora, Vol. 38, pp. 376-404 and 414-452.

1937. Local Plants of the Inner Coastal Plain of Southeastern Virginia. Rhodora, Vol. 39, pp. 321-366; 379-415; 433-459; 465-491.

1940. A Century of Additions to the Flora of Virginia. Rhodora, Vol. 42, pp. 355-416; 419-498; 503-521.

1941. Another Century of Additions to the Flora of Virginia. Rhodora, Vol. 43, pp. 485-552; 559-630; 635-658.

1947. Additions to and Subtractions from the Flora of Virginia. Rhodora, Vol. 49, pp. 85-114; 121-141; 145-158; 175-193.

Fernald, M. L. and Griscom, Ludlow
1935. Three Days of Botanizing in Southeastern Virginia. Rhodora, Vol. 37, pp. 129-157; 167-189.

Kearney, T. H.
1901. Report on a Botanical Survey of the Dismal Swamp Region. USDA Contrib. from U. S. Nat. Herb. Vol. 5, pp. 321-585.

Krummes, W. T.
1940. The Muskrat; A Factor in Waterfowl Habitat Management. Trans. 5th N. A. Wildlife Confer. pp. 395-398.

Martin, A. C. and Uhler, F. M.
1939. Food of Game Ducks in the United States and Canada. Tech Bull. No. 634, USDA Bureau Biol. Survey.

McAtee, W. L.
1939. Wildfowl Food Plants, Their Value, Propagation, and Management. Collegiate Press, Inc., Ames, Iowa.

Mosby, H. S.
1946. Reconnaissance Investigation, Back Bay Waterfowl Food Plant Status and Problems, May 15th to September 1st, 1946. Typed Report, Commission of Game and Inland Fisheries, Richmond, Virginia.

Simmons, C. S. and Shulkcum, Edward
1945. Soil Survey: Princess Anne County, Virginia. USDA, Supt. Docu., Washington, D. C.

Stearnes, L. A. and Goodwin, M. W.
1941. Notes on the Winter Feeding of the Muskrat in Delaware. Jour. Wildlife Mgt. Vol. 5 (1), pp. 1-12.

Theroux, F. R., Eldridge, E. F. and Mallman, W. L.
1943. Laboratory Manual for Chemical and Bacterial Analysis of Water and Sewage. McGraw-Hill Book Co., Inc., N.Y.

U. S. Dept. of Commerce Weather Bureau
1947. Monthly Climatological Summary with Comparative Data, Cape Henry Station, Fort Story, Virginia, January-December, 1947.

Whipple, G. C.
1927. The Microscopy of Drinking Water. 4th Ed., Rev. by G. M. Fair and M. C. Whipple. John Wiley and Sons, Inc., New York.

LITERATURE EXAMINED BUT NOT CITED.

Anderson, W. L.
1947. Wet Land, How It Should Be Used. Trans. 12th N. A. Wildlife Confer. pp. 425-429.

Arthur, S. C.
1929. Winter Requirements of Migrating Waterfowl. Trans. 16th Amer. Game Confer. pp. 98-102.

Bartley, A. M.
1943. Utilization of Marsh Resources. Trans. 8th N. A. Wildlife Confer. pp. 38-44.

Bauer, H. L.
1943. The Statistical Analysis of Chaparrel and Other Plant Communities by Means of Transect Samples. Ecology, Vol. 24, pp. 45-60.

Bauman, A. C.
1947. The Effects of Ammonium Sulfamate on Emergent Aquatic Vegetation. Trans. 12th N. A. Wildlife Confer. pp. 346-355.

Beetle, A. A.
1943. A Key to the North American Species of the Genus Scirpus Based on Achene Characters. Amer. Mid. Nat. Vol. 29, pp. 533-538.

Bellrose, F. C., Jr.
1941. Duck Food Plants of the Illinois River Valley. Nat. Hist. Survey Bull. Vol. 21, Art. 8, pp. 237-270.

1944. Waterfowl Hunting in Illinois; Its Status and Problems. Nat. Hist. Biol. Notes No. 17.

1944. Duck Populations and Kill: An Evaluation of Some Waterfowl Regulations in Illinois. Ill. Nat. Hist. Survey, Vol. 23, Art. 2.

1945. Relative Values of Drained and Undrained Bottomland in Illinois. Jour. Wildlife Mgt., Vol. 9 (3), pp. 161-182.

Bennett, L. J.
1938. The Blue-Winged Teal, Its Ecology and Management. Collegiate Press, Inc., Ames, Iowa.

Bourn, W. S. and Cottam, C.
1939. The Effect of Lowering Water Levels on Marsh Wildlife. Trans. 4th N. A. Wildlife Confer. pp. 343-350.

Britton, N. L. and Brown, A.
1943. An Illustrated Flora of the Northern United States, Canada, and the British Possessions. 2nd Ed., 3 Vol., New York Bot. Garden, New York, N. Y.

Buckingham, N.
1946. Problem of Commercialized Waterfowling. Trans. 11th N. A. Wildlife Confer. pp. 66-73.

Canfield, H. L.
1918. The Capture and Marketing of Carp. Eco. Cir. No. 40, Bureau of Fisheries, U. S. Dept. of Commerce.

Cartwright, B. W.
1946. Muskrats, Duck Production, and Marsh Management. Trans. 11th N. A. Wildlife Confer. pp. 454-457.

Chandler, D. C.
1942. Limnological Studies of Western Lake Erie. II Light Penetration and Its Relation to Turbidity. Ecology Vol. 23, pp. 41-52.

Clausen, R. T.
1947. Najas Muenscheri and Other Species of Najas in Eastern Virginia, Rhodora, Vol. 49, pp. 233-236.

Cottam, C.
1934. The Eel-Grass Shortage in Relation to Waterfowl. 20th Amer. Game Confer. pp. 272-279.

1947. Waterfowl at the Crossroads. Trans. 12th N. A. Wildlife Confer. pp. 67-85.

Cottam, C. and Bourn, W. S.
1939. Need Mosquito Control Be Incompatible with Wildlife? Trans. 4th N. A. Wildlife Confer. pp. 121-130.

Cottam, C. and Addy, C. E.
1947. Present Eel-Grass Condition and Problems on the Atlantic Coast of North America. Trans. 12th N. A. Wildlife Confer. pp. 387-398.

Creaser, C. W.
1930. Relative Importance of Hydrogen-Ion Concentration, Temperature, Dissolved Oxygen, and Carbon Dioxide Tension on Habitat Selection by Brook Trout. Ecology, Vol. 11, pp. 246-262.

Day, A. M.
1946. The Problem of Increased Hunting Pressure on Water-fowl. Trans. 11th N. A. Wildlife Confer. pp. 55-65.

Day, D. B.
1934. Lake Erie and Lake Michigan Marshes. Trans. 20th Amer. Game Confer. pp. 29-35.

Elder, W. H.
1946. Implications of a Goose Concentration. Trans. 11th N. A. Wildlife Confer. pp. 441-446.

Fassett, N. C.
1940. A Manual of Aquatic Plants. McGraw-Hill Book Co., New York, N. Y.

Fernald, M. L.
1938. Noteworthy Plants of Southeastern Virginia. Rhodora, Vol. 40, pp. 364-424; 434-459; 467-485.

1939. Last Survivors in the Flora of Tidewater Virginia. Rhodora, Vol. 41, pp. 465-502; 529-559; 564-577.

1942. Seventh Century of Additions to the Flora of Virginia. Rhodora, Vol. 44, pp. 341-404; 416-452; 457-479.

1943. Virginian Botanizing Under Restrictions. Rhodora, Vol. 45, pp. 357-413; 445-480; 485-511.

1944. Setaria Faberii in Eastern America. Rhodora, Vol. 46, pp. 57-58.

1945. Botanical Specialties of the Seward Forest and Adjacent Areas of Southeastern Virginia. Rhodora, Vol. 47, pp. 93-142; 149-182; 191-204.

Glazener, W. C.
1946. Food Habits of Wild Geese on the Gulf Coast of Texas. Jour. Wildlife Mgt., Vol. 10, pp. 322-329.

Hawkins, A. S., Bellrose, F. C., and Smith, R. H.
1946. A Waterfowl Reconnaissance in the Grand Prairie Region of Arkansas. Trans. 11th N. A. Wildlife Confer. pp. 394-402.

Hayden, Ada
1943. A Botanical Survey in the Iowa Lake Region of Clay and Palo Alto Counties. Iowa State College Jour. Sci., Vol. 17, No. 3, pp. 277-416.

Hewitt, O. H.
1942. Management of an Artificial Marsh in Southern Ontario for Ducks and Muskrats. Trans. 7th N. A. Wildlife Confer. pp. 277-283.

Hitchcock, A. S.
1935. Manual of the Grasses of the United States. USDA Misc. Pub. No. 200, U. S. Govt. Printing Office, Washington, D.C.

Hochbaum, H. A.
1944. The Canvasback on a Prairie Marsh. The American Wildlife Inst., Washington, D. C.

1946. Recovery Potentials in American Waterfowl. Trans. 11th N. A. Wildlife Confer. pp. 403-418.

Howard, W. J.
1940. Wintering of the Greater Snow Goose, The Auk, Vol. 57.

Hunt, K. W.
1943. Floating Mats on a Southeastern Coastal Plain Reservoir. Bull. Torrey Bot. Club, Vol. 70, pp. 481-488.

1947. The Charleston Woody Flora. Amer. Mid. Nat. Vol. 37, pp. 670-756.

Johnson, A. M.
1931. Taxonomy of the Flowering Plants. The Century Co., New York, N. Y.

Kortright, F. H.
1943. The Ducks, Geese, and Swans of North America. The American Wildlife Inst. Washington,D. C.

LaMotte Chemical Products Co., Towson 4, Baltimore, Maryland
1944. The ABC of pH Control, A Handbook of LaMotte Chemical Control Units for Science and Industry.

Low, J. B.
1947. Review of New Techniques - Waterfowl. Trans. 12th N. A. Wildlife Confer. pp. 339-345.

Low, J. B. and Bellrose, F. C., Jr.
1944. The Seed and Vegetative Yield of Waterfowl Food Plants in the Illinois River Valley. Jour. Wildlife Mgt. Vol. 8, pp. 7-22.

Lutz, H. J. and Chandler, R. F., Jr.
1946. Forest Soils. John Wiley and Sons, Inc., New York.

Lynch, J. L., O'Neil, T. and Lay, D. W.
1947. Management Significance of Damage by Geese and Muskrats to Gulf Coast Marshes. Jour. Wildlife Mgt., Vol. 11, pp. 50-76.

Massey, A. B.
1944. The Ferns and Fern Allies of Virginia. Bull. of VPI, Vol. 37, No. 7.

1945. Native Grapes. Bull. of VPI, Vol. 38, No. 9.

Massey, A. B. and Ball, C. R.
1944. The Willows of Virginia. Bull. of VPI, Vol. 37, No. 9.

McAtee, W. L.
1915. Eleven Important Wild-Duck Foods. USDA Bull. No. 205.

1941. Wildlife of the Atlantic Coast Salt Marshes. Wildlife Cir. 11, USDI, FWS, Govt. Printing Office, Washington,D.C.

Moyle, J. B.
1945. Some Chemical Factors Influencing the Distribution of Aquatic Plants in Minnesota. Amer. Mid. Nat. Vol. 34, pp. 402-420.

Moyle, J. B. and Hotchkiss, Neil
1945. The Aquatic and Marsh Vegetation of Minnesota and Its Value to Waterfowl. Tech. Bull. No. 3, Minn. Dept. of Conservation.

Muenscher, W.C.
1936. Keys to Woody Plants. Published by the Author, Ithica,N.Y.

1944. Aquatic Plants of the United States. Comstock Publishing Co., Inc., Cornell University, Ithica, N. Y.

Nichols, G. E.
1930. Methods in the Floristic Study of Vegetation. Ecology, Vol. 11, pp. 127-135.

Oosting, H. J. and Billings, W. D.
1942. Factors Effecting Vegetational Zonation on Coastal Dunes. Ecology, Vol. 23, pp. 131-142.

Penfound, Hall, and Hess
1945. The Spring Phenology of Plants In and Around the Reservoirs in North Alabama with Particular Reference to Malaria Control. Ecology, Vol. 26, pp. 332-352.

Penfound, W. and Hathaway, E. S.
1938. Plant Communities in the Marshlands of Southeastern Louisiana. Ecological Mono. Vol. 8, pp. 1-56.

Pirnie, M. D.
1935. Michigan Waterfowl Management. Game Div., Dept. of Conser., Lansing, Michigan.

1941. Muskrats in the Duck Marsh. Trans. 8th N. A. Wildlife Confer. pp. 308-312.

Robinson, B. L. and Fernald, M. L.
1908. Grays's New Manual of Botany, 7th Ed., American Book Co., New York, N. Y.

Rickett, H. W.
1920. A quantitative Survey of the Flora of Lake Mendota. Abstract in Science, N. S. Vol. 52, pp. 641-642.

1924. A quantitative Study of the Larger Aquatic Plants of Green Lake, Wis. Trans. Wisc. Acad. Sci. Arts and Litrs., Vol. 21.

Schuette, H. A. and 'Alder, Hugo
1922. Notes on the Chemical Composition of Some of the Larger Aquatic Plants of Lake Mendota, II Vallisneria and Potamogeton. Trans. Wis. Acad. Sci., Arts and Ltrs.

1928. III Castalia Odorata and Najas Flexilis. Trans. Wis. Acad. Sci., Arts and Ltrs.

Smith, R. H.
1942. Management of Salt Marshes on the Atlantic Coast of the United States. Trans. 7th N. A. Wildlife Confer. pp. 272-277.

Smith, E. V. and Swingle, H. S.
1941. The Use of Fertilizer for Controlling the Pondweed Najas Guadalupensis. Trans. 6th N. A. Wildlife Confer. pp. 245-251.

Sperry, C. C.
1947. Botulism Control by Water Manipulation. Trans. 12th N. A. Wildlife Confer. pp. 228-232.

Surber, E. W.
1943. Weed Control in Hard-Water Ponds with Copper Sulfate and Sodium Arsenate. Trans. 8th N. A. Wildlife Confer. pp. 132-140.

Taylor, H. F.
1917. The Carp: A Valuable Food Resource. Eco. Cir. No. 31, Bureau of Fisheries, Dept. of Comm.

Uhler, F. M.
1944. Control of Undesirable Plants in Waterfowl Habitats. Trans. 9th N. A. Wildlife Confer. pp. 295-303.

Uhler, F. M. and Cottam, C. E.
1935. Mosquito Control and Its Effect on Wildlife. Trans. 21th Amer. Game Confer. pp. 291-294.

Wells, B. W.
1928. Plant Communities of the Coastal Plain of North Carolina and Their Successional Relations. Ecology, Vol. 9, pp. 230-242.

1946. Vegetation of Holly Shelter Wildlife Management Area. N. C. Dept. Conser. and Devel., Div. of Game and Inland Fisheries. State Bull. No. 2, P-R Series 1.

Wells, B. W. and Shunk, I. V.
1931. The Vegetation and Habitat Factors of the Coarser Sands of the North Carolina Coastal Plain: An Ecological Study. Ecol. Mono. Vol. 1, pp. 465-520.

Wherry, E. T.
1927. Divergent Soil Reaction Preference of Related Plants. Ecology, Vol. 8, pp. 197-206.

Wiebe, A. H.
1941. Density Currents in Impounded Waters - Their Significance from the Standpoint of Fisheries Management. Trans. 6th N. A. Wildlife Confer. pp. 256-265.

1942. The Rough Fish Problem in TVA Waters. Trans. 7th N.A. Wildlife Confer. pp. 410-416.

1946. Improving Conditions for Migratory Waterfowl on TVA Impoundments. Jour. Wildlife Mgt. Vol. 10, pp. 4-8.

Wiebe, A. H. and Hess, A. D.
1944. Mutual Interests of Wildlife Conservation and Malaria Control on Impounded Waters. Jour. Wildlife Mgt. Vol. 8, pp. 275-283.

Wing, L. W.
1937. Cycles of Water-Levels. Trans. 2nd N. A. Wildlife Confer. pp. 346-379.