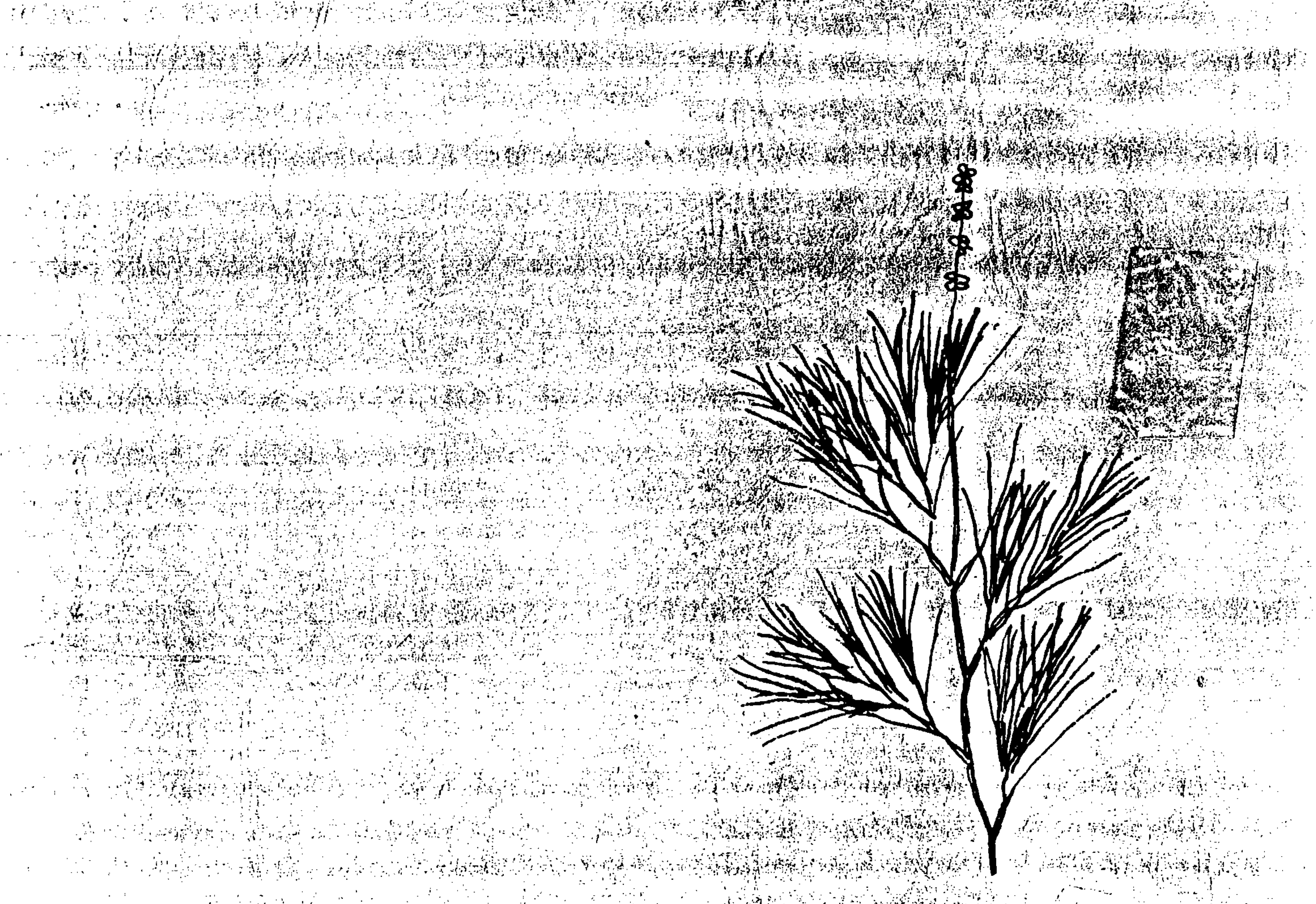
BACK BAY-CURRITUCK SOUND DATA REPORT



Introduction and Vegetation Studies

COOPERATIVE STUDIES 1958 - 1964

BY: BUREAU OF SPORT FISHERIES AND WILDLIFE
NORTH CAROLINA WILDLIFE RESOURCES COMMISSION
VIRGINIA COMMISSION OF GAME AND INLAND FISHERIES

Back Bay-Currituck Sound Study-Personnel

The following study personnel most directly contributed to conduct of the study. Those marked with an asterisk contributed narrative or final tables for this report.

John L. Sincock*, Chief, Section of Wetland Ecology, U. S. Fish and Wildlife Service - served as Chief Biologist and Coordinator of the study, 1958-1965.

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Robert E. Wollitz*, Fisheries Biologist, Virginia Commission of Game and Inland Fisheries, assigned to the study, 1959-1962.

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Back Bay-Currituck Sound Coordinating Committee

The following persons served at one time or other on the 6-man coordinating committee which reviewed general needs, conduct and news releases of the study.

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Back Bay-Currituck Sound Data Report-Introduction and Vegetation Studies - Volume I

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INTRODUCTION

The factors affecting the brackish to freshwater estuaries of Back Bay, Virginia, and Currituck Sound, North Carolina, have been a subject of considerable controversy for almost half a century. The primary concern has been a reported decline in waterfowl use of the area. The reason most frequently suggested for that decline has been a reported decrease in production of waterfowl foods, particularly the submerged aquatic species. There is concern also for the preservation of the fine freshwater fisheries of the area.

No less than 50 reasons for the present conditions have been suggested, several of which seemed plausible. Studies of certain environmental conditions have been conducted sporadically for short periods in the past, but an aura of indefinite explanations shrouded this complex ecological problem. The controversy continued. No complete documentation of all the principal components of the existing waterfowl and fish habitat, the fish and waterfowl populations, nor major factors affecting the ecology of the area was done prior to the initiation of this study.

None of the previous studies inquired deeply into the needs, food requirements, and carrying capacity of the habitat for waterfowl and fish. They were primarily oriented to physiological studies of the plants.

Herein- is the reason for this study and this "basic data" report--To document these factors as fully and as accurately as possible with the hope of answering three basic objectives.

(1) To identify the primary physical, chemical, and biological factors responsible for the reduction in waterfowl use of the Back Bay-Currituck Sound Area.

(2) To determine procedures for increasing waterfowl use of the area while retaining or improving fishery values.

(3) To determine the feasibility of applying these procedures on an operational basis.

This voluminous data report <u>is not</u> a publication. These data will be prepared for publication within a few months' time. The data report merely overcomes one of the obvious objections to past studies of the area--that basic data could not be found for reinterpretation or historical record. Some repetition will be found, and the narrative should be considered for what it is--a very rough, incomplete, first-draft. The data have not all been fully analyzed, nor have varying interpretations of the investigators and their agencies been fully resolved.

The four volumes in this data report are entitled Introduction and Vegetation Studies, Waterfowl Studies, Fish Studies, and Environmental Factors.

Neither pages nor tables have been numbered in this report and it is necessary to refer to the rather gross table of contents on specific subjects.

ORGANIZATION OF THE STUDY

The study was conducted by fish and waterfowl biologists of the U.S. Fish and Wildlife Service, the North Carolina Wildlife Resources Commission, and the Virginia Commission of Game and Inland Fisheries. The overall scope and administrative coordination of the study were the responsibility of a six-man committee, represented by two persons from each of the three agencies. This Back Bay-Currituck Sound Coordinating Committee generally met twice a year to review general progress and needs of the five to six man study team of biologists. The chief Federal biologist assigned to the study served-as principal investigator and coordinator of the study.

Certain facets of the study were started in May 1958; however, several months elapsed before complete studies were designed and the study was reasonably well staffed.

Although full staffing of a waterfowl biologist and a fisheries biologist from each of the 3 agencies was never fully achieved, the work from 1958 through 1964 represents approximately 36 man-years of effort.

Most aspects of the study were terminated in January 1962 after almost 4 years of studying the area under the prevailing fresh to slightly brackish water conditions. On March 7, 1962, the so-called "Ash Wednesday" Storm, one of the worst to ever hit the Atlantic Coast, forced ocean water across the narrow barrier beach and increased the salinity of the freshwaters to a degree that was being considered for recommended management---13 percent of sea strength.

As one biologist expressed it: "It was an opportunity that comes once in a lifetime--to have 4 years' prior data, your recommendation fulfilled by natural events, and to follow up on the results." Naturally, the study was continued in almost full detail through April 1964. Certain primary studies will be continued indefinitely to monitor more recent management of the area by pumping of ocean water into Back Bay, which was started in May 1965.

Throughout its stormy and sometimes dubious history, certain "coincidences" have beclouded any easy identification of cause and effect relationships. This difficulty has not dissuaded most persons from conjecture nor conclusions.

Similarly, the memories of specific conditions in former years by long-time residents were invaluable for overall understanding of the current complaints.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
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September 10, 1969

Office of Conservation Education
Bureau of Sport Fisheries and Wildlife
U. S. Department of the Interior
Washington, D.C. 20240

Gentlemen:

We have a preliminary 4-volume typed report entitled "Back Bay - Currituck Sound Data Report," which was released jointly by the Bureau of Sport Fisheries and Wildlife and the states of Virginia and North Carolina in 1965-1966. The authors promised that a revised condensation of the report would be published as a number of the Special Scientific Report series. If the revised report has been issued, please send us one copy of it.

Also, please send us one copy of Resource Publication No. 55 (RP-55) "Suitability of the Susquehanna River for Restoration of Shad," and the latest cumulative list of in-print publications distributed by your office,

Sincerely,

L. Ruggles Porter, Jr.

L. Ruggles Porter, Jr.
Supervisor

Not issued

SC Pub

However, these "recalled" data were often too poorly known in the first place to be of much use in reconstructing a factual account of the history of vegetation, fish, or waterfowl abundance.

Certain sources of data were found that enlightened our understanding of the area. Among the more important were the publications of Critcher, Chamberlain, and Bourn, the hunting club records of waterfowl kill, certain records and correspondence of the Corps of Engineers, monthly salinity records from 1924-1937 by the Back Bay Protective Association, certain early vegetation maps by Hotchkiss, and miscellaneous records of the River Basins Office of the U.S. Fish and Wildlife Service in Raleigh, North Carolina.

While many ecological explanations still elude us, the presentation of these data serves to establish a quantitative record for the first time; perhaps, to be of ultimate value in the future.

LOCATION OF FIELD STATIONS

Two field stations were maintained in the area throughout the study; one was located at the Virginia Game Commission Warden's Headquarters on Back Bay near Nawney Creek, and the other was on the causeway to Churchs Island in Currituck Sound. The seaplane belonging to the Virginia Game Commission was available for aerial inventories of waterfowl, marsh mapping, boat counts, etc.

MAJOR ENVIRONMENTAL CHANGES IN THE AREA

Dunbar (1956) presents a map showing the period during which four inlets were open into Currituck Sound. These were: (1) Musketo (1585-1671), (2) "Old" Currituck (1585-1731), (3) Carthys (or Caffey's) (1585- ? and 1798-1811), and (4) New Currituck (1713-1828).

The last inlet into Currituck Sound closed in the period 1828 to 1830. After that time salt water entered the area only from the Albemarle and Chesapeake Canal, from the south end of Currituck Sound, and occasionally directly across the low lying barrier beach during storms. A more detailed account of the history of salinity in the area will be given in the discussion of water chemistry, but briefly, since 1830 the area has changed from a saline condition to a brackish condition, and since the late 1930's some upper reaches have been virtually fresh. Some reports near the turn of the century refer to certain portions of the area as fresh. However, one should consider that most people can not detect salt much below 7 percent of sea strength, and these references based on taste may have misrepresented the facts.

During the period 1914 to 1919 an estimated 10 million cubic yards of bottom were dredged from the A and C Canal and the North Landing River. Dredging of certain marshes and canals was conducted in Back Bay from 1923 to about 1926. Dredging activities in the general vicinity of the North Landing River and Currituck Sound;

BACK BAY - CURRITUCK SOUND DATA REPORT

Introduction and Vegetation Studies, Volume 1.

This data report is one of four volumes of data and preliminary analysis of data on the cooperative study of the ecology of Back Bay, Virginia, and Currituck Sound, North Carolina, from 1958 through 1964. Other volumes soon to be released present data on waterfowl studies, fish studies, and environmental factors.

This report is not a publication. Subsequent publication will be made of a condensation of these four volumes in the U. S. Fish and Wildlife Service Special Scientific Report Series.

December 1965

have been conducted every 2 to 4 years since 1923, although not as great as in the period 1914 to 1919. In Back Bay, filling of the Sandbridge Marshes at the northern end of the area was started in 1963 and has continued through 1965.

In addition to these major dredging activities, many hundreds of miles of lateral farm ditches now connect with the Back Bay-Currituck Sound Area.

The turbidity of the waters of Back Bay and Currituck Sound was apparently never quantitatively determined prior to Bourn's study of the area from 1926 through 1930. Several references mention the clearness of the water in the period prior to the extensive dredging activities. Bourn (1932), however, described the waters as extremely turbid and concluded: "The results of field determinations and' laboratory experiments show conclusively that the turbidity of the waters of Back Bay and Currituck Sound has probably been the chief factor responsible for the destruction of the submerged seed plants."

Chamberlain (1948) studied the Back Bay area in 1947 and he also described the waters as very turbid and concluded that turbidity was the primary factor limiting aquatic growth.

The A and C Canal (part of the Intracoastal Waterway), which was constructed by a private company in 1859, connects Norfolk Harbor with the North Landing River. In 1912 the Federal Government purchased this canal and the lock at Great Bridge, Virginia. After April 1, 1917, the lock was left open and not operated until new locks were constructed and put into operation on August 10, 1932. Bourn (1929 and 1932) stated that during that time "salty, polluted, turbid water flowed into Currituck Sound." After reconstruction of the locks this water no longer entered the area.

Chamberlain (1948) mentioned that the causeway between the mainland and Knotts Island was built in the latter part of the last century, which prevented exchange of water between Back Bay and the North Landing River, until Corey's ditch was put in, about 1915. Bourn, however, referred to construction of the causeway in the'early 1920's.

The completion of sand fences, or man-made sand dunes on the beach, between 1933 and 1935, further prevented the entrance of salt water into Back Bay and northern Currituck Sound.

However, in the period 1951 to 1955 small quantities of ocean water reportedly came across a low place in the beach opposite Monkey Island in Currituck Sound.

The first major introduction of ocean water since the mid-1930's occurred on March 7, 1962, when an extra-tropical storm hit the coast.

HISTORICAL ACCOUNTS OF CHANGES IN HABITAT AND WILDLIFE VALUES

It is not knownwith certainty whether waterfowl use of the area increased significantly after the closing of the Currituck Inlet in 1830. No doubt the area had certain waterfowl values as well as salt-water fishing values, even when strongly saline. The submerged aquatic vegetation prior to 1830 most certainly was different, and probably was composed of eelgrass (Zosteramarina), widgeongrass (Ruppia maritima), muskgrasses (Chara spp.), and possibly marine algae. The marsh vegetation probably was predominantly composed of brackish water species, e.g. needlerush (Juncus roemerianus), saltmarsh cordgrass (Spartina alterniflora), saltgrass (Distichlis spicata), saltmeadow cordgrass (Spartina patens), and was less productive for waterfowl and muskrats than it is now.

Forrest (1853) stated that the shores of the sound were "very remarkable for extensive fishing operations" and apparently greatest at the inlet. Dunbar (1956) stated that "with the freshening of the sound, the saltwater fish disappeared and freshwater fish took their place.

Market hunting for waterfowl became a leading occupation after the Civil War and continued until 1918, when the Migratory Bird Treaty Act made the sale of migratory waterfowl illegal.

Although no quantitative estimates of fish, waterfowl, or vegetation can be found much before 1930, there can be no doubt that the Back Bay-Currituck Sound Area was a principal wintering ground for waterfowl by the middle of the last century. The area still should be regarded as one of the most valuable water-fowl habitats on the Atlantic Coast.

Weiland (1897) in a paper aptly entitled "Currituck Sound, Virginia and North Carolina--A Region of Environmental Change," stated: "One of the most important geological changes which has taken place along the Atlantic coast in recent time was the closing up of the Currituck Inlet, North Carolina, by drifting sands in 1828. Previous to that year this inlet formed such a passage from the ocean through a narrow outer beach into the waters of Currituck Sound as is formed by either the new or Ocracock Inlet to Pamlico Sound now. With the closing of the Currituck Inlet there was the conversion of upwards of one hundred square miles of shallow salt to brackish water area to fresh water; and it is within the memory of men now living that the resultant changes were immediate and striking.

"Previously the sound had been a valuable oyster bed. Within a few years the oysters had all'died out and their shells may now be seen in long rows where they have been thrown out in the dredging for a boatway in the Coinjock Bay, a southwestern extension of the Sound. Further, there were such changes in vegetation as brought countless thousands of ducks of species that had been only occasional before. The salt water fishes were driven out and fresh water fishes took their place."

In 1909, McAtee (1917) made some of the first recorded observations on the vegetation in Currituck Sound. He stated that sago pondweed (Potamogeton pectinatus) was the dominant plant and extremely abundant; bushy pondweed (Najas flexilis) (possibly N. puadalunensis) and wildcelery (Vallisneria spiralis) (now Vallisneria americana) were abundant; redheadgrass (Potamogeton perfoliatus) was common; widgeongrass (Ruppia maritima) was scattered; and leafy pondweed (Potamogeton foliosus) was scarce in the Sound. Chara spp. blanketed the bottom of almost the whole of Currituck Sound.

Although the correspondence about the demise of the "grass" after 1918 is staggering, it seldom distinguishes the types of plants. Even today many residents of the area do not know most of the common aquatic plants.

Jadwin (1929) in Senate Document No. 23 stated that it was reported that "migratory birds have been reduced in Currituck Sound" and further that "the fresh fish catch in Currituck Sound is reported to have dropped from 2,000,000 pounds in 1920 to 300,000 pounds in 1927."

O'Conner (1929) presented testimony at this same Senate Hearing that summarized the opinion of those questioned that': "There has been a steady, progressive diminution in the number of ducks in Back Bay since about 1920, and it is the opinion of those questioned that the decrease is due to, and compares with, the decrease in the amount of duck food. The decrease in the number of ducks in the south part of Currituck Sound or lower Currituck Sound, as it is called, has not been so great, and information has been given that they were present in as great numbers.. as ever, but that the duck food was scarce and the ducks apparently went somewhere else to feed...."

Jewett (1929) submitted further testimony at the hearing that: "In Currituck Sound and Back Bay during the hunting season of 1926-27, while the hunting was reported as only fair or poor during the early part of the season, during the latter part of the season it was reported that ducks were more plentiful in Currituck Sound than they had been for many years, and the season ended with many very good bags.'" He made reference to the fact that the opposite opinion could likewise be found among some residents.

In April 1951, 25 long-time residents of Back Bay-Currituck Sound Area sent notarized letters to the District Engineer, U.S. Army Corps of Engineers in Norfolk pertaining to their long-time observations of changes in the habitat and the fish and waterfowl populations. The theme of all these letters deplored the prevailing waterfowl, fish,and habitat conditions at that time and related the former, better conditions that existed in the era 1900 to 1935. These letters frequently referred to the destruction of aquatic vegetation by dredging activities, and also to the better conditions that existed prior to exclusion of the ocean water by the sandfences.

Several interesting opinions are contained in these letters:

(1) One states that 21 years ago [1930] the water in front of his home on the North Landing River looked like an alfalfa field. "Ducks and geese were so thick in those days that when they flew over they gave the appearance of clouds."

(2) A letter from a former Coast Guardsman refers to the ocean water flow across the barrier beach causing him to miss patrols prior to 1924 and he states: "The general effect of the salt water on the grass was definitely very favorable since it would grow back to its normal thickness the following summer. Generally speaking, I have seen the grass in the middle of Back Bay so thick that yellow shanks walked on top of it the same as if they were on land. There is no grass growing in the bay at the present time and the water opposite....Morse's Point, Currituck Sound, N. C., is fresh enough that I could drink it." He further mentioned the tremendous reduction in waterfowl and estimated less than 5 percent geese and 2 percent of most species of ducks in comparison' to 35 to 40 years ago [1911-1916].

(3) Another letter states that before 1924: "The grass, sago. and wildcelery, was so thick that before the hunting seasons we would make several trips using a battery boat which had a big wheel on her, to make a path for the little boats to go in and out. Also before 1924 there were about 200 people fishing plenty of the time in the sound and bay. At that time they were known to catch such fish as flounder, a few spot, croakers, and trout." This letter also mentions that "people in this area have always been bothered occasionally by high water--even twenty-five to fifty years ago--but the water did not do so much damage because the waters did not stay as high as long."

(4) Another Coast Guardsman, who patrolled the beach from Cape Henry to Hogs Head during his tenure, stated: "Regular fall north-easters used to bring salt water from the ocean into Back Bay and Currituck Sound three or four times a year between 1902 and 1920." He expressed the belief that the salt water improved the growth of aquatic vegetation and based his conclusion partly on the fact that aquatics grew in the North Landing River near Munden, Virginia, during the time the locks were out at Great Bridge, stating further that the "grass" disappeared when the water became fresh.

(5) A letter from a 74-year-old man in 1951 stated "that some time during the fall and winter of three years in succession--1893, 1894, 1895, severe storms brought so much salt water in the big bay [Back Bay Area] that the grass was killed near that shore, but within one year it had grown back to almost the same as before the three storm years."

(6) A 66-year-old minister, who earlier had engaged in farming and fishing, recounted the former abundance of grass, waterfowl, and bass. He stated: "A lot of dredging some years ago caused the

water to become muddy and thick and helped kill the grass, and then the absence of salt water caused by the building of the lock at Great Bridge had the final damaging effect." He mentioned that in his young days "there were 32 fishing crews working and at times they averaged about 1,000 lbs. per week per crew."

(7) One letter from a 77-year-old man in 1951 mentioned a crab factory at the site of his home at Williams Landing when he was a young boy.

The average age of these life-long residents who wrote in 1951 was 67 years.

In the absence of specific data on the waterfowl and fish populations and the abundance of aquatic vegetation, those observations by life-long residents, who had made their living from fishing and hunting, should receive due consideration. The consensus of their observations would be interpreted by all as relating the following:

(1) Waterfowl, bass, and aquatic vegetation were relatively scarce in 1950-51. Carp were more abundant than formerly; the waters were fresh and turbid.

(2) Waterfowl, bass, white and yellow perch, flounder, spot, rock, croakers, and trout were far more abundant prior to 1924, and apparently prior to 1935 than in 1951.

(3) They strongly believed that the exclusion of salt water by construction of the sandfences prior to 1935, and the restoration of the locks in the A and C Canal, were instrumental in destruction of the aquatic vegetation.

(4) They further, almost to a man, contended that the private dredging in the marshes and governmental dredging in the A and C Canal were the cause of the turbidity that they contended destroyed the vegetation. They contended that the turbidity was made worse when the waters freshened.

(5) The numerous references to salt water entering across the beach around the turn of the century, and frequently thereafter until completion of the sandfences, imply that the waters were brackish at times, even though other incidental reports referred to the waters as fresh.

(6) Vegetation reportedly did grow in the deeper portions of Back Bay, and in the North Landing River there was vegetation until restoration of the locks at Great Bridge in 1932.

Mr. C. C. Sperry, Assistant Biologist of the Bureau of Biological Survey, inspected duck food conditions in October 1924 and reported the following:

Back Bay, Virginia

"Aquatic Vegetation. By far the greater part of the open water in Red Head Bay, Sandy Bay, and Big Bay was entirely bare of submerged plant growth. A good stand of sago pondweed (Potamogeton pectinatus), locally known as old-fashioned Bay grass, was seen in the southern end of the great Narrows while scattering plants of sago as well as of widgeon grass (Ruppia maritima), and bushy pondweed (Naias flexilis)-- mostly young growth, were found in the lower end of North Bay. A few plants of the above kinds together with some of wild celery(Vallisneria spiralis) and coontail (Ceratophyllum demersum) also were observed at the mouth of Nawney Creek. In the shoal water bordering Ragged Island a young growth of sago, celery, and widgeon grass extended some 50 yards out into the open water while one of the Ragged Island ponds contained a good stand of these 3 plants mixed with bushy pondweed and redhead grass (Potamogeton perfoliatus)--locally known as Turkle grass; the sago, widgeon grass, and redhead grass bore mature seeds.

"The bottom was a mixture of soft mud and sand in most of North Bay, Red Head Bay, and Big Bay but farther to the east it was harder and mostly sand.

"Theories to explain the cause of scarcity of vegetation were plentiful and varied. The following 'explanations' will be discussed in the order named:

1. Water too salt.
2. Water too fresh.
3. Vegetation destroyed by carp.
4. Water stagnant, due to Knotts Island causeway.,
5. Pollution from inlet streams.

Currituck Sound, North Carolina

"Aquatic vegetation was abundant over practically the entire Sound being less plentiful, of course, in the main channels and totally lacking on some of the hard sandy shoals. Sago pondweed was by far the dominant plant in the Sound. It was found widely distributed both in deep and shoal water, on mud or sandy bottom, in open and in protected bays; often the plants were close enough to the surface to make the water smooth or 'slick' over considerable area. Patches of sago bearing a good crop of seed were frequent.

"Widgeon grass was locally abundant in almost pure stands and occurred in scattering quantity over most of the Sound but its proportion to sago was probably as low as 1 to 10. Mature fruit was present although plants in flower or bearing immature fruit were the general rule.

"Musk grass (*Chara* spp.) was present over much of the bottom of the Sound, forming a carpet 3 or 4 inches in depth in some of the bays. Oogonia were numerous.

"Bushy pondweed was nowhere abundant or even common although its distribution was quite general. Most of the plants were young and tender; no seeds were found.

"Redhead grass was scarce everywhere I went and nearly all plants seen were young. However, the guides reported beds of some size in landward protected bays.

"Wild celery was locally abundant in large beds--usually in shoal water, and was common as a'shallow water plant along some of the island shores but was scarce or absent throughout the great expanse of open water. It was especially rare toward the southern end and also along the eastern side of the Sound. Young plants were plentiful on the bars formed in dredging channels. Seed pods containing immature fruit were abundant in the big beds while most of the celery fringing the shore was composed of young plants. Celery plants, entire and fragmentary, were scattered over the water's surface and windrows of them were banked along the wave washed shores but no other plant was thus washed up in quantity.

"Barnacles were present but much less numerously than in Back Bay.

"Carp were reported to be more than plentiful and natives blamed them for the floating celery as a like condition prevailed throughout the summer when there were no geese or diving ducks present."

H. P. Baily of New York in a letter dated December 15, 1924, reported no "grass" at all in lower Back Bay, that the water was salty, fishing nearly destroyed, and that ducks were few.

Sperry again inspected the Back Bay-Currituck Sound Area from August 16 to August 20, 1926, in response to claims of rotting of duck foods in Back Bay, Virginia. His field report mentioned the following: "The waters were high. The water in Back Bay was everywhere fresh to the taste. The water in Currituck was more brackish than in Back Bay yet not disagreeable to the taste although a sample from near the south end of Knotts Island tested ten percent sea water. In Back Bay there were praticaIly no submerged plants in the deeper water except in sections of North Bay and even there the growth was restricted to a patchy carpet of young plants of *Naias flexilis*. The few plants of wildcelery and widgeongrass observed were likewise very young and only a few inches in length. No sago pondweed or redheadgrass was seen. Further search in Ships Bay, Redhead Bay, Sand Bay, and most of Big Bay revealed only an occasional submerged plant. One little patch of sago and widgeongrass, possibly two or three acres in extent, was located in Big Bay (just north of Pellitory Point) but the brown and unhealthy appearing plants held a very poor crop of matured seeds. Some of the island ponds supported a good growth of sago, widgeon, Naias, and celery while on shoals, e.g. near the island shores, along the sandy beach, bordering the channel through the Great Narrows, and in the inland coves there was a narrow fringe of submerged plant growth,. chiefly sago, some of which was well seeded."

Sperry reported that grass was plentiful in upper Currituck and he saw "several large beds of various species of submerged plants, although the water was so high that few 'slicks' were in evidence." He stated that "reports from the sound were that the grass was 'beautiful' and 'it's the best grass we've had in ten years'." He concluded, however, that: "Duck food plants in Back Bay and upper Currituck Sound, are in very unhealthy condition. Sago is probably in the worst shape but widgeongrass and redheadgrass also are in a bad way. Wildcelery and bushy pondweed are not much affected while muskgrass is undamaged."

Sperry mentioned long slicks of redheadgrass immediately east of the north end of Churchs Island. He mentioned that bushy pondweed was not abundant in either Back Bay or upper Currituck and implied that it was relatively new to the area. He mentioned also the silicate remains of hydroids, particularly on sago pondweed, a root rot, and another malady in the form of loss of vitality of leaves when the roots were seemingly not affected. He concluded that: "Salt water is certainly not the direct cause of damage for sago and widgeongrass, plants which ordinarily withstand a high concentration of salts, are the ones most affected." Because the diseased plants were noticed to be first affected near the mouth of the North Landing River he stated "the logical conclusion is that the pollution, or whatever. is causing the trouble comes into the sound via the Chesapeake and Albemarle Canal.

Bourn's study from 1926 to 1930 was the first major investigation of the aquatic plants of the area. In 1932, he presented a list of the aquatic plants in order of abundance as follows: "Sago pondweed dominant and comprising over 60 percent of the total aquatic plant growth; bushy pondweed, wildcelery, redheadgrass, widgeongrass, coontail (Ceratophyllum demersum), and leafy pondweed. In addition to the seed plants, Chara spp. and Nitella spp. occurred in appreciable quantities in North Bay and along a few sandy shores."

Bourn (1932) made a few general statements about plant abundance as follows: "In 1926 the larger and deeper parts of Currituck Sound and Back Bay, constituting about two-thirds of the total area, were barren. The growth of submerged angiosperms was limited mainly to the waters of North Bay, the southern part of Currituck Sound, the shallow coves and the margins of the larger bodies of water, and the ponds and ditches in the marshes. Plants had disappeared from the main and deeper parts of Back Bay and Currituck Sound."

Bourn (1932) further stated: "At the end of 1929, however, about 90 percent of the total water area was observed to be barren of seed plants. The relatively small quantities of plants, the most important of which were Potamogeton pectinatus, L. [sago pondweed], Potamogeton perfoliatus, L. [redheadgrass], and Ruppia maritima, L. [widgeongrass] remaining at that time was limited to clear, shallow waters in relatively isolated sections along the shores of the larger bodies of water."

No reasonably reliable estimates of waterfowl populations could be found prior to the midwinter inventories in 1937, but the hunting club records attest to extensive waterfowl use of the area even during periods when complaints about destruction of the habitat were occurring in the 1920's.

Mr. W. L. McAtee (1927) conducted a field inspection of Back Bay and Currituck Sound during the period November 20-23, 1927, and reported as follows:

Back Bay, Va.

"Food conditions. - To show the'extent to which inspection was carried, localities visited will be mentioned in detail; a summary to be presented later.

"Back Bay proper from Public Landing some miles northward; has plenty of sago pondweed.

"Redhead Bay: - A stretch of water with chiefly hard sand bottom, that never has had a good stand of wild duck foods has only a little sago pondweed now.

"Great Narrows: - The southern end has some wild celery, bushy pondweed, musk grass and sago pondweed.

"Ship's Bay: - Here plenty of bushy pondweed, musk grass, and sago pondweed were found, together with some wild celery.

"North Bay: - Much bushy pondweed, some sago pondweed and a little wild celery were found.

"Sand Bay: - Traces of sago pondweed and wild celery found but the bottom mostly bare as always so far as my knowledge goes.

"Cedar Island Channel: - Plenty of well developed sago pondweed here.

"Capps's Creek Slough: - Contained much musk grass, and bushy pondweed, besides plenty of healthy sago pondweed.

"Buzzard's Bay: - Reported by Mr. Bourn of the Boyce-Thompson Institute to have widgeon grass and sago pondweed common, also some wild celery.

"Batteries: - On Nov. 21 the following numbers of battery rigs were observed, Back Bay 9, North Bay 5, and Sand Bay and Cedar Island Slough 12, a total of 26. None appeared to be violating the 700 yard provision.

"Wildfowl seen: - November 20, a rest day, and therefore better for observing the birds, the following migratory game birds (approximate numbers) were seen on Back Bay as a whole: Swans 300, geese 3000, canvasbacks 2000, Marila sp. 500, ruddy ducks 1200, wigeon 4000, pintails few, black ducks few, coots 5000.

Currituck Sound, N. C.

"Food conditions: - Reported on by separate localitites summarized later.

"Mouth of Albemarle and Chesapeake Canal; nothing.

"About 1/2 mile from mouth of canal toward Mackay Island: - There is a little bushy and sago pondweed, mostly rotted.

"About 1 mile from mouth of canal: - The sago pondweed is somewhat better and a little redhead grass, bushy pondweed, and wild celery were found.

"About 2 miles from mouth of canal; - Some rotted wild celery and sago pondweed were found.

"Near mouth of Back Creek: - Here there is considerable drainage from marshes, and the sago pondweed, and some redhead grass and wild celery looked good.

"Near mouth of Indian Creek: - Sago and bushy pondweeds were fair in amount conditions.

"The Lump: - [Between Churchs and Knotts Island] Healthy sago and bushy pondweed and some wild celery were seen here; this famous ducking locality is reported to have been covered with water plants in October, more so than for years.

"Johnson's Shoal: - Much healthy sago pondweed.

"South Channel Shoal: - Plenty of good sago pondweed with a good crop of seeds; also a little celery.

"Swan Island Shoal: - Sago pondweed abundant.

"South Side of Great Shoal: - Plenty of well seeded sago pondweed.

"North of Monkey Island: - Dense sago pondweed with plenty of seed.;.some wild celery and musk grass.

"South of Monkey Island:, - Dense sago pondweed, well seeded. Here a 'slick' a mile or more in diameter reminded one of the 'old days'.

"Lighthouse Bay: - Dense sago with seed; little redhead grass.

"Southeast of Morgan's: - Plenty of sago pondweed with seed.

"Currituck Club Channel: - Good sago and bushy pondweed, and musk grass, and a little wild celery and redhead grass.

"Upper end of the Narrows: - Plenty of sago pondweed and musk grass, and more wild celery than seen elsewhere.

"Narrow Shore: - Much musk grass and a little sago pondweed.

"Mouth of Powell Creek': - Considerable musk grass and a large bed of wigeon grass; this locality connected by a small canal with the main Albemarle and Chesapeake Canal has only salt resistant plants.

"Gull Rocks: - Dense beds of sago pondweed well seeded; sparse wild celery.

"Channel near upper end of Church's Island': - Plenty of sago pondweed and a little wild celery.

"Batteries: - Only two batteries were seen on upper Currituck Sound, Nov. 22.

"Wildfowl: - A special trip was made Nov. 23 to see wildfowl and the territory from south end of Swan Island Marsh to Lighthouse Bay was covered. The following approximate numbers were seen: Swans 2350; geese 7600, wigeon 7500, redheads 25, ruddy ducks 335, and coots 2200. A guide reported flushing about 200 canvasbacks and 500 redheads earlier in the morning.

Summary

"Food conditions: - These are vastly improved over what was observed season before last. The crop of sago pondweed is large, mostly healthy and well seeded. There is enough of this plant to feed a large number of waterfowl should they visit the area. However none of the other plants have recovered to the same extent as has sago pondweed and there is a lack of variety in the stand of water plants in great contrast to what prevailed years ago. Unhealthy conditions are apparently local and the malign influence of salt water is plainly evident. Improved conditions this year are due to prevailing southerly winds which help to prevent influx of salt water from the Albemarle and Chesapeake Canal, and to abundance of rain during the growing season.

"Batteries: - Back Bay has a limit of 100 batteries, far too many for a body of water of its size, while upper Currituck Sound has a limit of 30. Much more battery shooting is done in the former than in the latter body of water.

"Wildfowl: - Back Bay, Va., and Currituck Sound, N. C., certainly do not have the numbers of wildfowl visiting them that could formerly be observed there.

"Swan: - The number of swans, in the long run, remains about the same, a conclusion agreed to by some of the most experienced wildfowlers of the region. In my opinion there is no reason for considering an open season on these birds.

"Geese : - Canada geese are more abundant if anything than in former years.

"Marsh ducks: - The numbers present are fairly satisfactory, wigeon being unusually numerous this: year.

"Diving ducks: - The vast flocks of bluebill, redheads, and canvasbacks formerly frequenting these waters have not been seen in recent years. This year there have been, from the veteran wildfowler's point of view, almost none of them. Canvasbacks have been numerous on the Potomac and Susquehanna, however, and may reach the Currituck region later on."

Mr. E. R. Johnson (1927) presented a statement of 24 residents of Currituck County at a meeting in Washington, D. C., which was held to discuss the proposal for a lock in the A & C Canal. The statement was as follows: "The decrease in the number of canvas-back, redhead, and broadbill, ducks that dive for their plant food, became very apparent about five years ago. Previous to that time vast flocks of ducks, containing from twenty to fifty thousand in a flock, could be found scattered throughout this locality. We estimate that the yearly total of such flocks was in excess of a half million and we believe that frequently they exceeded a million.

"At the present time we do not believe that in all this locality of say 100 square miles there are 10,000 such ducks." He went on with the quote 'The ducks that arrived would not remain. Last year great masses of canvasback arrived and all but say five thousand left within a few days.'

Neil Hotchkiss, biologist with the United States Fish and Wildlife Service, prepared a field map of the vegetation in Back Bay in 1929, and also a map of the vegetation in northern Currituck Sound the same year. These maps have been redrafted for inclusion in this report. In many respects they are similar to the vegetation distribution when this study was started in 1958.

Hotchkiss' report on his field examaination on June 20-21, 1929, of the North Bay and Back Bay area mentioned poor hunting the last year (1928); the water when examined was practically fresh;

the marshes north of Redhead Bay and west of the Great Narrows werelargely Typha angustifolia, with some Spartina cynosuroides, much Eleocharis sp., a little Scirpus validus, S. robustus, and S. americanus.

He stated: "The principal aquatic plants are Potamogeton pectinatus, Vallisneria, and scattered Naias flexilis. All the plants noticed appeared to be healthy. In Redhead Bay, sago pondweed (Potamogeton pectinatus) is quite abundant and in fairly good flowering and fruiting condition. Wildcelery (Vallisneria) is fairly common there, also. Aquatics are few in Sandy Bay. On the southwest side of Ragged Island there is considerable sago pondweed, the plants being abundant only where the bottom is soft. Their development here is said to be much better than last year. Plants apparently fluctuate in abundance and distribution a great deal from year to year.

"The marsh bays north of Redhead Bay have few plants. In the western part of Ships Bay there is considerable sago pondweed and wildcelery, the latter much dug up--by carp (?).

"Plants in North Bay, except wihdcelery, are few. There is much floating wildcelery. Sago pondweed occurs in the northernmost bays. It grows also just inside the mouth of the nearby enclosed bay southwest of Porpoise Point and near the south end of the Great Narrows.

"Naias is scattered nearly everywhere.

"In Nawney Creek are a number of aquatics not generally noted in the region: Potamogeton perfoliatus (flowering and fruiting), some Ceratophyllum, Zannichellia, Utricularia sp., Spirodella (a little), Castalia odorata, etc."

Hotchkiss' general remarks in the 1929 report mentioned "the marshes just north are among the least used by hunters in Back Bay; Canvasbacks frequented the large bay in the marshes just west of the Great Narrows (Great Cove) last year."

He stated further: "The general reputation of Back Bay for waterfowl is well-known, but the abundance of food and the number of birds haveapparently fluctuated more in recent years than before. For instance, there were few enough last year so that one or two clubs did not operate at all. Some form of pollution--generally considered to be by salt water--is apparently responsible for the poor development of aquatic plants in certain years."

He stated that the Chief Warden of the Eastern Shore Game Protective Association of Virginia "believes that the use of many automatic guns is largely responsible for driving ducks away from Back Bay."

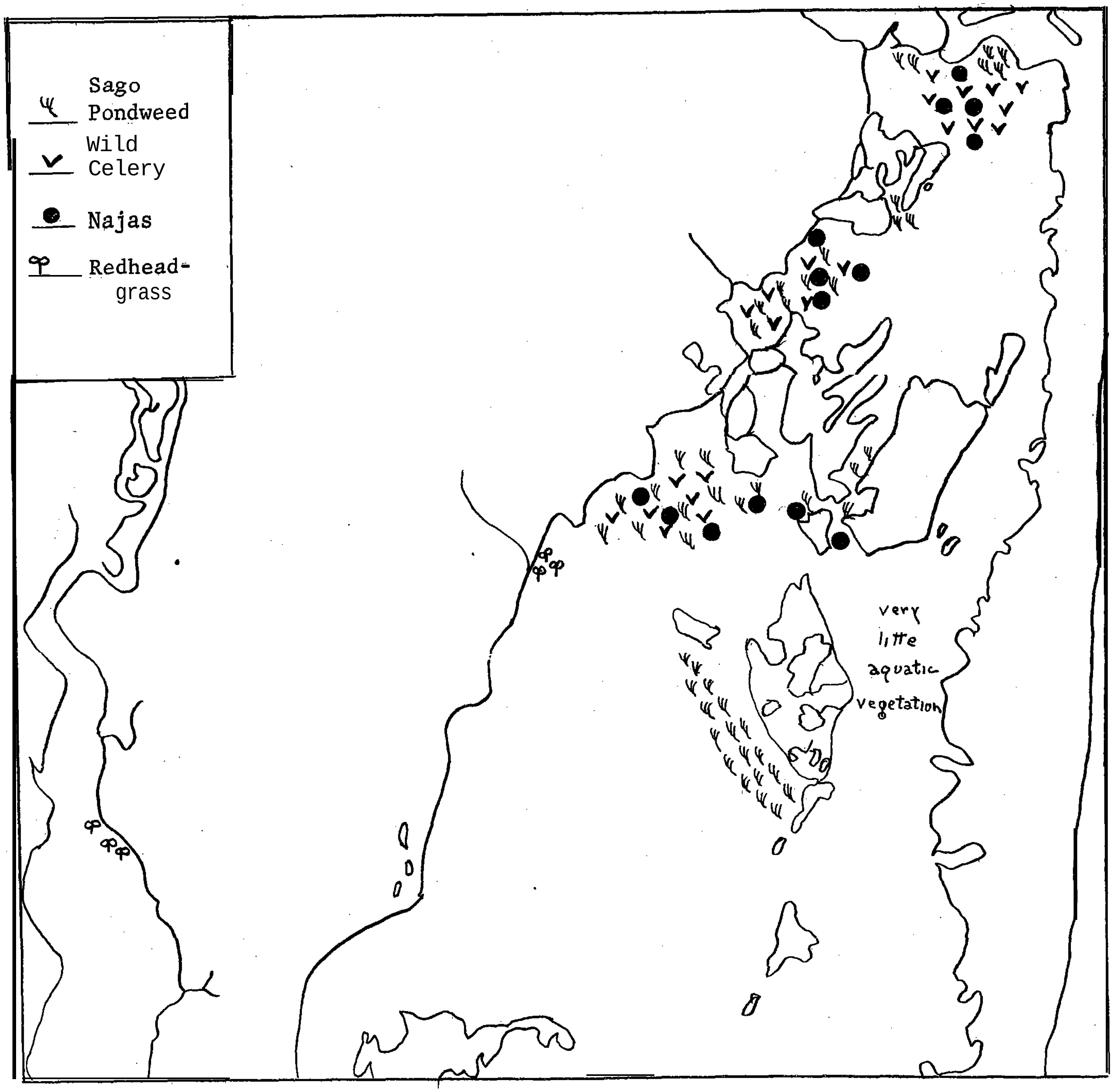

Figure ________ Revision of a Map of Aquatic Vegetation in Back Bay, Virginia. Prepared by Mr. Neil Hotchkiss on June 20-21, 1929.

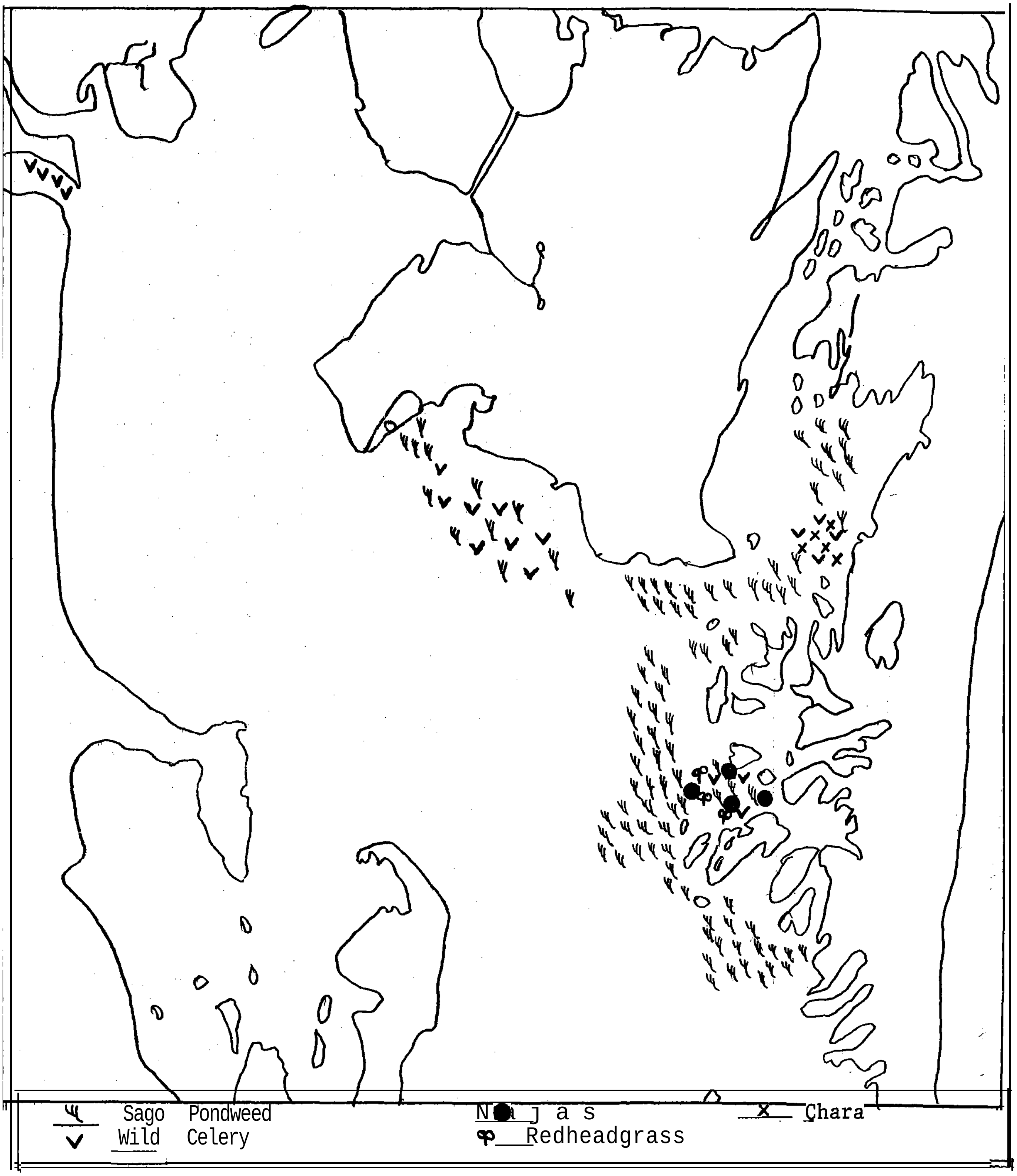

Figure ________. **Revision** of a Map of Aquatic Vegetation in Upper Currituck Sound, North Carolina. Prepared by Mr. Neil Hotchkiss on June 20-21, 1929;

A field report by Hotchkiss and Ekvall based on inspection of tipper Currituck Sound on June 23-24,1929, states that (about the Swan Island Area) "the water is very slightly brackish to taste and is somewhat cloudy in appearance. Sago pondweed (Potamogeton pectinatus) is the most abundant species. Considerable Naias flexilis, some Vallisneria, some Chara, and a little Potamogeton perfoliatus also occur. Sago pondweed was very common off the south end of Knott's Island and eastward. On shoals east of the south end of Knott's Island Chara covered the slightly muddy, sandy,bottom near the marshes on the east side of the Sound. With it was a little sago pondweed and Vallisneria. They all appeared in good health. Swan are reported to feed here . . ..Considerable sago pondweed occurred northward and eastward toward the marshes on the east: side of the channel, and on the shoals west of Swan Island. Off the marsh southeast of Swan Island was considerable Naias flexilis, some Vallisneria, and a little Potamogeton perfoliatus. Sago pondweed plants were not so healthy appearing here, having quite a little hydroid growth on them. Sago pondweed was scattered on down the Sound off the marshes to Jenkins Cove, from which it was fairly abundant two or three miles out toward the north end of Church's Island--scattered from there to a point west of Swan Island.

"Westward from Knott's Island Landing was considerable sago pondweed and wildcelery, Vallisneria, broken up and-floating. A little sago pondweed was seen in Bellows Bay. North Landing River apparently had little aquatic vegetation. Some Potamogeton perfoliatus: occurred at Munden. Many barnacles were observed there and elsewhere in the Sound. Some wildcelery occurred just inside the mouth of Tull Bay.!'

Hotchkiss (1929) stated: "O. H. Bonney of Knott's Island, N. C., says that aquatics are best in years following the coming of storm tides over the beach. He thinks also that the large amount of plants (especially wild celery) shipped from Curritnck affects their abundance. He said that 90 percent of last year's bass were caught west of Mackay Island.!'

Uhler inspected the Sandbridge Marsh and the north end of North Bay on June 18-19, 1932, and his field report mentions: "Water brackish to the taste throughout the whole area. Normally this water is reported to be fresh. Aquatic vegetation (with the exception of white water lily and lotus) very limited in the ponds and channels. Tremendous concentration of ducks after close of last shooting season, (till late March) reported to have cleaned it out, because illegal shooting on Back Bay, North Bay, etc. concentrated the birds in these protected marshes.

"The widgeon grass, sago pondweed and redhead grass were thrifty and abundant in adjacent North Bay. Carp plentiful and probably are a serious handicap in attempting to get aquatic vegetation to grow."

In a memorandum dated January 1935, Hotchkiss stated that the food supply in Currituck Sound was slight at the present time, due to the great influx of salt water in the 1933 storm.

A statement by Hall, Bourn, and Cottam (not dated--but presumably early 1940's) mentions "that the opening of the locks (at Great Bridge) during periods of ebb tide will result in destruction of the valuable plant and animal life of these waters may be shown from the fact that an experiment of the Army Engineers carried on from July 1934 to January 1935, (7 months) caused a regression in the recovery of the flora and fauna of these waters. Subsequently, studies made during the winter and summer of 1935 showed conditions markedly worse than in July 1934." They stated further: "Waterfowl and fish food conditions are rapidly improving in these waters and as a consequence more wildlife are now attracted to these areas than has occurred at any time since the destruction of these resources in the late 1920's."

Bourn inspected the Back Bay and Currituck Sound Area with Mr. Roland Halstead during the period May 24-31, 1945. In his report he mentioned that: "While traveling from the refuge headquaters to Ragged Island in December 1944, considerable difficutly was had in clearing the boat propeller from sago pondweed, the growth of which at that time far surpassed any stand of the plant to be found, in those waters during the period 1925-1931, inclusive. I agreed then and I concur now with the refuge manager that there was a surplus of plant food on the refuge last season, a suppply exceeding the needs of the ducks and geese that visited Back Bay last season. There is no question, however, that a shortage of vegetation in the general area of Back Bay and Currituck Sound has existed for the past few seasons." Bourn mentioned further that there was a normal growth of wildcelery, naiad, widgeongrass, muskgrass, sago pondweed, and redheadgraxs in most places except in places of excessive depth.

On October 20, 1948, a public hearing was held in Princess Anne, Virginia, to discuss recommended methods of managing the locks at Great Bridge and various proposals for new canals to decrease loss of crops by flooding and management of Back Bay and Currituck Sound. Mr. Perkins, then refuge manager of the Back Bay National Wildlife Refuge, refuted the claim that there was no aquatic vegetation and stated: "I have only been here for six years but each year I have been here, there has been a very decided increase in the amount of waterfowl foods in the bay. And this year, by far, is the best year we have had in the past six, that I know of." When asked what area, he responded: "The whole of Back Bay, North Bay, all up in the area in the vicinity of the refuge and as far as I can determine from talking to men located along the coast, the whole of Currituck Sound is in much better condition than it has been any time in the last six years."

The midwinter waterfowl inventories in 1937 were the first quantitative estimates of any value to document use of the Back Bay Area; no records can be found for Currituck Sound until the midwinter inventory of 1942. No one doubts the fact that around the turn of the century tremendous numbers of waterfowl used the Back Bay-Currituck Sound Area and other important areas.

However, it is unfortunate that the local populace has always identified the drastic reduction in use of the Back Bay-Curritnck Sound Area with the coincidental decline in the quality of that habitat. From the preceding statements of Perkins, it could be inferred that conditions in 1942 were less productive than in 1948, for he mentioned a progressive improvement in the habitat. However, during this same period the recorded waterfowl population on the midwinter inventory declined from 1,135,000 waterfowl to about 300,000 waterfowl.

Another apparent conflict in the logic of assuming that "less grass" always means "fewer-ducks" can be illustrated in the comparison of the club records of waterfowl kill and several of the estimates already quoted on the status of habitat. Bourn made mention in 1926 that two-thirds of the area was barren of vegetation, and in 1929, 90 percent of the area was barren. The club records based on 671 man-days indicated a kill of 12.9 waterfowl per man-day of effort in 1926, and in 1929 the record of 636 man-days indicated a kill of 11.2 per man-days of effort. And this occurred when only 10 percent to 33 percent of the area was productive of vegetation!

Chamberlain (1948) prepared a map showing the distribution and relative abundance of aquatics in the Back Bay Area in October 1946 and October 1947. In comparison to a survey by Mosby (1946) in the summer of 1946, Chamberlain's study indicated certain improvements. Mosby indicated the order of'abundance was wildcelery, bushy pondweed, widgeongrass, Chara, Nitella, and sago pondweed. Chamberlain indicated the order of abundance as bushy pondweed (Najas guadalupensis), wildcelery, sago pondweed, widgeongrass, Nitella, and redheadgrass. In comparing the former dominance of sago pondweed in 1932 from Bourn's estimate, Chamberlain suggests: "The decrease in Potamogeton pectinatus may well be due to the decrease in salinity since construction of the sandfence, and the present position of Najas guadalupensis due to the fact that it is more tolerant of turbid water than are the other species."

Chamberlain, incidentally, was apparently the first one to identify the bushy pondweed as Najas guadalupensis rather than Najas flexilis, as it was called by all former investigators. In the period of study 1958-1964 all that we observed was Najas guadalupensis.

The salinity of the water averaged only about 2.3 percent of sea strength from, June through September 1946, as shown by Chamberlain's study. He mentioned also "salinities of 4.1 percent at the north end of Knott's Island Channel, 7.5 percent in Currituck Sound, and 21.4 percent in Albemarle Sound were found during the summer."

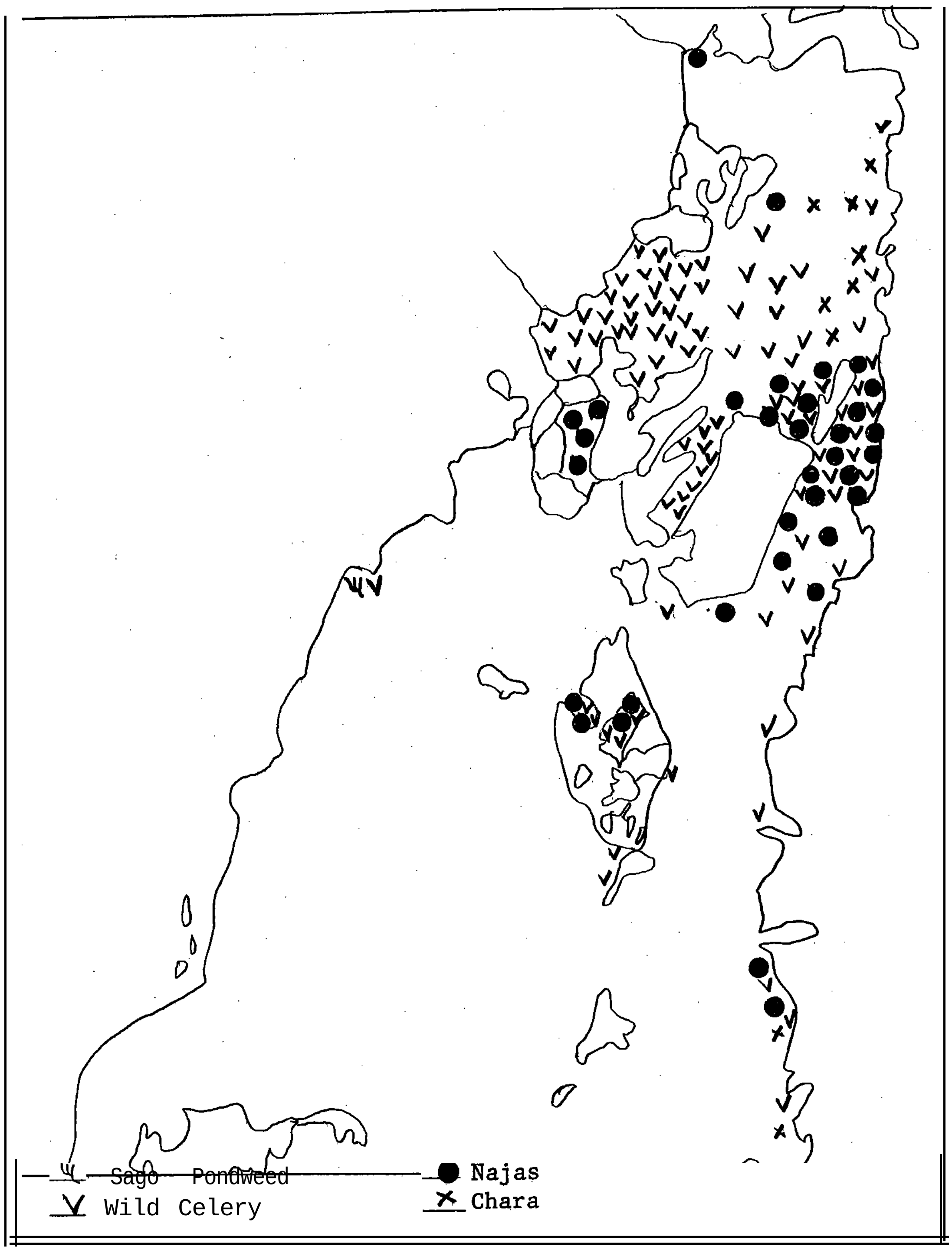

Figure . ______ Revision of a Map of Aquatic Vegetation in Back Bay, Virginia. Prepared by Mr. Henry Mosby in October 1946.

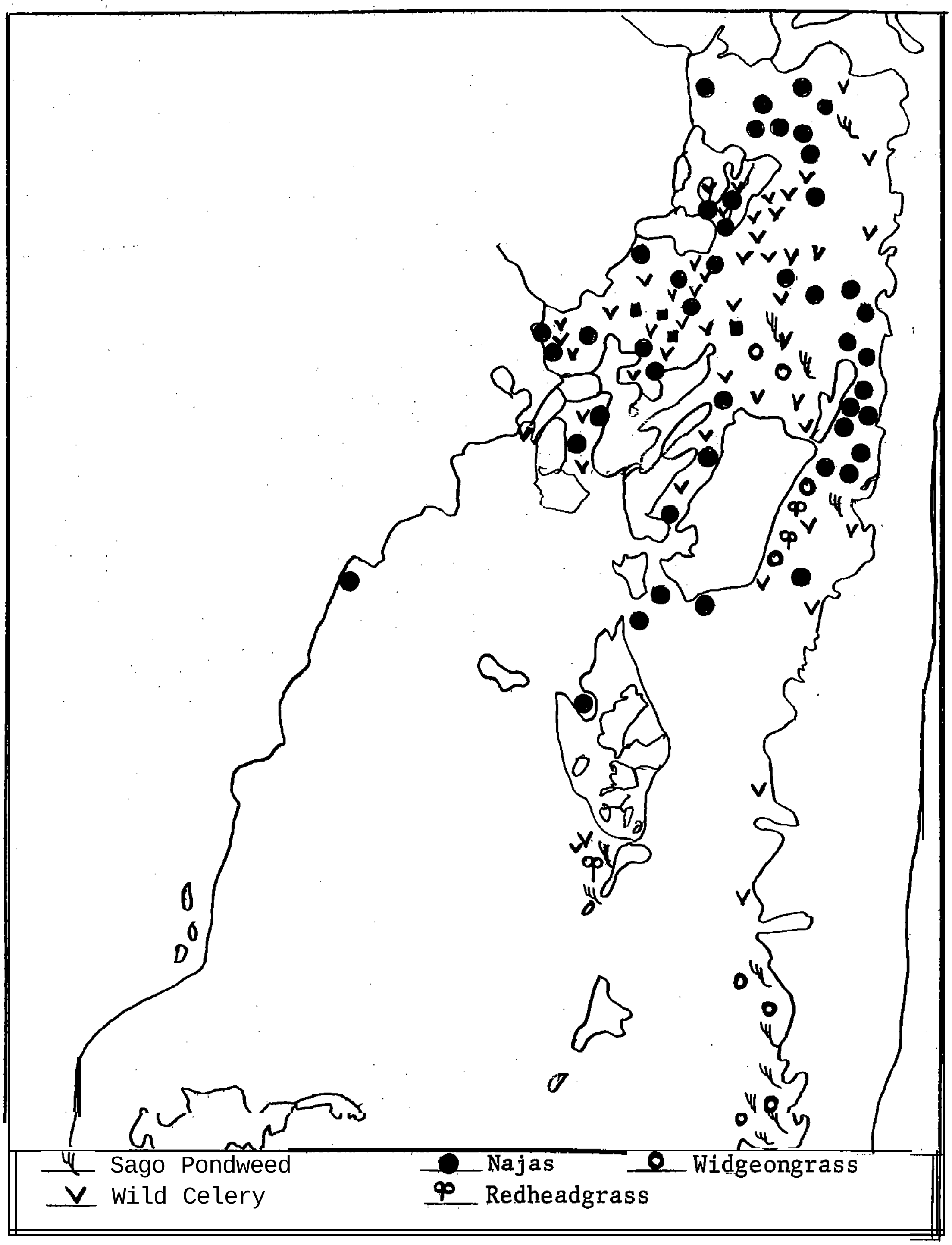

Figure _______. Revision of a Map of Aquatic Vegetation in Back Bay, Virginia. Prepared by Mr. E. B. Chamberlain, Jr. in October 1947.

Chamberlain discussed the turbidity of these waters at length and concluded that turbidity was the primary factor limiting plant growth; and that the chief cause of turbidity was due to wave action.

Bourn, in a memorandum of January 1952, stated: "Periodic surveys of biological conditions in Back Bay and Currituck Sound show such improvements increasing progressively from year to year since the closing of the locks in 1932 that there have been annual surpluses of waterfowl food in those waters since 1943; the maximum production of submerged aquatic plants in 1951."

Roseberry (1952) undertook a study of the relationships of commercial and sport fishing in Back Bay in 1951. He estimated a total commerical harvest in the 1950-51 season of 235,648 pounds, of which 61.7 percent were carp, 20.6 percent were white and yellow perch, 7.1 percent were channel catfish, and rock bass made up about 1.0 percent. Shad, herring, etc. comprised the remainder of the harvest. The commercial value of the harvest from Back Bay was $15,000.

Roseberry estimated that anglers exerted a fishing pressure of 26,428 hours on Back Bay, or 11.5 fishing hours per acre for the 1951 fishing season. They harvested 7,835 bass and 13,610 fish of all species. Based on tag returns it was estimated that anglers harvested 7 percent of the legal size bass. The tagged bassrecaptures did not indicate a mass movement of bass. Roseberry recommended that an attempt should be made to increase the harvest of fish by both sport and commercial fishermen. He mentioned that the water level fluctuations that occur in Back Bay may affect the reproduction of carp, largemouth bass, and pumpkinseed.

In April 1953, Dr. Cottam, Assistant Director of the U. S. Fish and Wildlife Service, reported on a public meeting at Creeds, Virginia, held to discuss proposals for dredging of oyster shells in the North Landing River. He stated: "Major J. L. Murphy, vice president of the United Sportsmen's Clubs of North Carolina, and formerly a high official in the Corps of Engineers who supervised much of the dredging of the Intercoastal Waterway through Currituck....pointed out that much of the dredging was done under his direction and he had occasion to watch it, and there was no question in his mind that dredging was primarily responsible for the killing of the vegetation because the whole Bay became highly turbid and the plant life disappeared. He pleaded that a similar mistake be not made again."

In response to a report from the Virginia Commission of Game and Inland Fisheries that duck foods and fish were virtually non-existent in the North Landing River, Clarence Cottam inspected that area on June 6, 1953. He reported "that upstream from the southwest point of Mackay Island across the river southwesterly to the west bank about midway between the town of Currituck and the mouth of Tull Bay, almost no submerged aquatics were found in North Landing River and its broad estuary.',' He mentioned the high turbidity and referred to secchi disc readings of 12 to 16 inches above Pungo River Bridge, and 16 to 28 inches in lower parts of the river. Reference was also made to dying out of normal heavy growth of plant life in Buzzards Bay adjacent to Corey Canal, which connects with the North Landing River.

Shortly after Cottam's visit, the Corps of Engineers, the Virginia Commission of Game and Inland Fisheries, and the Fish and Wildlife Service conducted a short-term study to determine the effect of opening the bypass valves in the locks at Great, Bridge on "cleaning" up the water in the North Landing River.,

Barber (1955) mentioned the food conditions for waterfowl in North Carolina, stating: "The four severe hurricanes which struck the coast of North Carolina during 1954 and 1955 caused moderate to severe damage to the aquatic plant beds in practically every coastal sound and river. Damage was probably lightest in Currituck Sound. Aquatic plants were already in poor condition in the lower Sound, possibly as the result of salt water intrusion during three dry summers, but more likely as the result of extensive hydraulic dredging operations carried on by a local hunting club. Heavy intrusions of salt water during the late summer hurricanes destroyed much of the remaining vegetation below the Narrows. Above the Narrows, damage was much less and on Sedge Island Shoal and northward there appeared to be little or no damage to celery, sago, redheadgrass, and widgeongrass. The abundant growth of muskgrasses, however, which usually is to be found in much of the Sound was greatly reduced."

Martin, Hotchkiss, and Lawson (1956) fairly well summarize the opinions about the area in the following statements:

"Among the various factors that have been held responsible for plant destruction, none seems to have been clearly proved as a primary or major cause. Parasites and disease doubtless played a part but-whether their role was primary or secondary is not known. Pollution has been suggested as an important factor, but sewage has been found beneficial to plant growth in other places and its harmful role here does not appear to have been demonstrated. Nor has there been proof that industrial wastes caused the destruction. The extremes of 3% and 20% of sea salinity recorded in 48 consecutive months from 1925 to 1929 in Back Bay are well within the tolerance limits of most of the waterfowl food plants of the Bay and are close to optimum for sago pondweed, redheadgrass, wigeongrass, wildcelery, and leafy pondweed, as determined by the Boyce Thompson Institute. Furthermore, the harmfulness of the water entering North Landing River from the open canal is challenged by a number of reports indicating that "grass" was plentiful in that locality after it had died out elsewhere. It has been testified by several reputable residents that before a new lock was installed a number of hunters moved their shooting sites into the upper part of North Landing River because of good growths of aquatics there.

"Turbidity has been and still is (Back Bay was very turbid during a high wind at the time of this inspection) an important factor, though just what caused or started it is another matter, Once unfavorable conditions eliminated or reduced plants in any location there was more opportunity for wind and waves to agitate the mucky bottom and little opportunity for plants to become re-established. Carp have contributed to the turbidity but reports from different sources do not indicate that they have been a major factor.

"In recent times there have been major shifts of opinion regarding. conditions in the Back Bay area. Before 1932, many residents protested the absence of a lock in the canal whereas now they blame recent flooding of farms largely or partly on the lock. Also, whereas navigation interests formerly opposed installation of a lock on the grounds that it would hinder boat traffic, they now regard its removal as undesirable because of dangerous currents that tides and wind would bring into the canal. The prevailing attitude about salinity has also been reversed. Prior to 1932, general opinion was that the canal was admitting too much saltiness into Back Bay but now the concensus seems to be that insufficient salinity is responsible for the shortage of vegetation'.

"One support of the idea that more salt is needed is widespread testimony that ocean water which has occasionally washed over the barrier beach has proved beneficial to vegetation after an initial setback. In addition, it is known that salinities of about 10% of sea strength clear up muddy water and stimulate the growth of important Back Bay duck foods, such as sago pondweed, widgeongrass, and redheadgrass. Some residents point to conditions from 1950 to 1956 as further evidence of need for more salt in Back Bay. In the fall of 1950, an overflow from the ocean into Currituck Sound approximately doubled the low salt content of both Currituck and Back Bay and the next year the "grass" was said to be more abundant than in 19 years. Later overflows combined with several years of low rainfall kept the salinity about the same until the arrival of hurricanes in the fall of 1955. Heavy precipitation then and normal rainfall in 1956 returned the salinity of Back Bay to its recent low average and vegetation this year is reported to be much reduced as compared to 1955."

In response to reports that ducks were starving in the Back Bay Area, Martin (1956) investigated the conditions on December 22, 1956, reported finding an abundance of excellent duck-food plants in at least two-thirds of Back Bay, and prepared a map showing its distribution. He mentioned the direct relationship between water depth and quantity of vegetation as the "increased barrier to light." During the inspection he found healthy growths of bushy pondweed and sago pondweed abundant in shallow water of 2 to 4 feet depth, and noted that Nitella, redheadgrass, and wildcelery were locally common. He stated: "The limited food resources and poor hunting in deeper parts of the bay this winter are particularly disappointing because of the contrast with last winter when the "grass" and hunting were exceptionally good in this zone. Reliable local testimony indicates that last winter the submerged growths were the best in more than 30 years."

Dickson (1955), North Carolina Wildlife Resources Commission Fisheries Biologist, started ecological studies of Currituck Sound in April 1955, and he reported water salinities in percent of sea strength at various stations ranged as follows from April to October: Currituck Courthouse, 4 to 11 percent; Coinjock Landing, 7 to 12 percent; Poplar Branch, 7 to 19 percent; Grandy, 7 to 23 percent; Wright Memorial Bridge, 9 to 52 percent on the west side, and 7 to 80 percent on the east side. He stated: "By late June the plant growths were so luxuriant that all parts of the water surface were covered. Only those parts of the water where boat traffic was heavy lacked the heavy growths of plants. The area of the sound south of Poplar Branch maintained a growth of only one species of plant, sago pondweed (Potamogeton pectinatus). The northern section of the sound was characterized by a variety of plant species. Sago pondweed predominated the plant growth; but large quantities of wildcelery (Vallisneria spiralis) "(americana)", pondweed (Potamogeton foliosus) Raf., redheadgrass (Potamogeton perfoliatus) L,, and Chara spp. were found."

Dickson mentions that the hurricanes of August 12 and 17 damaged about 70 percent of the aquatics in some major sections to the south with little recovery later in the year, but in the northern part of the sound excellent stands of plants were found until November 1955.

Dickson (1956 and 1957) continued his observations in 1956 and 1957 and found average salinities lower than in 1955. In comparison, the average salinities (in percent of sea strength) at the sample stations throughout the summer were as follows:

	1955	1956	1957
Currituck Courthouse	7.29	3.46	3.38
Coinjock Canal	9.18	5.62	5.12
Poplar Branch	12.22	6.52	5.18
Grandy	15.73	6.88	5.65
Wright Memorial Bridge (west)	21.10	19.01	9.60
Wright Memorial Bridge (east)	29.50	14.38	11.00

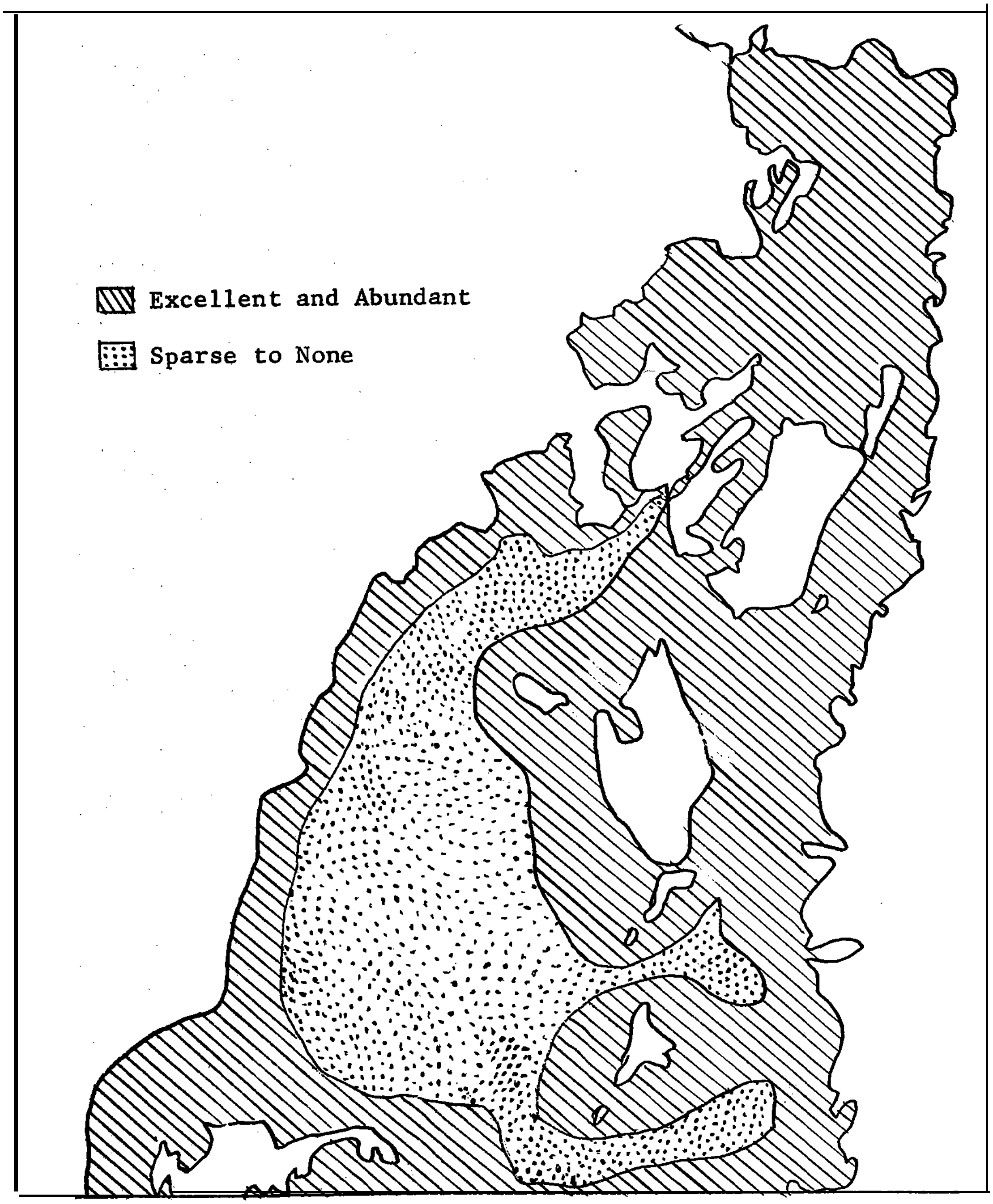

Figure _______. Generalized Map of Aquatic Vegetation in Back Bay, Virginia. Prepared by Dr. A. Martin, December 1956.

He found no evidence either year of stratification of salinity with increasing depth.

Dickson's (1956) statements about aquatic vegetation were that: "During 1956 the growth of aquatic vegetation in Currituck Sound was not as good as has been observed in past years, except for those areas where shallow water was present. Poorest growth of plants was found in the deeper water throughout the sound. It is evident that certain habitat changes have occurred which prevented the growth of plants in water over three feet deep."

Dickson stated: "It is not likely that the salinities found in Currituck Sound during the 1956 growing season would have any detrimental effect on most of the common aquatic plants unless it was that the salinities were below the optimum for the plants and this retarded growth to some degree."

He further stated: "It is most probable that the paucity of plants in the Sound during the 1956 season can best be attributed to the great destruction of plants by the hurricanes' which occurred in the fall of 1955." He conjectured that the lack of vegetation permitted increased turbidities that limited growth.

Dickson (1957) recounted the events of 1955 through 1957 and mentioned that in 1956 the Sound remained very turbid throughout the year. Dickson expanded the study of Currituck Sound somewhat in 1957 and included turbidity measurements. He mentioned a significant reduction in turbidity in the southern part of the Sound, and conjectured that the sandy bottoms and the precipitation of suspended matter by higher salt content might be responsible. Secchi disc readings averaged 13 to 19 inches in the northern part of the Sound in the spring of 1957, and 12 to 32 inches in the southern part of the Sound.

Water salinities were slightly lower in Currituck Sound in 1957 than they were in 1956;

Dickson reported in 1957: "The growths of aquatic plants were rated as good in most areas of the Sound. The best stands of vegetation were found along the eastern shore from Knott's Island down to Caffee's Inlet. Particularly good growths were noted in the Swan Island portion and near the Big Narrows with scattered patches of plants found throughout most of the other areas. Wfldcelery, sago pondweed, and widgeongrass were predominant. It should be noted that wildcelery was found in abundance only north of the Waterlily area in previous years but in 1957 good growths of this species were observed down into the Narrows." He concluded "that there was a general increase in the amount of aquatic vegetation during the 1957 growing season. The increase of vegetation was somewhat restricted, however, when compared to seasons of maximum abundance."

A report in August 1958 by the Branch of River Basin Studies of the TJ. S. Fish and Wildlife Service, states: "Three hurricanes in August and September 1955 wrought considerable damage to the aquatic plant resources of the Back Bay-Currituck Sound area. Poor growing conditions in the spring of 1956 compounded this damage. With somewhat better growing conditions in 1957 and early 1958 there has been substantial recovery by the plants, although in general neither the thrift of the plants nor the degree of bottom coverage is equal to that occurring before the hurricanes of 1955."

The foregoing account represents all information known about the abundance of aquatic vegetation in Back Bay and Currituck Sound prior to this study. A few further indices and accounts of waterfowl and fish populations are discussed in the respective volumes of this basic data report.

Despite the claim that the area has been studied for many years and that both professional and lay opinions of-conditions have been offered, it is obvious that the 2- or 3-day visits by biologists or hunters could not begin to adequately acquaint them with conditions or reasons for the conditions. This is particularly true of estuaries where the mere factual documentation of existing vegetation is a difficult, time-consuming task.

The need for quantitative assessment of the habitat, wildlife use, and environmental factors was obvious.

QUANTITATIVE SURVEYS OF AQUATIC VEGETATION, 1958-1964

Transect Survey Objective

The objective of the transect surveys was to determine trends in kinds and amounts of aquatic vegetation throughout Back Bay, Virginia, and Currituck Sound, North Carolina, for the purpose of evaluating the area for fish and waterfowl. After the "Ash Wednesday" Storm of March 7, 1962, the objective included the evaluation of the effects of the ocean water intrusion.

Field Procedures

During the summer of 1958, 20 transects were selected across the Back Bay-Currituck Sound Area according to an approximately systematic sampling plan. Accompanying maps and tables indicate locations and the number of samples per transect line. In the Back Bay Area, 264 samples were taken on each survey, and 420 samples were taken in the Currituck Sound Area.

Twenty-three transect surveys were completed of the entire area between May 1958 and November 1964. Approximately 900 man-days of effort were used in field work and tabulation of the data.

Normally, the transects were sampled four times each year, in February, May, August, and November. At stations located every 500 yards along the transect, three samples of the bottom, each 2 square feet in size, were taken with modified oyster tongs.

The 12 foot oyster tongs had a metal plate welded on to the "teeth" of the tongs and the lower "biting" edge was sharpened so that it effectively dug into the soil and root system of the aquatics.

Initially the sampling locations were staked with poles. However, when the investigators became more familiar with the area, blind locations, marsh points, and constant running time by the boat between stations were used to locate sampling stations. Ice, storms, and human disturbance made it difficult to maintain markers.

Each sample was placed in a wire basket, made of one-fourth inch hardware cloth, suspended over the side of the boat. The basket was moved vigorously through the water to remove the soil. All vegetation from each sample was removed from the basket and spread loosely on the deck of the boat, so that an ocular estimate could be made of the percentage that each species constituted of the total volume. Any aquatic plant comprising less than 1 percent of the total volume was listed as a trace. Originally the muskgrasses were not separated to genera, but after November 1959, they were distinguished as *Chara* spp. and *Nitella* spp.

After completing the ocular estimates the vegetation was squeezed into a ball and shaken to remove excess water on the plants. Care was taken not to actually crush the plants, particularly the musk-grasses, and release the plant fluids. The ball of vegetation was then submersed in a water displacement measuring device. Readings were taken on a 10 ml. pipette attached to the measuring device and they provided an index to true volume. All three samples at each station were recorded and measured separately.

Other data obtained in conjunction with the transect survey of vegetation were water depth, secchi disc readings of turbidity, bottom type. Normally the water samples for chemical analysis were taken at the same time.

Recording and Calculation

A series of standard forms were used to record the ocular estimates of each species of aquatic, the total volume of the sample, the percent frequency on each transect, the calculations of volume per transect-line, the conversions to oven-dry_ weight, and the expansions of total area represented by each transect.

The surface acres of water represented by each transect, transect locations, and number of stations and samples were as follows:

Tran-sect	Location	Number Stations	Number Samples	Number So. Ft.	Area Represented
A	North Bay; Murden's Club to point on Beach Marsh	7	21	42	1,112
B	Shipps Bay; Lovitt's Ditch to Little Is. Coast Guard Sta.	10	30	60	2,234
C	Great Cove and Fisherman Cove, Back Bay Refuge	6 (3 in each cove)	18	36	1,663
D	Redhead and Sand Bay; Nawney Creek to Black Is. through Little Narrows	15	45	90	3,571
E	Back Bay and Sand Bay; White-hurst Pt. to Barbers Hill Landing	15	45	90	5,346
F	Back Bay and Sand Bay; Pellitory Pt. to Green Pt. passing south Little Cedar Is.	17	51	102	5,193
G	Back Bay and Sand Bay; East point of Egg Is. to Horse Is. Cr.	10	30	60	2,785
G_1	Buzzard Bay; Public Landing to Slover Landing	8	24	48	1,316
$A-G_1$	Total for Back Bay, Virginia	88	264	528	23,222'
H	Virginia-North Carolina State Line, Knotts Is. Ch.	6	18	36	1,653
I	Knotts Is. Bay, Below Marsh	6	18	36	2,469
J	Knotts Is. Landing to Swan Is.	7	21	42	3,591
K	North Landing Rvr; Tull Bay to Knotts Is. near Cory's Ditch	15	45	90	15,988
L	North end Churchs Is. to Beach Marsh	11	33	66	18,274
M	Coinjock Bay; Maple to Cedar Bay	13	39	78	5,816
N	Waterlily Bay to Corolla Lighthouse	19	57	114	7,244
O	Aydlett to east side Sanders Bay	14	42	84	9,958
P	Grandy to road landing on Beach Marsh	12	36	72	8,356
Q	Jew's Island to Caffey Inlet	14	42	84	8,632
R	Thoroughfare Island to Duck	13	39	78	10,376
S	Parallel to Wright Memorial Bridge	10	30	60	5,601
H-S	Total for Currituck Sound, N.C.	140	420	840	97,959
A-S	Total: Back Bay and Currituck Sound	228	684	1,368	121,181

Each transect was assumed to represent the area half the distance to the adjoining transect, with the exception of transects C and Gl in Back Bay. These two transects obviously were representative only of the shallow cove areas and the respective adjoining acreage to each of these was thus assigned. In Back Bay the pond acreage of Ragged Island was included in the area represented by transect C.

Estimates of total volume and weight of vegetation for Back Bay, Currituck Sound, and the total area were based on the sum of the weighted totals of the transects, rather than the unweighted averages shown on some of the accompanying tables.

The ratio of wet volume to oven-dry weight varies for most species of aquatic plants; the ratio may also vary slightly with each species between samples, and possibly at different stages of maturity. However, it was believed to be relatively constant, so that the following ratios of wet volume to oven-dry weight were used throughout the study:

Species	Ratio wet volume (cc>/ dry weight (grams)	cc per lb.
Sago pondweed	11.0	4990
Wildcelery	16.8	7620
Redheadgrass	11.3	5126
Chara spp.	5.5	2495
Nitella spp.	8.4	3810
Bushy pondweed	10.9	4944
Widgeongrass	11.0	4990
Eleocharis parvula	12.0	5443
Sapittaria subulata	15.3	6940
Potamogeton berchtoldi	11.0	4990
Anacharis canadensis	11.3	5126

These ratios, incidentally, contribute to a better. understanding of why wildcelery, Sagittaria subulata, and Eleocharis parvula, with their relatively shallow root system, tend to float to the surface and windrow. The greater densities of Chara spp. and Nitella spp. might also contribute to the adaptability of these poorly anchored plants to survive turbulence and remain attached to the soft bottoms of the bay.

Because of the varying species composition between transect surveys, and the different density ratios, it is possible that a certain volume of all vegetation on one survey can have a greater or lesser total dry weight than an equal volume on another survey.

Accuracy of the Transect Surveys

As described in the section on statistical analysis procedures, confidence limits at'95 percent confidence for volume computations on Back Bay ranged from plus or minus 26 to 51 percent of the

Table . Thousands of Pounds (oven-dry weight.) of Each Species of Aquatic Vegetation in Back Bay, Virginia, and Currituck Sound, North Carolina, as Determined by Each Transect Survey from August 1958 to November 1961.

	Aug. 58	Oct. 58	Nov. 58	May 59	Aug. 59	Nov. 59	Feb. 60	May 60	Aug. 60	Nov. 60	Feb. 61	Aug. 61	Nov. 61
Back Bay													
Sago	1,342	829	479	3	652	487	20	3	48	422	10	623	30
Wildcelery	450	568	58	69	1,925	1,037	0	131	2,621	744	3	3,474	507
Redheadgrass	0	35	12	45	239	337	45	188	265	794	148	1,912	785
Muskgrass	785	867	629	15	279	1,325	199	8	714	761	22	846	762
Chara*	--	--	--	--	--	--	0	0	629	276	22	797	393
Nitella*	--	--	--	--	--	--	199	8	85	485	0	50	369
Najas	3,713	4,740	3,849	841	4,574	7,085	4,463	2,214	5,456	7,640	2,542	7,647	3,997
Widgeongrass	0	10	15	19	104	654	373	79	182	681	268	107	98
Eleocharis	0	18	0	Tr.	253	245	106	49	197	257	23	16	51
Sagittaria	0	4	9	0	0	52	7	0	98	54	60	115	263
P. berchtoldi	0	0	0	0	0	0	0	0	0		0		0
Total	6,290	7,071	5,051	992	8,026	11,222	5,213	2,672	9,581	11,353	3,076	14,740	6,493
Currituck Sound													
Sago	3,650	2,746	3,257	2,987	1,793	2,948	426	470	3,290	3,717	1,846	4,629	3,062
Wildcelery	941	3,175	281	255	2,246	409	10	947	5,032	1,555	16	5,059	1,402
Redheadgrass	105	349	200	454	1,463	3,338	451	1,659	2,560	4,150	517	3,464	2,588
Muskgrass	5,760	9,528	6,621	0	7,787	14,083	800	70	2,792	3,630	150	2,929	4,528
Chara*	--	--	--	--	--	--	96	0	2,298	1,644	132	2,718	3,375
Nitella*	--	--	--	--	--	--	704	70	494	1,984	18	211	1,153
Najas	6,777	11,598	8,039	4,463	6,952	12,424	4,054	4,161	15,538	16,674	5,124	12,171	11,455
Widgeongrass	320	4	0	544	2,678	4,673	1,606	2,831	2,571	2,573	1,676	786	1,572
Eleocharis	0	0	0	0	0	149	17	44	160	338	22	186	74
Sagittaria	0	0	0	0	0	0	0	0	90	175	11	53	127
P. berchtoldi	0	0	0	0	0	0	0	0	129	6	0	0	0
Total	17,553	27,400	18,398	8,703	22,919	38,024	7,364	10,182	32,162	32,818	9,362	29,277	24,808

* Chara and Nitella not separated until February 1960.

Table . Thousands of Pounds (oven-dry-weight) of Each Species of Aquatic Vegetation on Back Bay, Virginia and Currituck Sound, North Carolina as Determined by Each Transect Survey from May 1962 to August 1963.

Species	May 1962	August 1962	November 1962	February 1963	May 1963	August 1963
Back Bay :						
Sago Pondweed	118	1,449	862	187	360	Trace
Wildcelery	103	3,559	318	Trace	681	1,611
Redheadgrass	516	2,698	2,148	142		50
Chara	Trace	180	670	Trace	1	463
Nitella		56	-			7
*Muskgrass	Trace	236	670	Trace	1	470
Najas	1,711					
Widgeongrass	188	4,809	5,117	3,049	1,168	1,315 223
Eleocharis		62			4	
Sagittaria	59	419	139	20	43	133
P. berchtoldii	Trace	Trace	Trace	-	Trace	-
	92					
Total :	2,787	14,093	11,019	4,225	2,771	3,802
Currituck Sound:						
Sago Pondweed	3,046	5,141	9,600	2,726	3,201	4,487
Wildcelery	1,031	6,157	452	4	1,811	11,474
Redheadgrass	2,764	[illegible]	4,497	1,210	2,916	5,887
Chara	585	5,488	567	226	190	5,274
Nitella						49
*Muskgrass	585	59776 288	5,064	226	190	5,323
Najas	59181	10,535	10,308	6,060	6,211	
Widgeongrass						
Eleocharis	44	131	60	54	4	54
Sagittaria	49221	11,008	3,134	4,610	3,022	17,867
P. berchtoldii		Trace				6,019
Total :	17,321	48,481	31,416	14,932	179379	519197
Grand Total :	20,108	62,574	429435	199157	20,150	549 999

Trace equals less than 500 pounds.

* Muskgrass total includes Chara and Nitella species.

Table . Thousands of Pounds (oven-dry-weight) of Each Species of Aquatic Vegetation on Back Bay, Virginia, and Currituck Sound, North Carolina; as Determined by Each Transect Survey from November 1963 to November 1964.

Species	1963 November	1964 November
Wildcelery	61	8
Redheadgrass	Trace	0
Chara	11	172
Nitella	Trace	80
Muskgrass 1/	11	253
Najas	73	28
Widgeongrass	Trace	3
Eleocharis	20	Trace
Sagittaria	132	Trace
Total Back Bay	297	291
Sago Pondweed	3,259	2,729
Wildcelery	1,143	1,562
Redheadgrass	4,587	3,544
Chara	2,393	742
Nitella	117	397
Muskgrass 1/	2,510	1,139
Najas	12,873	21,076
Widgeongrass	5,110	2,157
Eleocharis	120	66
Anacharis	0	44
Sagittaria	41	0
Total Currituck Sound	29,643	32,317
Grand Total	29,940	32,608

Trace equals less than 500 pounds

1/ Muskgrass includes Chara and Nitella species.

Table . Percent Frequency of Aquatic Vegetation on Each Transect on Back Bay, Virginia, and Currituck Sound, North Carolina, from May 1958 to November 1961.

		1958					1959			1960					1961		
Transect	No. Samples	May	July	Aug.	Oct.	Nov.	May	Aug.	Nov.	Jan.	Feb.	May	Aug.	Nov.	Feb.	Aug.	Nov.
A	21	100	100	100	100	100	81	100	-100	100	100	100	100	76	86	71	76
B	30	90	100	100	100	100	100	100	100	100	100	100	100	100	97	100	100
C	18	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
D	45	44	47	67	47	24	33	42	49	49	36	78	62	71	84	51	40
E	45	33	47	20	11	20	18	20	20	18	11	29	51	47	47	60	31
F	51	47	47	53	33	24	33	35	45	33	47	39	73	63	57	61	43
G	30	100	70	70	57	33	53	73	70	63	70	63	80	93	73	80	73
G_1	24	---	100	100	92	96	100	100	100	95	100	100	100	100	100	100	100
Back Bay	264	62	68	68	57	51	55	61	63	60	60	68	78	76	75	73	63
H	18	100	83	100	100	100	83	100	100	X	94	100	100	100	100	94	100
I	18	100	100	100	100	100	100	83	100	X-	100	100	100	100	100	100	100
J	21	100	100	86	71	100	100	100	100	X	100	100	100	100	100	100	100
K	45	7	0	0	0	0	0	0	0	X	2	11	0	0	0	0	0
L	33	69	78	67	63	63	52	64	54	X	82	76	90	52	82	94	51
M	39	85	100	69	69	56	36	79	74	x	74	97	87	62	74	69	66
N	57	89	79	63	95	47	54	93	93	X	98	98	91	91	96	86	93
O	42	92	93	86	100	81	76	86	81	X	79	86	98	76	81..	93	88
P	36	92	82	67	85	86	83	71	81	X	94	86	89	67	94	72	83
Q	42	79	93	50	36	43	45	60	57	X	53	69	62	62	76	83	71
R	39	23	31	15	15	26	21	49	43	X	49	31	13	23	28	15	15
S	30	10	9	9	15	9	3	8	3	X	0	23	3	0	0	7	0
Currituek Sound	420	67	67	54	59	57	49	63	61	x	66	70	60	58	66	65	65

Table . Percent Frequency of All Species of Aquatic Vegetation on Back Bay, Virginia and Currituck Sound, North Carolina; as Determined by Each Transect Survey from May 1962 to August 1963.

Transect	Number Samples	1962 May	1962 August	1962 November	1963 Pebruory	1963 May	1963 August
		57	62				
A	21	87	97	67 97	100 81	100 86	100 57
B	30						
C	18				58		94
D	45	73	62	87	38	69	44
E	45	164	100	104	89	184	56
F	51	63	*71	61	51	82	45
G	30	93	97	97	70	93	67
G_1	24	100	100	100	100	100	100
Back Bay	264	77	**78	81	67	87	65
H	18	100	100	100	*** 100	100	100
I	18	100	100	100	89	100	100
J	21	100	100	100	100	100	100
K	45	9	0	4	7	2	4
L	33	73	70	85	76	91	88
M	39	95	97	95	90	90	92
N	57	95	93	100	96	100	96
C	42	81	83	100	86	90	93
P	36	97	100	94	92	83	100
Q	42	88	93	88	93	86	100
R	39	33					51
S	30	47	10 46	13 56	36 17	13 64	43
Currituck	420	74	72	76	****71	74	78

* Eased on 45 samples.
** Based on 258 samples.
*** Based on 12 samples.
**** Based on 414 samples.

Table . Percent Frequency of All Species of Aquatic Vegetation on Back Bay, Virginia, and Currituck Sound, North Carolina; as Determined by Each Transect Survey from November 1963 to November 1964.

Transect	Number Samples	1963 November	1964 November
A	21	29	5
B	30	87	10
C	18	83	6
D	45	41 1/	2
E	45	29	4
F	51	53	10
G	30	87	47
Cl	24	92	42
Back Bay	264	59 2/	14
H	18	67	78
I	18	100	100
J	21	100	100
K	45	0	0
L	33	76	82
M	39	92	77
N	57	100	100
0	42	95	67
P	36	86	94
Q	42	90	76
R	39	72	49
S	30	33	27
Currituck Sound	420	75	69

1/ Based on 39 samples
2/ Based on 258 samples

Table . Percent Species Composition of the Total Dry.Weight of Vegetation on Each August and November Transect Survey, 1958 to 1964, for Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Survey of (Date)	Total Vegetation in Thousands of Pounds	Percent					
		Sago	Celery	Redheadgrass	Muskgrass 1/	Najas	Widgeongrass
Back Bay							
August 1958	6,290	21	7	0	12	59	0
November 1958	5,051	9	1.	0	12	76	0
August 1959	8,026	8	24	3	3	57	1
November 1959	11,222	4	9	3	12	63	6
August 1960	9,581	1	27	3	7	57	2
November 1960	11,353	4	7	7	7	67	6
August 1961	14,740	4	24	13	6	52	1
November 1961	6,493	0	8	12	12	62	2
August 1962	14,093	10	25	19	2	34	6
November 1962	11,019	8	3	19	6	46	14
August 1963	3,802	0	42	1	12	43	6
November 1963	297	0	21	0	4	25	0
November 1964	291	0	2	0	87	10	1
Currituck Sound							
August 1958	17,553	21	5	1	33	39	2
November 1958	18,398	18	2	1	36	44	0
August 1959	22,919	8	10	6	34	30	12
November 1959	38,024	8	1	9	37	33	12
August 1960	32,162	10	16	8	9	48	8
November 1960	32,818	11	5	13	11	51	8
August 1961	44,017	11	11	8	7	28	2
November 1961	31,301	10	4	8	14	37	5
August 1962	48,481	20	11	13	12	22	23
November.1962	31,416	31	1	9	16	33	10
August 1963	51,197	9	22	11	10	35	12
November 1963	29,643	11	4	15	8	43	17
November 1964	32,317	8	5	11	4	65	7

1/ Includes *Chara* sp. and *Nitella* sp.

estimate. For Currituck Sound the range was from plus or minus 21 to 39 percent of the estimate. Normally the greater variance occurred, during seasons or years, when the least amount of vegetation was found.

Confidence limits for percent frequency ranged from plus or minus 5 percent to 6 percent for Back Bay, and from 3 percent to 4 percent for Currituck Sound.

Aside from the statistical analysis we cannot recall any instance in which our intensive field observations of the quantity of vegetation differed from the results of the transect survey. The survey was, in our judgment, very representative of the area.

The striking comparison of the percent frequency of each species on the transect survey and the master survey, which involved over 7,000 well-distributed samples, also attested to the representativeness of the transect survey.

Transect Surveys of Back Bay (1958-64)

In the following discussion of plant abundance, and the accompanying tables, it should be borne in mind that plant abundance does not necessarily imply production of waterfowl foods. Production of seeds, tubers, winterbuds, roots, etc.,is of vital importance if many of these plants are to be of value to waterfowl. Other sections of this report will discuss these characteristics and production. The total mass of the plants, including seeds, tubers, roots, stems, and leaves was sampled on the transect surveys.

As can be readily seen, discussion of abundance, frequency, rank, variation, and distribution of 10 aquatics, on 20 transects, on 23 surveys would be endless.

To simplify annual comparison we consider the November surveys as the ones most indicative of the conditions for waterfowl.

Total Aquatic Production of Back Bay

In total dry weight we calculated approximately 5 million pounds of vegetation in November 1958 in the Back Bay area. This increased to slightly over 11 million pounds in November 1959, and November 1960. In November 1961, productiondropped to approximately 6.5 million pounds. In November 1962, it increased again to about 11 million pounds. It declined drastically to slightly less than 300,000 pounds in November 1963 and 1964; and from all indications November 1965 will be about the same.

Statistical significance of these changes was demonstrated at the 99.5 percent level for the 1958 to 1959 increase, and the 1962 to 1963 decrease; significance at the 95 percent level was demonstrated for the 1960 to 1961 decrease; significance at the 90 percent level was demonstrated for the 1961 to 1962 increase.

No important significance could be domonstrated for the slight 2 percent increase from 1959 to 1960, or the decrease from 1963 to 1964.

The percent frequency of all vegetation on each November transect survey from 1958 through 1964 for Back Bay was 44, 58, 73, 58, 79, 56, and 13 percent. The consecutive changes from year to year were all significant at the 99.5 percent level of confidence.

Total Aquatic Production of Currituck Sound

Total dry weight of all species of aquatics in Currituck Sound in November 1958 was approximately 18 million pounds. Production more than doubled by November 1959 to 38 million pounds. It remained relatively the same in November 1960 at 33 million pounds, but a slight decrease to 25 million pounds was indicated in November 1961. The estimate was approximately 31 million pounds in November 1962. Production remained relatively stable in November 1963 and 1964, at about 30 and 32 million pounds, respectively.

The major increase of 106 percent between November 1958 and November 1959 was significant at the 99.5 percent level of confidence. The other relatively minor changes were not significant even at the 90 percent level of confidence.

The trends in total production for Currituck Sound, including the reduction in November 1961, were nearly identical to that of Back Bay until 1963. Whereas Currituck Sound maintained production at a fairly constant level in 1963 and 1964, the production in Back Bay suffered a drastic decline.

The percent frequency of all vegetation on each November transect survey from 1958 through 1964 for Currituck Sound was 49, 54, 49, 52, 70, 69, and 69 percent. In sequence, only the percent frequency change from 52 to 70 percent between November 1961 and November 1962 was significant at either the 90, 95, or 99.5 percent level of confidence.

Aquatic Plant Species Abundance on Back Bay and Currituck Sound 1958-1964

Aquatic Plant Population Characteristics

The quantity of each species of aquatic plant and changes in relative abundance are important in assessing the value of the area to waterfowl and in the interpretation of environmental influences. The data for all species on each survey are contained in this report, but the quantity of each species on each November survey best reflects the food conditions for waterfowl.

In the tables included in the narrative, the dry weight, percent frequency, and percent that each species comprises of the total weight are shown for each November survey for Back Bay and

Currituck Sound. The relationship between the weight and the frequency is of particular interest, in that an increase in weight without a corresponding gain in percent frequency implies greater growth of the plants without extension of distribution.

The percentage that each species comprises of the total weight is of interest in determining dominance and, in some instances, seems to reflect competition between species. For most species of aquatics in the Back Bay-Currituck Sound Area zonation is poorly defined. Mixtures of several aquatics are most commonly encountered at favorable sites. Some relatively pure stands of certain species are encountered where they are more tolerant or suited to, the conditions of turbidity, soil type; salinity, wave action, etc.

Major Environmental Changes

In examination of the following trends in quantities of each aquatic in Back Bay and Currituck Sound, certain major changes in environmental factors should be kept in mind.

The Back Bay area was virtually a fresh body of water from 1958 through 1961. In most years, turbidity was relatively high from October through June, with noticeable clearing of the water in July through September.

In November 1961, a persistent storm apparently damaged the aquatics on both Back Bay and Currituck Sound.

On March 7, 1962, the "Ash Wednesday" Storm raised the salinity of the Back Bay-Currituck Sound Area to an average of 13 percent of sea strength and the salinity remained relatively stable throughout the growing season. Light penetration of the water increased in some areas.

The salinity of the water decreased on Back Bay to its former low level early in the growing season of 1963; it remained at about 2 percent of sea strength through1963 and 1964.

Dredging activities were underway at the northern end of the Back Bay area in 1963, 1964, and 1965. Turbidity was greater during this time.

Currituck Sound had greater salinitiesthroughout the study than did Back Bay. Light penetration of the water was always greater in Currituck Sound. Currituck Sound underwent much the same major environmental influences, except it did not freshen as much in 1963 as did Back Bay, nor did the dredging activities at the north end of Back Bay appear to affect average turbidity readings in Currituck Sound from 1963 through 1965.

We do not presume to be able to interpret the reasons for all the changes in population characteristics of each species of aquatic. For purposes of this data report certain suggested relationships that seem logical are discussed; these, and other relationships, will be more fully examined prior to publication.

Changes in Total Oven-dry Weight, Percent Frequency, and Percent of Total Aquatic Vegetation, of Each Species on Back Bay, 1958-1964

Sago pondweed population characteristics on each November survey of Back Bay have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	479,000	6	9
1959	487,000	11	4
1960	422,000	7	4
1961	30,000	3	Tr.
1962	862,000	11	8
1963	0	0	0
1964	0	0	0

With exception of 1960, significant decline in abundance occurred each year between the August and November surveys of Back Bay. The decline was normally more pronounced in Back Bay than in Currituck Sound.

Of particular interest are the decline in sago pondweed between August and November 1961; its resurgence to a peak in August and November 1962 when the area was brackish; and its almost total absence in 1963 and 1964, when the area had freshened and dredging activities had increased the turbidity of the water.

In August 1965, sago pondweed was neither sampled nor seen during a transect survey.

As will be discussed more fully, sago pondweed on Back Bay has a very poor production of seed, and virtually no production of tubers. During years when the water was fresh, most of the sago pondweed became chlorotic in August and September and the dead plants fell to the bottom of the bay. In 1962, when the area was brackish, seed and tuber production were enchanced, the plants appeared healthier, and the die-off was not as severe.

Wildcelery population characteristics on each November survey of Back Bay have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	58,000	23	1
1959	1,037,000	30	9
1960	774,000	41	7
1961	507,000	40	8
1962	318,000	43'	3
1963	61,000	45	21
1964	8,000	6	2

The standing crop of wildcelery each November, after a great increase between 1958 and 1959, has progressively declined. However, the August surveys indicated a progressive increase from 1958 through 1962. In conjunction with the percent frequency, this suggests the diminution was more the result of poor survival in the fall, than of poor growth or restriction in distribution. This fall disintegration of wildcelery is not unique to the Back Bay-Currituck Sound Area but is frequently observed elsewhere. The buoyancy, leaf shape,and relatively shallow root system make wildcelery susceptible to uprooting by water turbulence or carp action. The carp food habit study indicated that the seed pods constitute a principal part of their diet late in the summer. Local fishermen frequently fish the wildcelery beds for carp.

Redheadgrass population characteristics on each November survey of Back Bay have been' as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	12,000	4	Tr.
1959	337,000	13	3
1960	794,000	18	7
1961	785,000	25	12
1962	2,148,000	30	19
1963	Tr.	3	Tr.
1964	0	0	Tr.

The trend in all three characteristics of the population of redheadgrass indicates a progressive increase in dominance from 1958 through 1962. In 1958, 1959, and 1960, redheadgrass also increased in abundance between the August and November surveys.

Redheadgrass seemed to be among the early dominants each spring. It seeded early in June, appeared to die-back somewhat in mid-summer, and then had a resurgence of growth and abundant seeding in late summer.

It seems possible that the strong resurgence of redheadgrass may be related to the die-back of wildcelery. Competition for suitable sites by these two species of plants may be reflected in these contrary population dynamics.

The muskgrass population characteristics on each November survey of Back Bay have been as follows;

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	629,000	23	12
1959	1,325,000	19	12
1960	761,000	19	7
1961	762,000	19	12
1962	670,000	14	6
1963	11,000	7	4
1964	253,000	6	87

As previously mentioned the muskgrasses, Chara spp. and Nitella spp., were not recorded individually on the transect surveys until February 1960. Two species of each genera-were known to occur. Further discussion of each genera is also presented.

Muskgrass reached a peak production in both Back Bay and Currituck Sound in November 1959. It declined-most drastically in Back Bay in 1963, along with most other aquatics, when the production dropped from 470,000 pounds to 11,000 pounds dry weight between August and November. Normally it increased each year between August and November.

In all years muskgrass was very scarce during the spring.

In November 1964, it was the most abundant aquatic in Back Bay.

The population characteristics of Chara spp. and Nitella spp. on each November survey of Back Bay have been as follows:

Chara spp.

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1959 1/		(17) 2/	
1960	276,000	8	2
1961	393,000	16	6
1962	670,000	14	6
1963	11,000	5	4
1964	172,000	5	59

Nitella spp.

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1959 1/		(9) 2/	
1960	485,000	16	4
1961	369,000	12	6
1962	0	0	0
1963	Tr.	1	Tr.
1964	80,000	5	27

1/ Not recorded by genera (see muskgrass)
2/ Percent frequency from August 1959 Master Survey

Dr. R. D. Wood identified muskgrass specimens sent to him from Back Bay and Currituck Sound in September 1962 as:

Nitella hyalina
Nitella furcata (possibly var. capitellata)
Chara zeylanica (approaching var. diaphana)
Chara fibrosa

Chara fibrosa was not noted in the Back Bay-Currituck Sound Area during the study until August of 1962 after the increase in salinity. At that time it was widely distributed in Currituck Sound, but still scarce in Back Bay.

In Back Bay, *Chara* spp. apparently declined in 1960 from peak abundance in 1959, as shown by the total weight of muskgrass in November 1959 and the percent frequency of *Chara* spp. on the master survey. The agreement between the transect and master survey data on percent frequencies permits this assumption for 1959 when the muskgrasses were not recorded separately.

Chara spp. declined markedly between August and November 1963 in Back Bay.

As shown by the August 1959 master survey, *Nitella* spp. had a frequency of occurrence of 9 percent in Back Bay. After the increase in salinity to 13 percent of sea strength in 1962, *Nitella* spp. was not encountered on the transect surveys in its former abundance. It was totally absent in November 1962, February and May 1963, and only a trace was found in November 1963. Some recovery was noted in November 1964.

During years when fresh water conditions existed in Back Bay, *Nitella* spp. normally exhibited a great increase in growth between August and November. It would die-back considerably by February of each year and be very scarce or absent by May of each year.

Bushy pondweed, or naiad, population characteristics on each November survey of Back Bay have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	3,849,000	35	76
1959	7,085,000	52	63
1960	7,640,000	72	67
1961	3,997,000	58	62
1962	5,117,000	67	46
1963	73,000	45	25
1964	28,000	6	10

Naiad was the dominant plant at all seasons on the 18 transect surveys from August 1958 through May 1963. Accompanying the drastic decline in total vegetation and in most species, naiad dropped to secondary importance in August 1963.

Frequently naiad increased between August and November, and in later winter and early spring there was no question of its dominance.

Although the ocean water intrusion in March 1962 caused some plasmolysis on naiad early in the summer, there was good growth late in the summer and in early fall.

Seeding was almost totally absent on the naiad in this area.

Widgeongrass population characteristics on each November survey of Back Bay have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	15,000	3	0
1959	654,000	10	6
1960	681,000	9	6
1961	98,000	6	2
1962	1,590,000	14	14
1963	Tr.	4	0
1964	3,000	1	1

The increase in widgeongrass in 1962 was to be expected with the increase in salinity that year. The die-back in 1963 and 1964 corresponds to the general decrease in most of the dominant plants. In the period 1958 through 1962, widgeongrass normally increased substantially between the August and November surveys of Back Bay.

Dwarf spikerush, _Eleocharis parvula,_ population characteristics on each November survey of Back Bay have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	0	3	0
1959	245,000	9	2
1960	257,000	8	2
1961	51,000	5	1
1962	175,000	8	2
1963	20,000	5	7
1964	Tr.	4	Tr.

This spikerush was also a minor constituent of the aquatic plant production. It was frequently seen to be uprooted in the cove areas in late summer and early fall.

Sagittaria, _Sagittaria subulata,_ population characteristics on each November survey of Back Bay have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	9,000	6	Tr.
1959	52j000	4	Tr.
1960	54,000	5	Tr.
1961	263,000	11	4
1962	139,000	6	1
1963	132,000	7	44
1964	Tr.	3	Tr.

Sagittaria was a minor species in the area, except during the period of drastic die-back of the dominant species in 1963. It then became the dominant plant, even though it was also reduced in abundance from the year before, when it comprised only 1 percent of the total weight.

The growth form on this particular variety of Sagittaria subulata was very small, and similar in size to Eleocharis parvula.

Changes in Total Oven-dry Weight, Percent Frequency, and Percent of Total Aquatic Vegetation of Each Species on Currituck Sound, 1958-1964

Sago pondweed population characteristics on each November survey of Currituck Sound have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	3,257,000	28	18
1959	2,948,000	18	8
1960	3,717,000	16	11
1961	3,062,000	13	10
1962	9,600,000	26	31
1963	3,259,000	14	11
1964	2,729,000	14	8

The major distinction in annual abundance of sago pondweed in Currituck Sound occurred in 1962, when the yield tripled in 1 year. The percent frequency from 1958 through 1961 indicates a gradual shrinking in distribution. Throughout the course of the study sago pondweed was healthier, more productive of seeds and tubers, and less disease-ridden in Currituck Sound than in Back Bay. In Currituck Sound it appeared to grow earlier in the spring and to stand erect longer in the fall, than at Back Bay.

Wildcelery population characteristics on each November survey of Currituck Sound have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	281,000	22	2
1959	409,000	16	1
1960	1,555,000	45	5
1961	1,402,000	32	4
1962	452,000	33	1
1963	1,143,000	31	4
1964	1,562,000	40	5

Whereas wildcelery declined progressively on each November survey of Back Bay after 1959, no similar decline occurred on Currituck Sound. The temporary decline in 1962 possibly resulted from the somewhat higher salinities in Currituck Sound than in Back Bay. The August surveys on both areas demonstrated a progressive increase through 1962; however, the increase in Currituck Sound continued through August 1963, but it did not continue in Back Bay. This appears to demonstrate further that climatic factors were not responsible for the decrease in Back Bay in 1963, but, some localized factor, namely turbidity, was responsible.

Wildcelery reached a peak of about 11.5 million pounds dry weight in August 1963. Survival rate between August and November survey varied between 4 percent and 53 percent in Back Bay, and 9 percent and 31 percent in Currituck Sound. The major exception to a similar pattern in the survival rate between August and November in the two areas occurred in 1959 when 53 percent of the wildcelery survived in Back Bay, but only 18 percent survived in Currituck Sound. In all other years the survival rate was slightly higher in Currituck Sound. The reason for this one exception is not known.

Redheadgrass population characteristics on each November survey of Currituck Sound have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	200,000	5	1
1959	3,338,000	20	9
1960	4,150,000	21	13
1961	2,588,000	19	8
1962	2,777,000	32	9
1963	4,587,000	33	15
1964	3,544,000	26	11

Although no trend in dry weight of redheadgrass on the November surveys of Currituck Sound is apparent, nor are the fluctuations clearly related to major environmental factors, the August survey weights demonstrate an increase from 1958 through 1963. As is shown by the November percent frequency values this increase was, at least in part, due to extension of its distribution in Currituck Sound.

It is interesting to note that redheadgrass increased each year in both areas between August and November of 1958, 1959, and 1960, however, it declined in both areas between August and November of 1961, 1962, and 1963. This suggests that a climatic or other major environmental factor, common to both areas, was involved.

Once again the similarity in pattern of growth prior to 1963, and the disparity in the growth of redheadgrass in Back Bay in 1963, points to the turbidity of the Back Bay area as the major cause of decline.

The muskgrass population characteristics on each November survey of Currituck Sound have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	6,621,000	35	36
1959	14,083,000	35	37
1960	3,630,000	20	11
1961	4,528,000	23	14
1962	5,064,000	33	16
1963	2,510,000	24	8
1964	1,139,000	20	4

As previously mentioned muskgrass reached a peak in both areas in November 1959. It has declined in dominance in Currituck Sound since that time as shown by all three of the population characteristics. In 1962, there was a slight increase in abundance and distribution.

Muskgrass normally increased each year between August and November in Currituck Sound, as it did in Back Bay. However, it decreased between August and November 1963.

The general decrease in muskgrass in Currituck Sound may be related to increased competition with other species.

The population characteristics of Chara spp. and Nitella spp. on each November survey of Currituck Sound have been as follows:

Chara spp.

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1959 1/		(20) 2/	
1960	1,644,000	12	5
1961	3,375,000	20	11
1962	4,497,000	28	14
1963	2,393,000	22	8
1964	742,000	14	2

Nitella spp.

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1959 1/		(14) 2/	
1960	1,984,000	11	6
1961	1,153,000	15	4
1962	567,000	6	2
1963	117,000	5	Tr.
1964	397,000	10	1

1/ Not recorded by genera (see muskgrass)
2/ Percent frequency from August 1959 Master Survey

In Currituck Sound, *Chara* spp., after its presumed peak in November 1959, declined in 1960 but increased through August 1963. Its yield and frequency of occurrence were somewhat less in November 1963 and in November 1964, the lowest frequency of occurrence and yieldwererecorded for that season of the year.

Normally, some *Chara* spp. could be found in May of each year and it appears to reach peak abundance in August and September, prior to the period of peak abundance of *Nitella* spp.

Nitella spp. was also retarded in Currituck Sound in 1962, but the lowest yield and frequency of occurrence for the fall season occurred in November 1963.

Bushy pondweed, or naiad, population characteristics on each November survey of Currituck Sound have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	8,039,000	41	44
19599	12,424,000	47	33
1960	16,674,000	52	51
1961	11,455,000	54	37
1962	10,308,000	59	33
1963	12,873,000	68	43
1964	21,076,000	62	65

Of the 23 surveys,naiad was the dominant vegetation on all except three surveys. It was second in abundance to the combined muskgrass species in August and November 1959, and second to widgeongrass in August 1962. *Najas* reached its peak abundance in November 1964. The rather progressive increase in percent' frequency and its percent of the total weight of aquatics attest to its increase and role of dominance.

In Currituck Sound, naiad either increased between each August and November survey or remained relatively constant, with the exception of a decrease between August and November 1963. This characteristic increase of naiad between August and November also occurred in most years in Back Bay.

Widgeongrass population characteristics on each November survey of Currituck Sound have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	0	0	0
1959	4,673,000	31	12
1960	2,573,000	30	8
1961	1,672,000	20	5
1962	3,106,000	37	10
1963	5,110,000	38	17
1964	2,157,000	27	7

Widgeongrass reached its peak production of 11 million pounds in August 1962, however, it died-back considerably prior to November of that year. A similar decline did not occur that year in Back Bay.

A good, enduring stand of widgeongrass occurred in Currituck Sound in 1963, but as noted with several other species, it virtually disappeared in Back Bay that year.

With exception of the August 1962 increase its erratic production does not readily correlate with the more obvious environmental factors.

Dwarf spikerush, Eleocharis parvula, population characteristics on each November survey of Currituck Sound have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	0	0	0
1959	149,000	6	Tr.
1960	338,000	6	1
1961	74,000	2	Tr.
1962	60,000	3	Tr.
1963	120,000	3	Tr.
1964	66,000	5	Tr.

Dwarf spikerush was also a minor constituent of the aquatic vegetation in Currituck Sound. It was not encountered in Currituck Sound until November 1959, but it occurred in all surveys thereafter. Normally, peak production of dwarf spikerush occurred between August and November.

Sagittaria, Sagittaria subulata, population characteristics in Currituck Sound have been as follows:

Year	Dry Weight in Pounds	Percent Frequency	Percent of Total Weight of Aquatics
1958	0	0	0
19-59	0	0	0
1960	175,000	3	1
1961	127,000	3	Tr.
1962	34,000	3	Tr.
1963	41,000	2	Tr.
1964	0	0	Tr.

Sagittaria was not encountered in Currituck Sound until August of 1960, and it appears to have declined since that time. It is confined primarily to the shallow water areas in the northern part of Currituck Sound.

It reached peak abundance in Currituck Sound in May 1962, and declined through the remainder of that year.

TRANSECT ANALYSIS BY SOIL TYPE AND DEPTH

The transect survey of Back Bay on November 8, 1968, was arbitrarily chosen for more detailed analysis of yield by soil type and depth. The data on volume-per square foot are presented in two fashions; first, by the volume per occupied sample, and second, by the volume from all samples taken.

Sago pondweed yield was reduced beyond 41 inches in water depth. Yield was about equal at depths from 24 to 41 inches. It occurred in greatest frequency at depths of 24 to 29 inches,

Wildcelery production increased from 24 to 36 inches, and the depth range from 36 to 65 inches was most productive. Wildcelery had reduced yield at depths of 66 to 71 inches and only a trace was produced in water over'.72 inches deep. It occurred most frequently at depths of 42 to 47 inches.

Redheadgrass was most productive in depths of 24 to 29 inches, and declined progressively thereafter. Only a trace was encountered in depths of 60 inches.

Chara spp. also was most productive in depths of 24 to 29 inches, and also tended to decline with increasing depth. None was found in depths greater than 60 to 65 inches.

Nitella spp. was most productive in those areas where it occurred at depths of 30 to 35 inches, but it declined in production sharply thereafter, and was not found in waters more than 65 inches deep.

Naiad increased its yield progressively from depths of 24 inches to 53 inches, with the 48 to 53 inch interval being the most productive. At greater depths production was somewhat erratic, but even at the 66 to 71 inch interval production was twice that of the 24 to 29 inch, or 30 to 35 inch interval. Only a trace of naiad occurred in depths of 72 to 77 inches.

Widgeongrass was more frequently encountered in the 24 to 29 inch depths, but its yield was greatest between 36 and 41 inches. At the 42 to 47 inch depth the yield was greatly reduced, and it was not encountered in greater depths.

Eleocharis parvula was most productive at the 30 to 35 inch interval, and tended to decline fairly progressively to maximum depths of 59 inches.

Sagittaria subulata occurred in abundance only at the 36 to 41 inch depth, although a trace was found at the 60 to 65 inch interval.

Coontail was scarce in the area and only encountered in the 30 to 35 inch interval.

STATISTICAL ANALYSIS: TRANSECT SURVEYS

A statistical analysis of the data compiled in the transect surveys of May 1958 through November 1964 was done to determine the confidence of the estimates. The analysis was divided into two distinct portions; namely, an analysis of all volume. estimate& and an analysis of all percent frequency estimates. Standard error and confidence limits at 95 percent confidence were computed for all estimated total in the aforementioned surveys2/. Additionally, the true mean value for all volumes and percent frequencies was computed.

For all volume estimates, the surveys were analyzed on the basis of a stratified random survey. Three 2-square-foot samples were taken at each 500 yard interval along each transect line. For the purpose of the volume analysis, however, the three samples taken together were considered to be one 6-square-foot sample. This was done because it was assumed that the variability between the three samples taken in essentially the same area would be far less than that for the entire transect line.

With the above procedure adopted, the mean value was computed for each transect line, and the totals of transect lines $A\text{-}G_1$ and H-S were weighted by area represented and individually averaged to derive a mean for Back Bay and Currituck Sound, respectively. From this mean of average cubic centimeters per sample, expansions were made to thousands of liters and thousands of pounds total vegetation. Variance was computed for each individual transect line and these values were weighted by the area represented and sample-size; and variance for the entire suryey was computed by the method outlined by Freese (1962:30).

Essentially the same process was followed for the analysis of the percent frequency of aquatic vegetation; however, sample size was considered to be each 2-square-foot sample taken. While this may seem to be a severe extension of the rules of statistical technique, vegetation within each transect area is homogeneous enough to allow this procedure. The variance of each transect line was computed and weighted, and variance was computed for each transect survey by the method outlined by Cochran (in Snedecor, 1956:510).

Confidence limits at 95 percent confidence were computed by the standard method of multiplying the standard error by the "t" value for n-l degrees of freedom at the desired confidence level. Degrees of freedom were 87 for Back Bay and 139 for Currituck Sound for all volume computations; and 263 for Back Bay and 419 for Currituck Sound for all-percent frequency computations.

1/ Volume estimates discussed here are for total vegetation; however, the same procedure was followed in all volume computations (i.e., tuber production).

2/ Computations for volume estimates were made only on surveys of August 1958-November 1964, inclusive.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
PATUXENT WILDLIFE RESEARCH CENTER
LAUREL, MARYLAND 20810

TELEGRAMS
Bureau of Sport Fisheries and Wildlife
Washington, D. C. 20240

June 17, 1966

Mr. Jerry Stegman, Chairman
Back Bay-Currituck Sound Coordinating Committee
2104 Hillsboro Street
Raleigh, North Carolina 27600

Dear Jerry:

Copies of the third and fourth volumes of the data report are being sent to the following persons:

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A few additional copies of the Waterfowl Studies, Volume 2, are available if needed, as are copies of the Environmental Factors, Volume 3. We are most limited in copies of the Fish Studies, Volume 4, and have only 1 extra copy of the Vegetation Studies.

Sincerely yours,

John L. Sincock

John L. Sincock
Chief, Section of Wetland Ecology

cc:
Recipients of report

Table . Average cc. Per Sq. Ft., Estimated Thousands of Liters of Vegetation, and Estimated Thousands of Pounds Vegetation (oven-dry weight) with the Standard Error and Confidence Limits at 95 Percent Confidence for Each Transect Survey of Back Bay, Virginia, from August 1958 through November 1964.

Transect Survey	Estimated Average cc Per Sq. Ft.1/	Standard Error as a Percent of the Average	Confidence Limits at 95% Confidence as a Percent of All Estimates	Estimated Thousands of Liters of Vegetation	Confidence Limits at 95% Confidence in Thousands of Liters	Estimated Thousands of Pounds Vegetation (oven-dry wt.)	Confidence Limits at 95% Confidence in Thousands of Pounds (oven-dry weight)
August 1958	30.62	14%	27%	30,980	± 8,364	6,290	± 1,698
October 1958	34.60	20%	39%	35,000	± 13,650	7,071	± 2,757
November 1958	23.78	22%	43%	24,060	± 10,345	5,051	± 2,172
May 1959	5.02	22%	44%	5,080	± 2,235	992	± 436
August 1959	44.05	14%	28%	44,560	± 12,477	8,026	± 2,247
November 1959	55.62	13%	26%	56,270	± 14,630	11,222	± 2,917
February 1960	25.35	25%	50%	25,650	± 12,825	5,213	± 2,606
May 1960	13.48	25%	50%	13,640	± 6,820	2,672	± 1,336
August 1960	52.50	15%	29%	53,110	± 15,402	9,581	± 2,778
November 1960	56.79	14%	28%	57,450	± 16,086	11,353	± 3,179
February 1961	15.13	21%	41%	15,310	± 6,277	3,076	± 1,261
August 1961	79.89	15%	29%	80,820	± 23,438	14,740	± 4,274
November 1961	32.41	15%	29%	32,790	± 9,509	6,493	± 1,883
May 1962	14.22	17%	34%	14,381	± 4,890	2,787	± 947
August 1962	79.25	15%	30%	80,165	± 24,049	14,093	± 4,228
November 1962	53.92	19%	38%	54,542	± 20,726	11,019	± 4,187
February 1963	20.81	23%	46%	21,051	± 9,683	4,225	± 1,943
May 1963	14.72	21%	41%	14,887	± 6,104	2,771	± 1,136
August 1963	21.99	20%	40%	22,250	± 8,900	3,082	± 1,233
November 1963	1.87	26%	51%	1,890	± 964	297	± 151
November 1964	0.94	67%	133%	951	± 1,265	291	± 387

1/ Average weighted by the areas represented by the values comprising the average.

Table . Average cc. Per Sq. Ft., Estimated Thousands of Liters of Vegetation, and Estimated Thousands of Pounds Vegetation (oven-dry weight) with the Standard Error and Confidence Limits at 95 Percent Confidence for Each Transect Survey of Currituck Sound, North Carolina, from August 1958 through November 1964.

Transect Survey	Estimated Average cc Per Sq. Ft.[1]	Standard Error as a Percent of the Average	Confidence. Limits at 95% Confidence as a Percent of All Estimates	Estimated Thousands of Liters of Vegetation	Confidence Limits at 95% Confidence in Thousands of Liters	Estimated Thousands of Pounds Vegetation (oven-dry wt.)	Confidence Limits at 95% Confidence in Thousands of Pounds (oven-dry weight)
August 1958	18.59	18%	36%	79,330	± 28,559	17,553	± 6,319
October 1958	29.84	13%	25%	127,320	± 31,830	27,400	± 6,850
November 1958	18.79	14%	27%	80,180	± 21,649	18,398	± 4,967
May 1959	10.27	20%	39%	43,820	± 17,090	8,703	± 3,394
August 1959	25.07	13%	25%	106,970	± 26,742	22,919	± 5,730
November 1959	38.72	17%	33%	165,220	± 54,523	38,024	± 12,548
February 1960	8.32	16%	31%	35,510	± 11,008	7,364	± 2,283
May 1960	12.49	18%	35%	53,310	± 18,658	10,182	± 3,564
August 1960	39.20	14%	27%	167,290	± 45,168	32,162	± 8,684
November 1960	37.52	17%	33%	160,110	± 52,836	32,818	± 10,830
February 1961	10.86	18%	36%	46,340	± 16,682	9,362	± 3,370
August 1961	35.70	13%	25%	152,350	± 38,087	29,277	± 7,319
November 1961	27.60	13%	26%	117,772	± 30,621	24,808	± 6,450
May 1962	20.69	13%	25%	88,290	± 22,072	17,321	± 4,330
August 1962	56.69	12%	23%	241,899	± 55,637	48,481	± 11,151
November 1962	34.23	15%	29%	146,072	± 42,361	31,416	± 9,111
February 1963	17.31	13%	26%	73,869	± 19,206	14,932	± 3,882
May 1963	21.37	14%	27%	91,173	± 24,617	17,379	± 4,692
August 1963	63.87	11%	21%	272,538	± 57,233	51,197	± 10,751
November 1963	33.99	13%	25%	144,947	± 36,236	29,643	± 7,411
November 1964	38.09	16%	32%	162,529	± 52,009	32,317	± 10,341

1/ Average weighted by the size of areas.

Table . Test of Significance ("T" Test) Comparing the Volumetric Estimates of Vegetation from Successive Transect Surveys from August 1958 to November 1964 of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay		Currituck Sound	
	Percent Change1/	Significance Levels2/	Percent Change1/	Significance Levels2/
August 1958 to October 1958	+13		+61	**
October 1958 to November 1958	-31		-37	**
(August 1958 to November 1958)	-22		+1	
November 1958 to May 1959	-79	***	-45	**
May 1959 to August 1959	+89	***	+144	***
August 1959 to November. 1959	+26		+54	*
November 1959 to February 1960	-54	***	-79	***
February 1960 to May 1960	-48	*	+50	
May 1960 to August 1960	+289	***	+214	***
August 1960 to November 1960	+8		-4	
November 1960 to February 1961	-73	***	-71	***
February 1961 to August 1961	+428	***	+229	***
August 1961 to November 1961	-59	***	-23	
November 1961 to May 1962	56	***	-25	
May 1962 to August 1962	+457	***	+174	***
August 1962 to November 1962	-32		+40	**
November 1962 to February 1963	-61	***	-49	***
February 1963 to May 1963	-29		+23	
May 1963 to August 1963	+49		+199	***
August 1963 to November 1963	-91	***	'47	***
November 1963 to November 1964	-50		+12	

1/ Percent computed' $\frac{B - A}{A}$ (see *heading column 1)

2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent; three indicate significance at 90, 95, and 99.5 percent; and a blank indicates non-significance at the indicated levels.

Table . Test of Significance ("T" Test) Comparing the Volumetric Estimates of Total Vegetation from Each August Transect Survey of Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay		Currituck Sound	
	Percent Change[1/]	Significance Levels[2/]	Percent Change[1/]	Significance Levels[2/]
August 1958 to August 1959	+44	*	+35	
August 1958 to August 1960	+71	**	+111	***
August 1958 to August 1961	+161	***	+92	***
August 1958 to August 1962	+159	***	+205	***
August 1958 to August 1963	-28		+244	***
August 1959 to August 1960	+19		+56	**
August 1959 to August 1961	+81	**	+42	*
August 1959 to August 1962	+80	**	+126	***
August 1959 to August 1963	-50	***	+155	***
August 1960 to August 1961	+52	**	-9	
August 1960 to August 1962	+51	*	+45	**
August 1960 to August 1963	-58	***	+63	***
August 1961 to August 1962	-1		+59	**
August 1961 to August 1963	-72	***	+79	***
August 1962 to August 1963	-72	***	+13	

1/ Percent computed-w (see heading column 1).
2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent confidence; three indicate significance at 90, 95, and 99.5 percent confidence; and a blank indicates non-significance at the indicated levels.

Table , Test of Significance ("T" Test) Comparing the Volumetric Estimates of Total Vegetation from All November Transect Surveys, 1958 to 1964, of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay Percent Change 1/	Back Bay Significance Levels/	Currituck Sound Percent Change 1/	Currituck Sound Significance Levels 2/
November 1958 to November 1959	+134	***	+106	***
November 1958 to November 1960	+139	***	+100	**
November 1958 to November 1961	+36		+47	*
November 1958 to November 1962	+127	**	+82	**
November 1958 to November 1963	-92	***	+81	***
November 1958' to November 1964	-96	***	+103	***
'November 1959 to November 1960	+2		+3	
November 1959 to November 1961	-42	**	-29	
November 1959 to November 1962	-3		-12	
November 1959 to November 1963	-97	***	-12	
November 1959 to November 1964	-98	***	-2	
November 1960 to November 1961	- 4 3	**	-26	
November 1960 to November 1962	-5		- 9	
November 1960 to November 1963	-97	***	-9.	
November 1960 to November 1964	-98	***	+2	
November 1961 to November 1962	+66	*	+24	
November 1961 to November 1963	-94	***	+23	
November 1961 to November 1964	-97	***	+38	
November 1962 to November 1963	-97	***	-1	
November 1962 to November 1964	-98	***	+11	
November 1963 to November 1964	-48		+12	

1/ Percent computed $\frac{B - A}{A}$ (see heading column 1)

2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance at 90 and 95 percent; three indicate significance at 90, 95, and 99.5 percent; and a blank indicates non-significance at the indicated levels.

Table . Test of Significance ("T" Test) Comparing the Volumetric Estimates of Both Widgeongrass and Sago Pondweed from the August and November Transect Surveys from 1961 to 1963 of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay		Currituck Sound	
	Percent Change1/	Significance Levels2/	Percent Change1/	Significance Levels2/
Sago Pondweed				
August 1961 to November 1961	-95.	*	-34	
August 1961 to August 1962	+33		+109	*
November 1961 to November 1962	+2764	**	+214	**
August 1962 to November 1962	-41		-1	
August 1962 to August 1963	-100	**	-54	*
November 1962 to November 1963	-100	**	-66	**
August 1963 to November 1963	0		-27	
August 1961 to August 1963	-100	**	-3	
November 1961 to November 1963	-100		+6	
Widgeongrass				
August 1961 to November 1961	-9		+100	**
August 1961 to August 1962	+656	**	+1199	***
November 1961 to November 1962	+1541	**	+98	***
August 1962 to November 1962	+97		-72	**
August 1962 to August 1963	-73	**	-45	*
November 1962 to November 1963	-100	***	+65	
August 1963 to November 1963	-100	**	-15	
August 1961 to August 1963	+108		+665	***
November 1961 to November 1963	-100	*	+225	***

1/ Percent computed $\frac{B - A}{A}$ (see heading column 1)

2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent confidence; three indicate significance at 90, 95, and 99.5 percent confidence; and a blank indicates non-significance at the indicated levels.

Table . Comparative Values of Estimated Percent Frequency of Aquatic Vegetation and Estimated Thousands of Pounds of Aquatic Vegetation with the Confidence Limits at 95 Percent Confidence on August Transect Surveys of Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Survey	Estimated Percent Frequency	Confidence Limits[1]	Estimated Thousands of Pounds	Confidence Limits[2]
Back Bay				
August 1958	63	± 6	6,290	± 1,698
August 1959	55	± 6	8,026	± 2,247
August 1960	74	± 6	9,581	± 2,778
August 1961	70	± 6	14,740	± 4,274
August 1962	76	± 6	14,093	± 4,228
August 1963	62	± 6	3,082	± 1,233
Currituck Sound				
August 1958	50	± 4	17,553	± 6,319
August 1959	57	± 4	22,919	± 5,730
August 1960	61	± 3	32,162	± 8,684
August 1961	61	± 3	29,277	± 7,319
August 1962	64	± 4	48,481	± 11,151
August 1963	72	± 3	51,197	± 10,751

1/ Expressed in percent 'frequency
2/ Expressed in thousands of pounds

Table . Precent Frequency of All Species of Aquatic Vegetation and Estimated Thousands of Pounds of Aquatic Vegetation with the Confidence Limits at 95 Percent on All November Transect Surveys of Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Survey	Estimated Percent Frequency	Confidence Limits 1/	Estimated Thousands of Pounds	Confidence Limits 2/
Back Bay				
November 1958	44	± 5	5,051	± 2,172
November 1959	58	± 6	11,222	± 2,917
November 1960	73	± 6	11,353	± 3,179
November 1961	58	± 6	6,493	± 1,883
November 1962	79	± 5	11,019	± 4,187
November 1963	56	± 6	297	± 151
November 1964	13	± 4	291	± 387
Currituck Sound				
November 1958	49	± 4	18,398	± 4,967
November 1959	54	± 4	38,024	± 12,548
November 1960	49	± 4	32,818	± 10,830
November 1961	52	± 4	24,808	± 6,450
November 1962	70	± 3	31,416	± 9,111
November 1963	69	± 4	29,643	± 7,411
November 1964	69	± 4	32,317	± 10,341

1/ Expressed in percent frequency
2/ Expressed in thousands of pounds

Table . Test of Significance ("T" Test) Comparing the Estimates of Percent Frequency of Aquatic Vegetation from All August Transect Surveys, 1958-1964, of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay: Increment During Interval 1/	Back Bay: Significance Level 2/	Currituck Sound: Increment During Interval 1/	Currituck Sound: Significance Level 2/
August 1958 to August 1959	-8	*	+7	**
August 1958 to August 1960	+11	**	+11	***
August 1958 to August 1961	+7		+11	***
August 1958 to August 1962	+13	***	+14	***
August 1958 to August 1963	-1		+22	***
August 1959 to August 1960	+19	***	+4	
August 1959 to August 1961	+15	***	+4	
August 1959 to August 1962	+21	***	+7	**
August 1959 to August 1963	+7	*	+15	***
August 1960 to August 1961	-4		0	
August 1960 to August 1962	+2		+3	
August 1960 to August 1963	-12	**	+11	***
August 1961 to August 1962	+6		+3	
August 1961 to August 1963	-8	*	+11	***
August 1962 to August 1963	-14	***	+8	***

1/ Expressed in percent frequency, not percent change.

2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent; three indicate significance at 90, 95, and 99.5 percent; and a blank indicatesnon-significance at the indicated levels.

Table . Test of Significance ("T" Test) Comparing the Estimates of Percent Frequency of Aquatic Vegetation from All November Transect Surveys, 1958-1964, of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay: Increment During Interval 1/	Back Bay: Significance Level 2/	Currituck Sound: Increment During Interval 1/	Currituck Sound: Significance Level/
November 1958 to November 1959	+14	***	+5	
November 1958 to November 1960	+29	***	0	
November 1958 to November 1961	+14	***	+3	
November 1958 to November 1962	+35	***	+21	***
November 1958 to November 1963	+12	***	+20	***
November 1958 to November 1964	-31	***	+20	***
November 1959 to November 1960	+15	***	-5	
November 1959 to November 1961	0		-2	
November 1959 to November 1962	+21	***	+16	***
November 1959 to November 1963	-2		+15	***
November 1959 to November 1964	-45	***	+15	***
November 1960 to November 1961	-15	***	+3	
November 1960 to November 1962	+6		+21	***
November 1960 to November 1963	-17	***	+20	***
November 1960 to November 1964	-60	***	+20	***
November 1961 to November 1962	+21	***	+18	***
November 1961 to November 1963	-2		+17	***
November 1961 to November 1964	-45	***	+17	***
November 1962 to November 1963	-23	***	-1	
November 1962 to November 1964	-66	***	-1	
November 1963 to November 1964	-43	***	0	

1/ Expressed as the change in percent frequency.

2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent; three indicate significance at 90, 95, and 99.5 percent confidence; and a blank indicates non-significance at the indicated levels.

Table . Percent Frequency[1] of All Species of Aquatic Vegetation with Confidence Limits at 95% Confidence for Back Bay, Virginia, and Currituck Sound, North Carolina, for Each Transect Survey from May 1958 through November 1964.

Transect Survey of (Date)	Back Bay Percent Frequency	Back Bay Confidence Limits in % Frequency	Currituck Sound Percent Frequency	Currituck Sound Confidence Limits in % Frequency
May 1958	62	± 6	61	± 4
July 1958	64'	± 6	62	± 4
August 1958	63	± 6	50	± 4
October 1958	51	± 6	52	± 4
November 1958	44	± 5	49	± 4
May 1959	49	± 6	44	± 4
August 1959	55	± 6	57	± 4
November 1959	58	± 6	54	± 4
January 1960	54	± 6	--	--
February 1960	54	± 6	61	± 4
May 1960	63	± 6	64	± 4
August 1960	74	± 6	61	± 3
November 1960	73	± 6	49	± 4
February 1961	72	± 6	60	± 3
August 1961	70	± 6	61	± 3
November 1961	58	± 6	52.	± 4
May 1962	76	± 6	66	± 4
August 1962	76	± 6	64	± 4
November 1962	79	+ 5	70	± 3
February 1963	63	7 6	65	± 4
May 1963	86	± 5	69	± 3
August 1963	62	± 6	72	± 3
November 1963	56	± 6	6 9	± 4
November 1964	13	± 4	69	± 4

1/ Percent frequency (an average) value weighted by the size of areas.

Table . Test of Significance ("T" Test) Comparing the Percent Frequency of Vegetation Estimates from Successive Transect Surveys from May 1958 to November 1964 of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay		Currituck Sound	
	Increment in Percent Frequency1/	Significance Levels/	Increment in Percent Frequency1/	Significance Levels2/
May 1958 to July 1958	+2		+1	
July 1958 to August 1958	-1		-12	***
August 1958 to October 1958	-12	***	+2	
October 1958 to November 1958	-7	*	-3	
(August 1958 to November 1958)	-19	***	-1	
November 1958 to May 1959	+5		-5	
May 1959 to August 1959	+6		+13	***
August 1959 to November 1959	+3		- 3	
November 1959 to January 1960	-4		No January Survey	
January 1960 to February 1960	0			
November 1959 to February 1960	-4		+7	**
February 1960 to May 1960	+9	**	+3	
May 1960 to August 1960	+11	**	-3	
August 1960 to November 1960	-1		-12	***
November 1960 to February 1961	-1		+11	***
February 1961 to August 1961	-2		+1	
August 1961 to November 1961	-12	**	-9	**
November 1961 to May 1962	+18	***	+14	***
May 1962 to August 1962	0		-2	
August 1962 to November 1962	+3		+6	**
November 1962 to February 1963	-16	***	-5	*
February 1963 to May 1963	+23	***	+4	
May 1963 to August 1963	-24	***	+3	
August 1963 to November 1963	6-		-3	
November 1963 to November 1964	-43	***	0	

1/ Expressed as a change in the percent frequency.
2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent; three indicate significance at 90, 95, and 99.5 percent; and a blank indicates non-significance at the indicated levels.

Table . Test of Significance ("T" Test) Comparing the Percent Frequency Estimates of Both Widgeongrass and Sago Pondweed from the August and November Transect Surveys from 1961 to 1963 of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay: Increment in Percent Frequency 1/	Back Bay: Significance Levels 2/	Currituck Sound: Increment in Percent Frequency 1/	Currituck Sound: Significance Levels/
Sago Pondweed				
August 1961 to November 1961	-6	***	-5	*
August 1961 to August 1962	+8	**	+4	
November 1961 to November 1962	+9	***	+13	***
August 1962 to November 1962	-5	*	+4	
August 1962 to August 1963	-15	***	-6	**
November 1962 to November 1963	-12	***	-12	***
August 1963 to November 1963	-2	**	-2	
August 1961 to August 1963	-5	***	-2	
November 1961 to November 1963	-3	**	+1	
Widgeongrass				
August 1961 to November 1961	0		+4	
August 1961 to August 1962	+9	***	+20	***
November 1961 to November 1962	+8	***	+17	***
August 1962 to November 1962	-1		+1	
August 1962 to August 1963	-3		-4	
November 1962 to November 1963	-10	***	+1	
August 1963 to November 1963	-7	***	+6	**
August 1961 to August 1963	+6	**	+16	***
November 1961 to November 1963	-2		+18	***

1/ Expressed as change in percent frequency of the species.
2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent confidence; three indicate significance at 90, 95, and 99.5 percent confidence; and a blank indicates non-significance at the indicated levels.

Table . Test of Significance ("T" Test) Comparing the Percent Frequency Estimates of Both *Najas guadalupensis* and Celery from the August and November Transect Surveys from 1961 to 1963 of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay: Increment in Percent Frequency 1/	Back Bay: Significance Levels/	Currituck Sound: Increment in Percent Frequency 1/	Currituck Sound: Significance Levels 2/
Najas				
August 1961 to November 1961	-16	***	-2	
August 1961 to August 1962	-10	**	-9	***
November 1961 to November 1962	-12	***	+5	*
August 1962 to November 1962'	+7		+12	***
August 1962 to August 1963	-16	***	+20	***
November 1962 to November 1963	-24	***	+9	***
August 1963 to November 1963	-1		+1	
August 1961 to August 1963	-27	***	+11	***
November 1961 to November 1963	-12	**	+14	***
Celery				
August 1961 to November 1961	-3		-15	***
August 1961 to August 1962	+11	**	0	
November 1961 to November 1962	0		+1	
August 1962 to November 1962	-14	***	-14	***
August-1962 to August 1963	+3		+16	***
November 1962 to November 1963	+1		-2	
August 1963 to November 1963	-15	***	-32	***
August 1961 to August 1963	+14	***	+16	***
November 1961 to November 1963	+1		-1	

1/ Expressed as -a-change in the percent frequency of the species.

2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent; three indicate significance at 90, 95, and 99.5 percent; and a blank indicates non-significance at the indicated levels.

Table . Test of Significance ("T" Test) Comparing the Percent Frequency Estimates of Both Redheadgrass and <u>Chara</u> sp. from the August and November Transect Surveys from 1961 to 1963 of Both Back Bay, Virginia, and Currituck Sound, North Carolina.

Transect Surveys Compared (Interval A to B)	Back Bay		Currituck Sound	
	Increment in Percent Frequency 1/	Significance Levels 2/	Increment in Percent Frequency 1/	Significance Levels/
Redheadgrass				
August 1961 to November 1961	+5	**	+3	
August 1961 to August 1962	+11	***	+6	**
November 1961 to November 1962	+5	*	+13	***
August 1962 to November 1962	-1		+10	***
August 1962 to August 1963	-16	***	+11	***
November 1962 to November 1963	-24	***	+1	
August 1963 to November 1963	-9	***	0	
August 1961 to August 1963	-5	**	+17	***
November 1961 to November 1963	-19	***	+14	***
Chara				
August 1961 to November 1961	+2		+6	**
August 1961 to August 1962	- 3		+8	***
November 1961 to November 1962	-3		+8	***
August 1962 to November 1962	+3		+6	**
August 1962 to August 1963	+5	*	0	
November 1962 to November 1963	-10	***	-6	**
August 1963 to November 1963	- 1 3	***	0	
August 1961 to August 1963	+2		+8	***
November 1961 to November'1963	-13	**	+2	

1/ Expressed'as a change in the percent frequency of the species.

2/ One asterisk indicates significance only at 90 percent confidence; two indicate significance only at 90 and 95 percent confidence; three indicate significance at 90, 95, and 99.5 percent confidence; and a blank indicates non-significance at the indicated levels.

Additionaly, a test of significance ("t" test) was performed to compared individual volume estimates and to compare individual percent frequencies in cases where proof of a significant difference, or lack of it, was desired. This was done by the standard method of dividing the difference of the estimated means ($\bar{d}$) by the standard error of the difference ($S\bar{d}$).

Results

All results of the tests of significance and volume and percent frequency computations are listed in the accompanying tables. The tests of significance showed that values ranged from highly -significant (t value> 2.81) to highly insignificant (t value< 1.00). In general, confidence limits at 95 percent confidence for volume computations concerning Back Bay ranged from plus or minus 26 percent of the estimate to plus or minus 51 percent of the estimate. For Currituck Sound, however, the range was from plus or minus 21 percent of the estimate to plus or minus 39 percent. Corresponding confidence limits for percent frequency computations ranged from plus or minus 5 percent frequency to plus or minus 6 percent for Back Bay, and from plus or minus 3 percent frequency to plus or minus 4 percent for Currituck Sound.

Justification for Method

In general, an analysis of a systematic sampling program such as was conducted for this report is extremely difficult. In fact, according to many statistical experts, there is no way to analyze a systematic survey except as a random survey. Also, it has been noted by Freese (1964:61) that in most cases a systematic survey, analyzed as a random survey, provides a higher degree of accuracy than a random survey would provide.

This is the method that was followed in the analysis of the data for both volumetric and percent frequency estimates. For volume estimates, a stratified random sampling technique was used. This was necessary due to the fact that for all practical purposes a systematic survey was conducted on each of the strata of a totally systematic survey.

For the percent frequency data, the same type of analysis was performed, and for the same reasons. Additional justification for the percent frequency analysis is found by perusal of the data obtained in the master surveys of 1959, 1960, and 1962. In the master surveys, it was found that percent frequency estimates almost exactly equaled those which were obtained from individual transect surveys.

Sago Pondweed Tank Studies

An analysis of variance ("F" test) was performed on the results of the Sago Pondweed tank studies to ascertain any significant differences in growth at the various salinities. It was determined that for purposes of the analysis there were eight replicates at each of the four salinity levels. Four of the replicates at each level were from salinity tests and four were from disease tests. The replicates from both the disease tests and salinity tests were combined due to the presence of extensive lesions on both sets of plants, including the controls in the disease study.

The analysis of variance was performed by the method outlined by Snedecor (1956), and a highly significant "F" value was obtained. Subsequent to this operation, Duncan's multiple range test was performed to determine individual differences.

In general, the growth differences at each of the four salinities were significant.:

RELATIVE ABUNDANCE OF AQUATIC VEGETATION IN BACK BAY AND CURRITUCK SOUND TO OTHER COASTAL HABITATS

Because of the great concern expressed about the lack of aquatic vegetation in Back Bay and Currituck Sound the impression could be created that this is an area now virtually devoid of aquatic plants, or that it rates poorly in comparison to other similar habitats.

In many years, nothing could be further from the truth.

To my knowledge no similar habitat has been so thoroughly studied and quantitative comparison to data from other areas is impossible. Therefore, based solely on my experience of having seen many habitats throughout the United States, I would rate Back Bay and Currituck Sound among the most productive during its good years, However, from 1963 through 1965, Back Bay must surely have ranked among the least productive. The years of non-productivity plus certain large areas which are consistently devoid of aquatics are the real crux of the problem of aquatic plant production in Back Bay and Currituck Sound.

THEORETICAL MAXIMUM AQUATIC PLANT PRODUCTION IN BACK BAY AND CURRITLJCK SOUND

Better evaluation of the known quantities of aquatic vegetation is possible if they are compared to a theoretical maximum quantity. Several methods could be used to estimate the maximum quantity of aquatic vegetation that would be possible. Two methods are employed here. In the first method, certain assumptions are made that are hopefully realistic. The second method would represent the theoretical maximum if our first assumptions are incorrect.

The first method assumes that a realistic maximum yield in dry weight of aquatic vegetation is about 1,100 pounds per acre. This is about the average of the peak production of each transect in the productive areas. It is further assumed that only 14,000 acres in Back Bay and 67,000 acres in Currituck Sound have the potential for aquatic plant production under any known management technique. This assumes that much of the void area in Back Bay Proper, the North Landing River, and the south end of Currituck Sound cannot be made more productive. The "realistic theoretical maximum" is therefore 15 million pounds in Back Bay and 74 million pounds in Currituck Sound.

The second method, and a very liberal one, is to assume that the entire 23,222 acres in Back Bay, and 97,959 acres in Currituck Sound could potentially produce aquatics. Also on the liberal side, it could be assumed from the accompanying table on yields per acre that the maximum production of the most productive transect in the period 1958-64 be used for the estimate. The maximunproduction was 1,767 pounds dry weight per acre on transect G_1 in August 1961.

The theoretical maximums based on these most liberal estimates are 41 million pounds in Back Bay and 173 million pounds in Currituck Sound.

The following table presents the estimates of a realistic maximum and a theoretical maximum and the comparison to the highest annual quantities known to exist from 1958-64.

Back Bay

Peak	Estimated Quantity (millions lb.,)	Percent of Realistic Maximum (15 million lb.)	Percent of Theoretical Maximum (41 million lb.)
Oct. 1958	7	47%	17%
Nov. 1959	11	73%	27%
Nov. 1960	11	73%	27%
Aug. 1961	15	100%	-37%
Aug. 1962	14	93%	34%
Aug. 1963	4	27%	10%
Nov. 1964	0.3	2%	1%

Currituck Sound

Peak	Estimated Quantity (millions lb.)	Percent of Realistic Maximum (74 million lb.)	Percent of Theoretical Maximum (173 -million lb.)
Oct. 1958	27	37%	16%
Nov. 1959	38	51%	22%
Nov. 1960	33	45%	19%
Aug. 1961	29	39%	17%
Aug. 1962	48	65%	28%
Aug. 1963	51	69%	30%
Nov. 1964	32	43%	19%

Under the stated conditions of either method,it is seen Back Bay from 1958 through 1962 approach itspotential production to a greater extent than did Currituck Sound. The opposite was true in 1963 and 1964.

The "realistic" maximum yield of aquatic vegetation was actually attained on Back Bay in August 1961, and almost reached in August 1962 when the estimated quantity of 14 million pounds was 93 percent of the maximum. The drastic decline in 1963 and 1964 is obvious, and the bay was truly a non-vegetated mudhole.

As implied, if the stated assumptions in calculating the "realistic" estimate of maximum production are only partially correct, then the percentages that the annual peak crop made up of the potential would be less. However, the "theoretical" maximum is considered exorbitantly high. It seems virtually impossible that the entire area could yield 1,767 pounds dry weight per acre.

Table . Pounds (oven-dry weight) Per Acre of All Species of Aquatic Vegetation on Each Transect Area of Back Bay, Virginia, and Currituck Sound, North Carolina; as Determined by Each Transect Survey from August 1958 to November 1964.

Transect	1958			1959			1960			
	Aug.	Oct.	Nov.	May	Aug.	Nov.	Feb.	May	Aug.	Nov.
A	733	851	512	36	954	1,250	761	265	930	237
B	541	710	712	280	935	1,432	581	329	577	666
C	1,115	1,038	832	99	1,463	978	647	242	1,431	1,463
D	109	278	52	0	228	453	375	214	525	589
E	66	11	34	0	5	0	0	0	28	149
F	144	69	67	0	50	256	46	6	199	294
G	110	171	66	4	89	315	23	54	217	518
G_1	478	706	467	115	848	895	222	222	930	1,005
Back Bay	271	302	218	43	346	483	224	115	413	489
H	707	1,277	670	303	704	894	108	143	1,060	1,146
I	922	994	1,010	641.	1,142	1,166	425	610	1,186	1,026
J	607	520	497	138	458	904	194	254	1,078	795
K	0	0	0	0	0	0	0	0	0	0
L	113	215	184	16	217	167	57	65	266	500
M	38	116	45	26	111	110	67	63	264	263
N	87	268	221	121	228	639	137	184	283	346
O	443	489	323	29'7	503	499	81	274	809	422
P	339	876	377	180	523	1,439	239	206	624	537
Q	149	44	90	56	46	471	24	18	158	109
R	46	154	0	0	115	100	0	3	51	262
S	0	44	124	0	9	0	0	0	0	0
Currituck Sound,	179	280	188	89	234	388	75	104	328	335
Grand Total	197	287	194'	80	255	406	104	106	344	365

Table . Pounds (oven-dry weight) Per Acre of All Species of Aquatic Vegetation on Each Transect Area of Back Bay, Virginia, and Currituck Sound, North Carolina; as Determined by Each Transect Survey from August 1958 to November 1964--continued.

Transect	1961 Feb.	1961 Aug.	1961 Nov.	1962 May	1962 Aug.	1962 Nov.	1963 Feb.	1963 May	1963 Aug.	1963 Nov.	1964 Nov.
A	60	187	315	79	148	204	119	'52	72	4	4
B	234	957	447	113	970	771	270	312	295	36	0
C	224	1,723	753	237	1,574	1,176	164	263	49	0	0
D	207	468	265	70	286	532	116	45	178	5	0
E	113	158	51	134	473	51	97	32	6	0	0
F	65	490	102	59	369	528	202	136	160	4	2
G	67	779	351	113	700	264	330	54	261	0	100
G1	202	1,767	890	350	1,368	1,120	255	295	572	131	0
Back Bay	132	635	280	120	607	475	182	119	164	13	13
H	220	917	445	268	1,688	640	246	88	323	37	215
I	307	973	567	487	1,223	927	622	469	959	522	476
J	162	605	356	400	1,243	1,174	392	327	1,026	633	140
K	0	0	0	0	0	0	0	0	1	0	0
L	88	354	236	146	495	428	93	106	552	230	534
M	147	96	251	364	475	340	157	116	560	233	166
N	138	356	301	121	255	359	289	218	609	377	475
O	252	729	578	212	565	356	101	274	544	428	520
P	149	304	610	455	1,270	372	276	548	1,320	806	819
Q	48	420	292	280	811	525	382	371	972	661	351
R	2	13	8	21	127	27	25	19	141	77	79
S	0	4	0	4	0	0	2	0	93	41	42
Currituck Sound	96	299	253	177	495	321	152	177	523	303	330
Grand Total	103	363	258	166	516	350	158	166	454	247	269

As frequently implied in this report the peak quantity of vegetation is not the sole standard whereby final assessment of the area for waterfowl ends. Survival of the standing crop, seed and tuber production, and aquatic plant species composition are all important. If in fact, the potential production was reached in Back Bay in 1961 and 1962, better seed and tuber production and more favored waterfowl foods would have further enhanced the potential for waterfowl.

As mentioned elsewhere in this report, and as I interpret the historical account of vegetation abundance in the area, Back Bay fluctuates more widely in the production of aquatics than does Currituck Sound. Back Bay varied between: 2 and 100 percent of its potential, whereas Currituck Sound was more stable at 37 to 69 percent of its potential production.

This relatively greater stability could have influence on waterfowl use by establishing the habit of wintering where the food supply is more dependable.

NON-VEGETATED AREAS IN BACK BAY AND CLJRRITUCK SOUND

In the discussion of theoretical maximum production of aquatic vegetation,reference was made to certain non-vegetated "problem" areas that may never again be vegetated. The four master surveys clearly illustrate the location of these areas. Although there are certain smaller units that are non-vegetated the most important are Back Bay, referred to here as Back Bay Proper to distinguish it from the entire area, the North Landing River, and the southern end of Currituck Sound.

From the few historical accounts of the vegetation of the Back Bay-Currituck Sound Area, one could assume that at least Back Bay Proper and the North Landing River were productive of aquatic vegetation. However, no reference can be found that would indicate that the deeper waters at the south end of Currituck Sound -eves 'were productive. Because of the 9-11 feet depths of the water, the predominantly sandy soils, and the long fetch of the wind through the southern end of Currituck Sound,it is most unlikely that the area ever did support much aquatic vegetation.

Aside from the years of poor aquatic growth over the entire area, the problem areas are then, in essence, the North Landing River and Back Bay Proper. These two areas have many similar characteristics. They both receive the greatest quantity of drainage of any subdivision of the area; silt deposits are excessive as shown in the accompanying tables and maps; silt is the predominant soil in both areas; water depths are greater than most other areas; the water quality, in particular the turbidity, is least desirable for the growth of aquatics; the fetch of the wind is relatively great in both areas. The North Landing River, which is the least productive of the two problem areas, is subjected to the added adverse factor of repeated dredging of the Intracoastal Waterway and the passage of large ships that continually create turbidity and disturb waterfowl.

I have no doubt that if a similar dredging and shipping operation is put through Back Bay most, if not all, of the area would be rendered as non-productive as the North Landing River.

It is interesting to note that the soft, semi-liquid silt soils that cover Back Bay Proper and the North Landing River are the most productive for aquatic plants when they are used as the soils in tank studies. This was clearly illustrated in the bioassay of aquatic plants in 1960. As shown in the tables, 484 sago pondweed tubers were produced in the silt soils taken from the non-vegetated areas as compared to only 38 tubers in the loam soils taken from the productive areas. Also the yield of total vegetation of all species was approximately twice as great in the "non-productive" silt soils.

The reasons that these silt soils are potentially, but actually not, productive are fairly obvious. Approximately 80 gallons of extremely turbid water-were collected from Back Bay Proper and the suspended silts were permitted to settle for several days. The textural and organic carbon analyses by the Soil Survey Laboratory revealed that these sediments were composed of 0.4 percent sand, 32.7 percent silt, 66.9 percent clay; the organic carbon was about 7.7 percent.

A textural analyses of samples taken from the bottom of Back Bay in August 1959 showed that the bottom surface soil was 62.8 percent silt, 23.4 percent clay, and 13.8 percent sand; the organic carbon was 3.74 percent.

Therefore, of the bottom soil composition, a relatively greater proportion of the clay contributes to turbidity than does the silt or sand.

These fine soil particles, plus the relatively high organic carbon, contribute to a fairly high cation exchange capacity whereby nutrients are more readily available to aquatic plants. As seen in the table, the soil sample from Back Bay had the highest cation exchange capacity of the 12 samples collected to represent major subdivisions of the entire area. It is considerably lower on the North Landing River but I believe that sample was not completely representative of the area.

On both areas the original and third pH reading after drying and rewetting were higher than all other samples.

It is an oddity that some of the soils that are potentially the most productive are in actuality the least productive. They contribute more directly to turbidity which is the primary limitation to aquatic plant growth.

If it were not for the turbidity, created primarily by the wind, these problem areas would support lush growths of aquatics as they apparently did prior to the heavy continued siltation of the area.

In years of warm springs and early summers without excessive winds, increased aquatic plant growth occurred in these problem areas and in adjoining areas that are affected by the turbidity created in the problem areas. Canversely, when cold, windy weather continues through May and June, aquatic plant production in the problem areas and adjoining areas is severely limited. Herein is the primary natural cause of the great fluctuations in plant production in Back Bay and Currituck Sound. However, other causes exist and are important. Salinity fluctuations and prevalence of plant diseases cannot be ignored as factors affecting aquatic plant production.

Turbidities caused by the activities of man can be even more devastating to aquatic plant production than the lesser turbidities created by the wind. Dredging of canals and ditches has been a primary cause of poor aquatic plant growth in certain years.

MASTER SURVEYS OF AQUATIC VEGETATION IN BACK BAY AND CURRITUCK SOUND

The master surveys were conducted in August of 1959, 1960, and 1962. They were designed to provide a more complete mapping of the distribution of each aquatic. Maps of the distribution of each aquatic accompany this report.

Field Procedures on the Master Surveys

The entire area was gridded into quadrates, 1,000 yards on each side. In each quadrate that was entirely an open water area, 10 one-half foot square samples were taken systematically with oyster nippers. Proportional sampling was used in quadrates that were not completely open water areas. The oyster nippers were modified with a metal plate similar to the modification on the oyster tongs used on the transect survey, but they were only one-fourth of the size.

The number of samples taken on each area was as follows:

	1959	1960	1962
Back Bay	1,463	1,469	1,426
Currituck Sound	5,304	5,465	5,591
Total	6,767	6,934	7,017

Water depth, soil type, and presence of each aquatic plant were recorded for each sample. Staff gauge readings were recorded each day that field work was conducted, and water depths were corrected to the average water level during the survey. No quantitative measurement was made of the vegetation because of the great number of samples taken, and the time that would have been required to wash and measure them. An arbitrary rating of trace or more than a trace was assigned to each aquatic plant; however, because of the accuracy of the transect survey data these quantitatitve ratings were never tabulated for the master surveys. Machine data processing was used for the 1960 data.

Three or 4 crews of 2 or 3 men normally completed each master survey in about 3 week's time. The master surveys were initiated immediately after completion of the transect surveys in the first week in August.

Comparison of the Percent Frequencies of Each Aquatic Plant on the 1959, 1960, and 1962 Master Surveys with Corresponding Transect Surveys

Comparison is made in the accompanying tables of the percent frequency of each species of aquatic on the August master surveys with the corresponding transect surveys.

As indicated by the sampling intensity,the master survey was approximately 5 1/2 times as intense on Back Bay as the transect survey and 13 times as intense on Currituck Sound as was the transect survey.

There is remarkable agreement of the data from the two surveys in all 3 years. Assuming greater accuracy of the master survey it is concluded the the transects on Back Bay sampled the vegetated areas somewhat more intensively than the non-vegetated areas. However, for the expansion to total weight the transects were weighted by the area represented and this served to increase the accuracy.

Percent Frequency of Each Aquatic in Each of the Waterfowl Areas, 1959, 1960, 1962

The master survey data for 1959, 1960, 1962 arepresented for each of the 20 subdivisions of the entire area on which waterfowl populations were determined. Area number 8 was not sampled in 1959; however, as shown for 1960 and 1962,only about 1 percent of the samples was vegetated and it was virtually the same in 1959. Area number 1 was not sampled in 1960 or 1962 but it also was about the same as in 1959.

These master survey data are related to waterfowl use in graphs depicting food conditions, disturbance factors,and waterfowl use on each of the 20 areas.

Maps of the Distribution of Each Aquatic in 1959, 1960 and 1962

The maps from the master surveys depict the percent frequency of each aquatic in each quadrate. Thus,10 dots represent:100 percent frequency, 9 dots represent 90 percent frequency, etc. Soil types, and the samples containing no vegetation are similarly shown. In some instances, the dots appear on the adjacent land area on the map but these apply only to the water area in that quadrate.

The three large areas: where vegetation was scarce are obvious. They are the south end of Currituck Sound (Section A), the North Landing River (Section C), and Back Bay Proper (Section D). Excessive depths seem to be the primary factor responsible for the void area in Section A, and silt soils, turbidity, and depth are the primary factors in Section C and Section D.

Table . Percent Frequency of Each Species of Vegetation on the Back Bay and Currituck Sound Area Encountered on the August-September 1959 Master Survey and Comparison to Frequencies from the August Transect Survey.

	Currituck Sound			Back Bay		
	Master No.	Survey %	Transect Survey %	Master No.	Survey	Transect Survey
Sago	744	14.0	17	141	9.6	12
Celery	1828	34.5	37	538	36.8	41
Redheadgrass	671	12.7	13	78	5.3	8
Chara	1065	20.1	--	247	16.9	--
Nitella	756	14.3	--	136	9.3	--
(Musk Grass)	(1349)	25.4	27	(272)	18.6	18
Najas	2180	41.1	43	665	45.5	45
Widgeongrass	1255	23.7	26	83	5.7	7
Eleocharis	58	1.1	0.5	65	4.4	7
Sagittaria	0	0	0	8	0.6	0
Anacharis	1	0.02	0	1	0.1	0
No Vegetation	2247	42.4	37	598	40.9	39
Vegetated	3057	57.6	63	865	59.1	61
No. Samples	5304		420	1463		264

Table . Percent Frequency of Each Species of Vegetation on the Back Bay and Currituck Sound Areas Encountered on the August 1960 Master Survey; and Comparison to Frequencies from the August 1960 Transect Survey.

	Currituck Sound		Back Bay	
	Master	Transect	Master	Transect
Sago	14.4	11	4.6	8
Celery	40.1	40	41.6	55
Redheadgrass	14.2	14	7.6	15
Chara	15.6	14	14.2	23
Nitella	6.2	6	7.8	11
Najas	54.4	56	57.2	68
Widgeongrass	24.9	25	5.9	10
Eleocharis	2.0	3	3.7	11
Sagittaria	1.3	2	2.3	6
Anacharis	0.1		0.3	
Potamogeton berchtoldi	1.0	1	0.2	
No Vegetation	35.9	34	34.2	22
Vegetated	64.1	66	65.8	78
No. Samples	5465	420	1469,	264

Table . Percent Frequency of Each Species of Vegetation on the Back Bay and Currituck Sound Areas Encountered on the August 1962 Master Survey; and Comparison to Frequencies from the August 1962 Transect Survey.

	Currituck Sound		Back Bay	
	Master	Transect	Master	Transect
Sago	22.0	22	6.6	16
Celery	47.8	47	43.8	57
Redheadgrass	23.6	22	27.3	31
Chara	22.6	22	10.4	10
Nitella	1.3	1	0.1	3
Najas	45.3	47	49.9	62
Widgeongrass	32.3	36	9.8	16
Eleocharis	2.0	3	3.5	7.
Sagittaria	1.5	1	3.2	8.
Anacharis	0.1	0	0.2	0.4
Potamogeton berchtoldi	0.2	0.4	0.4	1 .
Ceratophyllum	0	0	0	0.4
Unidentified	0	0	0	0
No Vegetation	30.9	28	33.3	22
Vegetated	69.1	72	66.7	78
No. Samples	5591	420	1426	258.

Table . Percent Frequency of Each Species of Aquatic Vegetation in Each Waterfowl Area from the Master Survey, August-September 1959,

Area	Samples	Sago	Celery	Redhead grass	Chara	Nitella	Najas	Widgeon grass	Eleo-charis	Sagit-taria	Vege-tated	No Vege-tation
1	9	0	78	0	22	0	100	0	0	0	100	0
2	95	3	86	11	35	14	87	16	5	4	98	2
3	99	12	85	5	36	18	86	24	4	2	100	0
4	281	16	48	5	15	7	66	2	5.	0	81	19
5	592	8	6	0	1	1	11	--	0	0	20	80
6	2'92	8	46	8	31	25	58	14	--	a--	77	23
7	113	7	63	22	39	18	80	3	32	4	96	4
8												
9	71	48	89	61	37	31	96	38	0	0	96	4
10	177	35	87	52	49	34	76	72	3	0	98	2
11	22	0	50	36	36	23	32	0	36	0	77	23
12	37	0	0	0	0	0	0	0	0	0	0	100
13	671	0	7	--	1	1	-3	3	--	0	7	93
14	536	9	21	13	12	5	21	15	2	0	29	71
15	329	--	42	16	30	14	53	10	8	0	64'	36
16	426	33	69	12	59	43	52	34	1	0	99	1
17	917	12	33	9	24	22	55	16	1	0	63	27
18	734	36	66	29	30	15	67	51	1	0	95	5
19	352	22	33	14	13	-18	58	41	--	0	66	24
20	1015	1	9	3	4	2	23	15	0	a	30	70
	6768											

-- Less than 0.5%.
Area #8 not sampled but this is a northerly extension of Area #13 and is similarly-vegetated.

Table . Percent Frequency of Each Species of Aquatic Vegetation in Each Waterfowl Area from the Master Survey, August 1960.

Area	Number Samples	Sago	Celery	Redhead-grass	Chara	Nitella	Najas	Widgeon-grass	Eleo-charis	Sagit-taria	Ana-charis	Pot. berch-toldi	Vege-tated	No Vege-tation
2	104	5	89	17	20	12	82	11	16	5	0	0	99	1
3	120	7	88	16	31	15	80	23	11	8	1	0	97	3
4	256	7	60	10	18	9	84	4	10	3	0		94	6
5	596	3	6	--	--	0	19	0	0	0	0	0.	21	79
6	280	5	50	7	29	18	83	13	--	0	4	0	97	3
7	115	4	76	32	19	12	83	1	11	20	0	2	96	4
8	159	0	1	0	[illegible]	[illegible]	0	0	0	0	0	0	I	99
9	102	2	67	41	[illegible]	30	81	9	5	4	0	0	92	8
10	186	12	78	53	16	14	84	49	10	3	2	1	95	5
11	3	0	33	0	0	0	33	100	-0	0	0	0	0	100
12	54	0	11	0	6	6	7	0	0	2	0	0	11	89
13	732	0	7	1	1	--	4..	3	0	--	0	0	8	92
14	551	9	33	11	15	5	29	22	2	2	0	0	40	60
15	285	3	53	15	21	8	69	3	10	8	0	0	76	24
16	385	45	68	23	50	31	79	44	3	1	0	1	99	1
17	1101	16	57	8	19	6	83	30	1	--	0	1	90	10
18	675	34	63	32	27	3	82	39	2	1	0	4	93	7
19	378	19	40	14	9	3	77	28	1	1	0	1	82	18
20	1011	5	12	6	2	1	29	24	0	0	0	1	41	59
	7093													

--- Less than 0.5%.
Waterfowl Area #1 not sampled.

Table . **Percent Frequency** of Each Species of Aquatic Vegetation in Each Waterfowl Area from the Master Survey, August 196

Percent of-Samples Containing

Area	Samples	Sago	Celery	Redhead-grass	Chara	Ni-tella	Najas	Widgeon-grass	Eleo-charis	Sagit-taria	Ana-charis	Pot. berch-toldi	Cerato-phyllum	Un-ident.	Vege-tated	No Veg
2	129	8	75	35	22	0	46	19	9	9	0	0	0	0	86	14
3	99	4	99	39	33	0	46	31	6	0	0	4	0	0	96	4
4	246	8	65	79	11	0	62	12	3	1	0		0	0	92	8
5	595	2	9	1	1	0	28	1		0	0	0	0	0	30	70
6	250	18	56	16	18	0	79	18	-	0	0		0	0	98	2
7	108	6	81	58	9	1	81	6	22	28	2	0	0	0	91	9
8	143	0	1	0	--	0.	0	0	0	0	0	0	0	0	1	99
9	143	7	80	57	38	0	71	31	1	4	1	2	0	0	97	3
10	161	34	83	69	43	7	60	71	6	8	0	0	0	0	98	4
11	32	0	63	47	28	3	47	22	6	13	0	0	3	0	69	31
12	83	0	8	0	18	1	5	1	0	4	0	0	0	1	12	88
13	723		8	2	3		3	5		1	0	0	0	0	9	91
14	559	6	34	16	12	0	30	20	1	2	0		0	0	45	55
15	313		61	29	45	13	81	15	11	12	1		0	0	90	10
16	414	43	65	30	60	--	17	57	2		0		0	0	94	6
17	1093	24	76	20	23	--	64	37	2		0	0	0	0	90	10
18	624	62	73	47	48	--	53	54	5		0		0	0	94	6
19	436	48	56	42	12	2	72	52			0		0	0	89	11
20	1010	9	16	10	4	0	45	24		0	0		0	0	58	42
	7161															

-- Less than 0.5%.

Waterfowl Area #1 not Sampled.

Table ___. Percent Frequency of Each Species of Vegetation by Section Encountered on the August-September 1959 and 1960 Master Surveys of Back Bay and Currituck Sound.

	Year	Section - A No.	Section - A %	Section - B No.	Section - B %	Section - C No.	Section - C %	Section - D No.	Section - D %	Total Area No.	Total Area %
No. of ½ Sq.Ft. Samples	1959	1366		1654		2439		1308		6767	
	1960	1410		1715		2463		1505		7093	
Sago	1959	57	4.17	398	24.06	298	12.22	132	10.09	885	13.08
	1960	109	7.73	453	26.43	228	9.26	67	4.45	857	12.08
Celery	1959	215	15.74	807	48.79	908	37.23	436	33.33	2366	34.96
	1960	284	20.14	1001	58.37	997	40.48	518	34.42	2800	39.48
Redhead Grass	1959	62	4.54	277	16.75	367	15.05	43	3.29	749	11.07
	1960	115	8.16	303	17.67	386	15.67	84	5.58	888	12.52
Chara	1959	70	5.12	468	28.30	609	24.97	165	12.61	1312	19.39
	1960	52	3.69	384	22.39	462	18.76	161	10.70	1059	14.93
Nitella	1959	49	3.59	383	23.16	383	15.76	77	5.89	892	13.18
	1960	20	1.42	83	4.84	274	11.12	77	5.12	454	6.40
Najas	1959	405	29.65	1017	61.49	858	35.18	565	43.20	2845	42.04
	1960	564	40.00	1436	83.73	1081	43.89	735	48.84	3816	53.80
Widgeon Grass	1959	291	XL.30	567	34.28	41")	17.10	63	4.82	1338	19.77
	1960	382	27.09	536	31.25	465	18.88	63	4.19	1446	20.39
Eleocharis	1959			8	0.48	87	3.57	28	2.14	123	1.82
	1960			32	1.87	82	3.33	48	3.19	162	2.28
Sagittaria	1959							88	0.61	8	0.12
	1960			17	0.99	61	2.48	26	1.73	104	1.47
Anacharis	1959			1	0.06	1	0.04			2	0.02
	1960					6	0.24	4	0.27	10	0.14
Pot. Berchtoldi	1959										
	1960	14	0.99	34	1.98	5	0.20	2	0.13	55	0.78
No Vegetation	1959	804	58.86	231	13.97	1222	50.10	588	44.96	2845	42.04
	1960	673	47.73	141	8.22	1152	46.77	658	43.72	2624	36.99
Vegetated	1959	562	41.14	J-423	86.03	1217	49.90	720	55.05	3922	57.96
	1960	737	52.27	1574	91.78	1311	53.23	847	56.28	4469	63.01

It will be noted that in 1962, Section A was more heavily vegetated than in 1960 or 1959. Section B also was slightly more heavily vegetated in 1960 and 1962 than in 1959. The non-vegetated areas near Coinjock and Aydlett on Section B were primarily the result of hard packed sand.

Section C maps indicating distribution of samples with no vegetation remained about the same in all 3 years, with only slightly more vegetation west of Churchs Island in 1962 than in the other 2 years. The large non-vegetated area is normally turbid and contains soft, flocculent silts. The Intracoastal Waterway passes through that area.

The Section D map indicating distribution of samples with no vegetation also is basically the same. In 1959, the upper North Landing River was not sampled, but it was 'about the same as in 1960 and 1962. North Bay, just below the area marked Sandbridge Club, contained some non-vegetated samples in 1962 that were not encountered in 1960 or 1959. In both 1962 and 1960, the Sand Bay hrea (coordinates R and S, 3-9) was more heavily vegetated than in 1959.

Sago pondweed has a wider distribution in Section A in 1962 than in the other 2 years. In Section B, sago pondweed was about equally distributed in all 3 years but much denser in 1962. In Sections C and D, it had somewhat wider distribution in 1959 than in 1960 or 1962. In the latter years it was less frequently encountered in Knotts Island Channel, along the west side of Ragged Island, in the lower part of Back Bay, and in Redhead Bay.

Wildcelery appeared about equally distributed in all sections each year, but its frequency increased each year in all sections. In Section D, it was slightly more abundant each year in the upper part of Sand Bay (Coordinates R and S, 9 and 10).

The progressive increase in redheadgrass from 1959 through 1962 can be discerned on all sections. The increase is particularly noticeable in the Back Bay area (Section D).

Naiad was similarly distributed in 1959 and 1960 but it was more frequently encountered in 1960 in all sections. However, it was largely absent from parts of North and Shipps Bays in 1960. In 1962, after the intrusion of ocean water, naiad was somewhat more widely distributed and abundant in the deeper waters in Section A. It was retarded on the eastern side of Section B and Section C, from Pointer Hill north to 'Swan Island. This is particularly interesting because this is the region that the greatest quantity of ocean water flowed into the area on March 7, 1962.

Naiad was more widely distributed in Section D in 1962 than in 1959 or 1960. It was encountered more frequently in the deep waters of Back Bay.

Widgeongrass was slightly more widely distributed each year; the increase was particularly noticeable in Sections B and C in 1962. As mentioned in the discussion'of the transect surveys it produced a much greater yield in 1962 than in other years.

Chara spp. was similarly distributed-in all sections in all 3 years, but in 1962 it was less widely distributed on the western side of Section C and less frequently encountered in Buzzards Bay (in Sections C and D). It was more frequently encountered in 1962 than in 1959 or 1960, except in Section D.

Nitella spp. was the most seriously affected of all aquatics by the ocean water intrusion in 1962. No map is presented for the distribution of Nitella spp., in Section D for that year it was not encountered. It was virtually eliminated from all other Sections in 1962, but was most abundant in Coinjock Bay in Section C; the area farthest removed from the point of ocean water intrusion. Some reduction was noticed in 1960 in Section: B.

Dwarf spikerush (Eleocharis parvula) did not occur in Section A in 1959 or 1960 and no maps are presented for that area. It appeared to be more widely distributed each year in all sections, but was slightly reduced in Shipps Bay in 1962.

In 1959, Sagittaria subulata occurred only in Section D. It occurred in Sections B, C, and D in 1960 and 1962. The distribution increased-considerably in 1960. In Section C and D, it remained about the same in 1960 and 1962. In Section B in 1962, it was restricted to the Coinjock area.

Potamogeton berchtoldi was not encountered in 1959. It was found in all sections in 1960, and was particularly abundant near Martins Point in Section A. In 1962, it was more restricted in all sections.

Anacharis canadensis was encountered only twice in 1959. It occurred only in Sections C and D in 1960 and Sections B and C in 1962.

Ceratophyllum sp. was encountered only in Section C in 1962. It occurs in some of the marsh ponds on Mackay Island.

Optimum Depths for Each Aquatic as Determined by the 1959 and 1960 Master Survey

The depth at which each aquatic was most frequently encountered can be discerned from the accompanying tables for the entire area, for each of four subdivisions, and on each major soil type.

Combining the 1959 and 1960 surveys the peak frequencies for each species occurred at about the following depths:

Sagp pondweed	3.0 - 4.0 ft.
Wildcelery	2.5 - 4.0 ft.
Redheadgrass	2.5 - 4.5 ft.
Nitella spp.	1.0 - 2.5 ft.
Chara spp.	2.0 - 3.0 ft.
Naiad	3.0 - 5.0 ft.
Widgeongrass	2.0 - 4.5 ft.
Eleocharis parvula	2.5 - 4.5 ft.
Sagittaria subulata	3.0 - 4.5 ft.
Total	2.0 - 3.5 ft.

The few samples taken at depths less than 1 foot tend to skew the data and should be ignored.

It will be noticed that naiad was more tolerant of depth than all other species, occurring in 10 and 12 percent of the samples at 10 to 10.5 feet in 1959 and 1960, respectively.

Most other species fell below 10 percent frequency at depths greater than 6 feet, but wildcelery was tolerant of depths to 8 - 8.5 feet..

Nitella was found in fair abundance to depths of 7.5 feet in 1959, but in 1960 was retarded at depths in excess of 4 feet. *Chara* also appeared to be retarded more at similar depths in 1960 than in 1959.

However, in 1959 the percent frequency of vegetated samples declined more rapidly at depths in excess of 5 feet than it did in 1960.

The 1960 master survey data were transferred from field sheets to International Business Machine data cards to facilitate more detailed analysis of the frequency-depth-soil type-geographical distribution relationships.

As mentioned elsewhere the light penetration normally was greater at the southern end of the area than at the northern end. Thus in comparing Section A, at the southern end, with Section D, at the northern end, we see that the frequency of vegetated samples on the dominant soil types was greater in Section A than at all corresponding depths in Section D. This is equally true when comparing Section A and Section C; and generally true in comparing Section B and Section C.

Table . Average Depth of Quadrats in Each Frequency Class of Total Vegetation (all species) (Master Survey, August 1959).

	Percentage Frequency of Total Vegetation by Quadrats											
	100	90	80	70	60	50	40	30	20	10	0	All Frequencies
Section A												
Av. Depth (ft.)	3.95	4.28	5.98	4.57	6.30	5.47	6.78	6.33	6.40	8.06.	7.93	6.06
No. Quadrats	42	5	9	6	8	14	5	13	12	10	44	168
Section B												
Av. Depth (ft.)	4.28	5.08	5.65	5.38	7.03	7.10	7.27	5.60	5.77	6.88	2.78	4.78
No. Quadrats	144	11	15	12	4	9	6	1	3	4	5	214
Section C												
Av. Depth (ft.)	3.19	4.00	4.28	'4.23	4.58	4.49	5.08	6.35	5.98	6.31	7.34	4.94
No. Quadrats	139	4	15	6	4	10	4	4	15	11	95	307
Section D												
Av. Depth (ft.)	3.41	4.99	4.21	4.84	5.13	5.68	4.96	5.77	5.88	5.95	5.73	4.56
No. Quadrats	71	9	7	5	8	4	11	6	6	10	32	169
All Section Average												
Av. Depth (ft.)	3.71	4.77	5.05	4.88	5.74	5.63	5.86	6.16	6.09	6.77	7.07	5.04
No. Quadrats	396	29	46	29	24	37	26	24	36	35	176	858
Percent Quadrats in each class:	46.15	3.38	5.36	3.38	2.80	4.31	3.03	2.80	4.20	4.08	20.51	100

Table . Average Depth of Quadrats in Each Frequency Class of Total Vegetation (all species) (Master Survey, August 1960).

	Percentage Frequency of Total Vegetation by Quadrats											
	100	90	80	70	60	50	40	30	20	10	0	All Frequencies
Section A												
Av. Depth (ft.)	4.76	5.91	5.80	5.25	5.29	5.42	[illegible]	[illegible]	7.98	8.95	[illegible]	6.36
No. Quadrats	38	8	16	11	11	15	7	[illegible]	11	14	27	168
Section B												
Av. Depth (ft.)	[illegible]	[illegible]	5.57	[illegible]	[illegible]	4.09	7.84	--	3.85	2.60	[illegible]	[illegible]
No. Quadrats	153	11	[illegible]	11	[illegible]	[illegible]	4	[illegible]	1	1	1	[illegible]
Section C												
Av. Depth (ft.)	[illegible]	[illegible]	4.27	4.40	3.98	4.88	5.52	5.65	6.06	[illegible]	6.98	5.05
No. Quadrats	[illegible]	14	14	10	6	9	7	3	13	32	79	323
Section D												
Av. Depth (ft.)	4.38	4.96	5.13	5.21	4.00	5.32	6.66	4.83	6.05	6.35	5.67	5.11
No. Quadrats	62	11	26	7	10	7	1	4	6	12	60	206
All Section Average												
Av. Depth (ft.)	4.34	5.51	6.05	5.56	4.74	5.05	6.41	6.11	6.67	7.17	6.71	5.40
No. Quadrats	389	44	62	39	32	37	19	17	31	59	167	896
Percent Quadrats in each class:	43.42	4.91	6.92	4.35	3.57	4.13	2.12	1.90	3.46	6.58	18.64	

Table . Percentage of Samples in Each Depth Interval Containing Each Species of Vegetation from All Sections of the Master Survey, August-September 1959 (Back Bay, Virginia-Currituck Sound, Korth Carolina).

Water Depth (ft.)	Sago Pond-weed	Celery	Redhead-grass	Nitella	Chara	Najas	Widgeon-grass	Eleo-charis parvula	Sagit-taria subulata	Percent Vegetated Samples	Percent Non-Vegetated Samples	Number of Samples
0 -0.49	0	50	0	0	0	100	50	0	0	100	0	2
0.50-0.99	33	92	0	42	33	83	25	0	0	. 85	15	12
1.00-1.49	5	56	10	25	27	38	19	8	0	86	14	63
1.50-1.99	6	67	18	35	42	55	22	4	0	93	7	125
2.00-2.49	19	77	24	36	49	50	41	5	0	96	4	345
2.50-2.99	28	80	36	28	50	59	42	6	0	94	6	499
3.00-3.49	31	75	34	15	38	61	39	5	0.2	92	8	595
3.50-3.99	30	67	28	9	27	64	40	4	0.7	86	14	451
4.00-4.49	24	59	17	11	20	65	37	2	0.2	81	19	442
4.50-4.99	13	39	7	10	20	48	23	0.7	0	66	34	442
5.00-5.49	10	36	3	13	19	50	18	0.6	0.4	64	36	474
5.50-5.99	11	23	1	16	9	44	16	0	0.2	56	44	477
6.00-6.49	9	10	0.2	19	11	37	9	0.2	0	46	54	497
6.50-6.99	5	5	0.2	8	8	25	5	0.2	0	26	74	485
7.00-7.49	2	6	0	10	10	34	4	0.2	0	42	58	444
7.50-7.99	0.5	4	0.2	3	3	19	2	0	0	20	80	438
8.00-8.49	0.2	0.2	0	3	2	20	0.8	0	0	22	78	455
8.50-8.99	0	0.4	0	0	0.4	13	0	0	0	14	86	256
9.00-9.49	0.7	0	0	0	0	12	0	0	0	12	88	136
9.50-9.99	0	0	0	0	0	8	0	0	0.	8	92	50
10.00-10.49	0	0	0	0	0	0	0	0	0	0	100	28
10.50-10.99	0	0	0	0	0	0	0	0	0	0	100	14
11.00-11.49	0	0	0	0	0	0	0	0	0	0	100	11
11.50-11.99	0	0	0	0	0	0	0	0	0	0	100	17
12.00-12.49	0	0	0	0	0	0	0	0	0	0	100	7
15.00-15.49	0	0	0	0	0	0	0	0	0	0	100	2
												6767

Table . Percentage of Samples in Each Depth Interval Containing Each Species of Vegetation from All Sections of the Master Survey, August 1960 (Back Bay, Virginia - Currituck Sound, North Carolina).

Water Depth (ft.)	Sago pondweed	Celery	Redhead-grass	Nitella	Chara	Najas	Widgeon-grass	Eleocharis parvula
1.00-1.49	0	17	0	33	33	50	0	0
1.50-1.99	0	70	11	44	44	63	7	0
2.00-2.49	13	57	14	31	48	61	31	1
2.50-2.99	16	68	29	23	43	65	38	3
3.00-3.49	24	71	28	20	40	68	43	5
3.50-3.99	26	68	36	10	31	72	34	6
4.00-4.49	24	65	28	6.	22	67	35	6
4.50-4.99	23	63	20	4	18	72	31	4
5.00-5.49	16	51	11	4	9	67	26	4
5.50-5.99	14	47	9	3	10	67	23	3
6.00-6.49	8	32	3	3	8	58	13	1
6.50-6.99	5	17	1	3	5	48	12	0.2
7.00-7.49	3	18	1	2	5	37	8	0
7.50-7.99	2	17	2	1	4	37	4	0
8.00-8.49	1	9	1	0.4	1	30	3	0
8.50-8.99	1	2	1	0	0	25	2	0
9.00-9.49	0	1	1	0	0	36	3	0
9.50-9.99	0	0	0	0	0	13	3	0
10.00-10.49	0	2	1	0	0	10	3	0
11.00-11.49	0	0	0	0	0	0	0	0
11.50-11.99	0	0	0	0	0	0	0	0
12.00-12.49	0	0	0	0	0	0	0	0
12.50-12.99	0	0	0	0	0	0	0	0
13.00-13.49	0	0	0	0	0	0	0	0
13.50-13.99	0	0	0	0	0	100	0	0
14.00-14.49	0	0	0	0	0	0	0	0
15.00-15.50	0	0	0	0	0	0	0	0

Table . Percentage of Samples in Each Depth Interval Containing Each Species of Vegetation from All Sections of the Master Survey, August 1960 (Back Bay, Virginia - Currituck Sound, North Carolina), continued.

Water Depth (ft.)	Sagittaria subulata	Pot. berchtoldi	Anacharis	Percent Vegetated Samples	Percent Non-Vegetated Samples	Number Samples
1.00-1.49	0	0	0	50	50	6
1.50-1.99	0	0	0	85	15	27
2.00-2.49	2	3	0	92	8	138
2.50-2.99	4	2	0	93	7	388
3.00-3.49	3	1	1	92	8	545
3.50-3.99	4	2	0.5	87	13	620
4.00-4.49	3	0.2	0.2	86	14	493
4.50-4.99	2	0.2	0.4	82	18	492
5.00-5.49	4	0.2	0	75	25	480
5.50-5.99	0.4	0.4	0	72	28	466
6.00-6.49	0.2	0.4	0	61	39	561
6.50-6.99	0	0.3	0	50	50	624
7.00-7.49	0.2	1	0	39	61	616
7.50-7.99	0	1	0	39	61	448
8.00-8.49	0	1	0	31	69	515
8.50-8.99	0	0.4	0	28	72	269
9.00-9.49	0	0	0	37	63	151
9.50-9.99	0	0	0	16	84	77
10.00-10.49	0	0	0	12	88	125
11.00-11.49	0	0	0	0	100	28
11.50-11.99	0	0	0	0	100	8
12.00-12.49	0	0	0	0	100	8
12.50-12.99	0	0	0	0	100	1
13.00-13.49	0	0	0	0	100	3
13.50-13.99	0	0	0	100	0	1
14.00-14.49	0	0	0	0	100	1
15.00-15.50	0	0	0	0	100	1
						7092 Total

All species declined in production with increased depth of water. We assume light penetration was the primary factor responsible, for the decline occurs on all soils in all geographical subdivisions of the area.

In the table that presents the average depth of quadrates in each frequency class. in 1959, the quadrates with the lower frequencies generally occur in deeper water, except for some variation in Section B. From this table it can be determined that 46 percent of the quadrates were in the 100 percent frequency class. The other 10 percent frequency class intervals occurred in only 2.80 percent to 5.36 percent of the total quadrates. The zero frequency class occurred in 20.51 percent of the quadrates. This demonstrates that areas were generally either well suited to grow aquatics or not suited to support them; few sparsely vegetated areas occurred.

Relationship of Soil Type to Aquatic Plant Frequencies on the 1960 Master Survey

As--shown in the master survey tables and maps of soil types distribution, the order of abundance of each dominant soil type in each section was as follows:

Sections and Number of Samples

	A	B	C	D
	Sand (1108)	Sand (895)	Sand (1318)	Silt (972)
	Loam (198)	Loam (497)	Loam (749)	Sand (295)
	Silt (60)	Silt (250)	Silt (184)	Loam (152)
	Shell (36)	Shell (40)	Clay (122)	Muck (30)
	Muck (5)	Clay (22)	Shell (56)	Peat '(28)
		Muck (8)	Muck (19)	Clay (26)
			Peat (13)	Shell (2)
Total	1407	1712	2461	1505

For the entire area it will be noted that at any specific depth the muck and peat soils were most poorly vegetated. Clay and shell soils were also generally poorly vegetated. Of the -3 dominant soil types at depths less than 5 feet, silt was slightly more frequently vegetated than loam, and they both were considerably more frequently vegetated than sand. At depths greater than 5 feet, loam was more frequently vegetated and the preference varied between silt and sand at the different depths.

In Section A generally the silt soils were most frequently vegetated, followed in order by loam, sand, and shell.

In Section B, the order was silt, loam,sand, shell, clay, and muck.

In Section C, the silt soils were most frequently vegetated at depths less than 5 feet, but atgreater depths loam was more frequently vegetated. At depths over 6 feet the order in which the dominant soils were most frequently vegetated was loam, sand, and silt. Clay was generally about fourth in order, but between 6 and 7 feet it was the most frequently vegetated in Section C.

In Section D, at most depths silt was slightly more frequently vegetated than loam. Either loam or clay might rank as second, and sand was about fourth in order of frequency with which the samples were vegetated.

Sago pondweed occurred with fair regularity on shell and muck but was generally infrequent on clay and peat. Wildcelery occurred frequently in all soil types.

Sago pondweed and wildcelery occurred with about equal regularity on sand, silt or loam at all depths.

Redheadgrass and naiad generally occurred more frequently, at most depths, on loam and silt than on sand. Naiad occurred in abundance on all soil types, but redheadgrass was infrequent on shell, muck, and peat.

Widgeongrass generally occurred with greatest frequency on sand, followed in order by shell, loam, and silt. It was generally infrequent on clay, muck, and peat.

Chara spp. occurred most frequently on sand, followed in order by shell, clay, and loam. It was generally infrequent on peat, muck or silt.

Nitella spp. was generally most frequent on sand, followed in order by clay and loam., It was generally infrequent on silt, shell, and peat. It did not occur on muck soil.

Eleocharis parvula showed a distinct affinity for clay, and in generaldescendingorder it occurred on muck, loam, sand, and silt. It did not occur on shell soils.

Sagittaria subulata occurred with greatest frequency on clay, followed in descendingorder by loam, silt, and sand. It did not occur on Shell or peat.

Potamogeton berchtoldi occurred with greatest regularity on loam, followed by silt and then sand. It did not occur on clay, shell, muck or peat.

Seed Production of Sago Pondweed and Redheadgrass

Because of the frequently reported lack of seed production on sago pondweed in the area and the potential importance of seed production as a source of waterfowl food, several seed production surveys were conducted from 1959 through 1963. Mr. Roland Halstead reported that many years ago when the area was more brackish the sago pondweed seed was so abundant that it was readily collected by the bushelful and sold. Because of numerous other jobs of higher priority and the lack of a truly good method of determining-the annual crop of seeds, the surveys were somewhat cursory and, perhaps, only provide an index to local differences. Seeds normally begin to form on redheadgrass in early June and on sago pondweed in late June. This production continues throughout the summer and fairly frequent surveys of intensive nature would be required to determine total annual yield.

Between 1959 and 1963 three different methods of assessing differences in sago pondweed seed production were used.

The first method was to cast a floatable 34 inch hula hoop at random over stands of surfacing sago pondweed and collect, count, and measure the volume of the seeds in the ring samples. In late June 1959, a total of 127 such samples were taken in 6 locations in the study area. As shown in the accompanying table there was anincrease in seed production from north to south in the Back Bay-Currituck Sound Area; no seeds were found in 27 samples in North Bay, while about 42,000 seeds occurred in 9 samples in the sourthern part of Currituck Sound.

In 1960 a similar survey in late June through mid-July again showed higher sago pondweed seed production in Currituck Sound than in Back Bay; 5.12 seeds/sample and 2.98 seeds/sample, respectively. This production compares to 1603.0 seeds/sample in Currituck, and 2.46 seeds/sample in Back Bay in 1959.

In Currituck Sound an identical survey was conducted on August 2, 1960, and it indicated a decline in seed production at that time to 1.49 seeds/sample.

Also in 1960 a second method used to assess seed production was to randomly collect a quantity of sago pondweed that completely filled our vegetation measuring device used on the transect surveys. This was equivalent to 1440 cc. Personal bias in selecting plants with or without seed was eliminated by using SCUBA equipment and making the collection from beneath the surface where seed production was not discernable. Plants were collected as encountered.

The relationship of seed production to volume of vegetation by this second method would permit rough calculation of total seed production based on the estimates of vegetative yield from the transect surveys.

One composite sample was taken at four locations in Back Bay and nine locations in Currituck Sound. The greater seed production was again demonstrated in Currituck Sound, with about 959 seeds per sample compared to only 5 seeds per sample in Back Bay.

In 1961 no comparable survey of seed production survey was conducted because much time was devoted to the collection of 1,000 sago pondweed samples for the study of plant disease. A seed survey of a third type was conducted in conjunction with that survey. In August and early September, 1,000 sago pondweed plants were collected from a total of 19 strata from pre-selected, random sampling points. The strata were numbered 1-18 north to south in the study area; stratum 19 was in Kitty hawk Bay south of the study area.

Based on estimated plant densities and area in the strata it was calculated that there were roughly 738 million sago pond= weed plants in the 19 strata. The number of seeds was counted on each of the 1,000 plant samples and calculations were made that there wereroughly 1¼ billion seeds, equivalent to about 21,000 pounds wet weight.

It is again shown in comparing seed production by locations that Currituck Sound produced a higher yield of sago pondweed seed than did Back Bay.

In 1962 after the study renewal because of the ocean water introduction the second method, of seed production in relation to plant volume, was used. The third method just mentioned might have been superior but the single objective of measuring seed yield would not justify the time and effort.

The survey was conductedat locations in Back-Bay and 16 locations in Currituck Sound. The average number of seeds. per sample was 10,332 in Back Bay and 3,964 in Currituck Sound. This was the first survey to indicate greater sago pondweed seed production in Back Bay. The seeds per sample in 1960 from Back Bay were 5 and from Currituck 959. The phenomenal increase in Back Bay in 1962, when the water salinity was about 13 percent of sea strength, was quite readily observable and it was by far the best seed crop seen.

In July 1963 sago pondweed was scarce in Back Bay and sufficient sample size was obtained in only one location. That one sample yielded 4,684 seeds. In Currituck Sound 15 samples yielded 9,680 seeds for an average of 645 seeds per sample. Both areas had poorer production than in 1962.

Redheadgrass seed production was first sampled in June 1960 in three locations in Currituck Sound using the floatable ring method. Forty samples were taken in each location and the average number of seeds per sample was: North Currituck 87, Mid-Currituck 101, and South Currituck 127. As seen in the accompanying table this was much greater than the yield from sago pondweed, which averaged only 1.49 seeds per sample 'from the 3" areas.

On July 12, 1960, the second method of assessing seed production, seed yield-plant volume, was used on redheadgrass. This indicated 60 seeds per 1440 cc. sample in Back Bay and 2,358 seeds per sample in Currituck Sound.

No survey of seed yield on redheadgrass was conducted in 1961.

In 1962 six 1440 cc samples in Back Bay yielded 8,113 seeds per sample. The yield per sample from 15 locations in Currituck Sound was 3,369.

In July 1963 only 1 sample was taken in Back Bay because of insufficient volume of redheadgrass; 117 seeds occurred in the one 1440 cc sample. Fifteen samples in Currituck Sound revealed 22,809 seeds for an average of 1,521 seeds per sample.

Summary of Sago Pondweed and Redheadgrass Seed Production Surveys

The phenology of-the annual yield of seed by sago pondweed and redheadgrass was too poorly known to be able to relate the results of a survey at any one moment to the total yield of seed during an entire growing season. What we did achieve was a rough index to gross difference in various locations and major changes from year to year.

Two facts of greatest importance were demonstrated: During the period 1959 to 1961 when Back Bay was fresh the seed production' of sago pondweed and redheadgrass was much lower than it was in most of Currituck Sound. This may have resulted primarily from the higher salinities in Currituck Sound, or possibly from a relatively greater increase in water depth in the northern part of the area from wind tides during the period when these pond-weeds were normally flowering. The bioassays in 1960 and 1961 demonstrated greater seed production in the higher salinities. A third reason might be greater light penetration in Currituck Sound stimulated earlier growth and enhanced seed production. Hodgson and Otto (1963) found that under laboratory conditions sago pondweed cultured under 400 ft-c of light and a 14-hr. photo period required approximately 900 degree-days over a 49 F. threshold to reach flower-bud stage.

The second fact of importance was the tremendous increase in seed production, particularly on sago pondweed in Back Bay and Currituck Sound when the water salinities were increased to 13 percent sea strength in 1962.

Three methods of assessing seed production were used, and a fourth method was rejected. The fourth method attempted to measure total seed deposition on the bay soils by washing out soil samples. Seeds were readily obtained by this method but it was impracticable to attempt to distinguish the yield from the current year from that of previous years.

The second method described, of relating seed yield. to a standard volume of randomly collected vegetation, was probably the most practical, rapid method.

Tuber Production of Sago Pondweed

Reportedly low yields of sago pondweed tubers and their potential as a favored waterfowl food caused our inquiry into tuber production in Back Bay and Currituck Sound. Similar to the seed production surveys it was a job of relatively low priority, but unlike the seed surveys tuber production was not so easily measured.

The only method attempted was to take 50 two-square-foot bottom samples in specified sago pondweed sites in several areas in Back Bay and Currituck, deposit the soils in large cans, and finally wash the soils through small mesh screen frames at our headquarters. Samples would normally include the top 5-7 inches of soil.

Annual surveys from 1958 to 1961 of four to five locations in Back Bay revealed no sago pondweed tubers. However, in November 1962, 3 areas sampled with 25 samples per area yielded 8, 38, and 73 tubers.

In Currituck Sound on November 6, 1959, two areas were sampled as described and one tuber was yielded from each area. In November 1960, four sample sites in Currituck yielded 0, 1, 2, and 3 tubers.

In 1961 no individual tuber study was conducted but they were searched for in conjunction with the transect survey. In Currituck Sound 46 two-square foot samples contained sago pondweed but no tubers were found.

In November 1962, 25 samples revealed 1.5 tubers per area in Currituck Sound. In February a 200-square-foot sample revealed 4 tubers of sago pondweed and 419 of wildcelery. One 2-square-foot sample on the transect survey disclosed 9 sago pondweed tubers. Similar reports of greater tuber production in Back Bay in 1962 in the presence of increased salinities were made by biologists working in the area.

Summary of Sago Pondweed Tuber Production Surveys

The method employed to obtain samples was not considered adequate for, while using SCUBA equipment, biologists dug by hand along the root system of several sago pondweed plants and found some root systems extended to depths beyond arm length. If tubers were formed below 6 inches in soil depth, we were not sampling them. From a practical point of view, however, if tuber production was occurring at soil depths greater than 6 inches, the tubers would be largely inaccessible to waterfowl.

Obviously the sampling effort was inadequate to calculate total yield of sago pondweed tubers; however, the almost total absence of tubers in the period 1958 through 1961 and the subsequent increases in 1962 indicate tuber production increased in response to higher salinities in the habitat just as it did in the 1960 and 1961 bioassays.

Tuber Production of Wildcelery

No individual survey was conducted to assess wildcelery tuber production, but in conjunction with the transect surveys of May and November 1962 and 1963, in Back Bay and the transect survey of November 1961 in Currituck Sound, the tubers in each sample were recorded.

In the accompanying tables these estimates were expanded to total numbers, volume, and wet weight by the same procedures used for the vegetation transect survey estimates. The estimates indicate some increase in November 1962 and May 1963 over similar periods the year before but these differences are not statistically significant.

The root system and depth at which wildcelery tuber production occurs are much shallower than that of sago pondweed. The sampling method seemed entirely adequate for wildcelery tubers.

Table . Total Number of Celery Tubers[1/] on Each Transect area of Back Bay, Virginia, and Currituck Sound, North Carolina; as Determined by Each Transect Survey on Which They Were Measured.

Transect	1961 November	1962 May	1962 November	1963 May
A	11	11	9	23
B	42	27	39	41
C	14	1	24	12
D	8	27	40	17
E	0	9	0	6
F	3	4	1	10
G	5	4	1	0
Cl	9	4	12	12
Total Back Bay	92	87	126	121
H	1			
I	3			
J	10			
K	0			
L	2			
M	4			
N	8			
0	'5			
P	3			
Q	8			
R	0			
S	0			
Total Currituck Sound	44			

1/ Sago pondweed tubers counted at the same time revealed only one on Transect B in May 1962; and in May 1963 - one on Trasect E, one on Transect H, and one on Transect N.

Table . Thousands of Wildcelery Tubers on Each Transect Area of Back Bay, Virginia, and Currituck Sound, North Carolina; as Determined by Each Transect Survey on Which They Were Measured.

Transect	1961 November	1962 May	1962 November	1963 May
A	12,596	12,596	10,173	26,644
B	68,133	43,800	63,267	66,186
C	28,253	2,173	48,538	23,907
D	14,000	46,666	68,444	29,555
E	0	23,289	0	16,302
F	6,787	9,049	2,262	22,622
G	9,707	8,493	2,427	0
Cl	10,893	4,587	14,333	14,333
Total Back Bay	150,299	150,653	209,444	199,549
H	2,160			
I	8,604			
J	37,547			
K	0			
L	23,880			
M	12,617			
N	22,089			
O P	26,027			
Q	37,600 14,560			
R	0			
S	0			
Total Currituck Sound	185,084			

Table. . Thousands of Liters of Celery Tubers on Each Transect Area of Back Bay, Virginia, and Currituck Sound, North Carolina; as Estimated from Each Transect Survey on Which They Were Measured; With the Confidence Limits of the Total at 95 Percent Confidence,

Transect	1961 November	1961 Confidence Limits 1/	1962 May	1962 Confidence Limits 1/	1962 November	1962 Confidence Limits 1/	1963 May	1963 Confidence Limits 1/
A	1		1		1		2	
B	6		4		6		6	
C	3		Tr.		4		2	
D	1		4		6		3	
E	0		2		0		1	
F	1		1		Tr.		2	
G	1		1		Tr.		0	
G1	1		Tr.		1		1	
Total Back Bay	14	± 38%	14 2/	± 67%	19 2/	± 71%	17	± 40% [illegible]
H	Tr.							
I	1							
J	3							
K	0							
L	2							
M	1							
N	2							
O	2							
P	1							
Q	3							
R	0							
S	0							
Total Currituck Sound	16 2/	± 45%						

1/ Expressed as a percent of the total,
2/ Includes Trace.
Trace equals less than 500 liters.

Algal "Slur" on Aquatic Plants

The locally termed "slur" on aquatic plants in Back Bay and Currituck Sound has occasionally been accused of being responsible for the aquatic plant die-off.

On August 5, 1958, two specimensof the "slur;" which is algal growth, were collected on sago pondweed plants in Buzzards Bay and sent to the Botany Department of the North Carolina State College. Dr. L. A. Whitford, identified the colonies of algae as being composed primarily of Nostoc spongioforme and Rivularia globiceps. He was of the opinion that neither would normally be expected to cause die-back of aquatic plants; it seemed more likely that their occurrence might follow die-back, and also be associated with the fertility from the common brackish water hydroid, Cordylophora lacustris, which attached to the aquatics.

Other algal species in these colonies included: Oscillatoria lemmermanni, Cosmarium sp., Oedogonium sp., Synedra pulehella, Cocconeis placentula, Chroococcus limneticus, Gomphosphaeria aponina, Merismopedia sp., Eunotia sp., Scenedesmus quadricauda, Pediastrum tetras, Staurastrum sp., Spirulina sp., Achnanthes sp., and Tetraedron sp. Others were also present.

Close observation throughout the area for about 6 years leads us to concur with Dr. Whitford's opinions. The slur did not appear to be a major problem nor a direct cause of the late summer die-back of sago pondweed or other aquatics. In a few instances these algal slurs, particularly in combination with silt from the turbid waters, served to weight small stands of sago pondweed to the bottom. In most instances these isolated occurrences followed decreased vitality and apparent plant death resulting from lesions on the plant stems. The lesions were believed to be a result of fungal disease.

In conjunction with the field collection of 1,000 sago pondweed samples in 1961 for study of the occurrence of fungus disease,observations were made on the presence of algae on each sample. This is mentioned in greater detail in the discussion of plant disease.

MARSH VEGETATION OF BACK BAY AND CURRITUCK SOUND

Although the marsh vegetation contributes approximately one-fourth of the-food for the total waterfowl population of the area, no intensive studies were conducted on the ecology or composition of the marsh vegetation. The reasons for this were: (1) The principles of marsh ecology are better known than are the principles of estuarine ecology. (2) The dynamics of the submerged aquatic vegetation were obviously the least stable characteristic of the waterfowl habitat, and,-hence, most demanding of our time.

However, because of the importance of the marshes to waterfowl and the fine potential for management of many of the marshes of Back Bay and Currituck Sound,generali.zed cover maps were prepared by aerial reconnaissance and photograph interpretation.

The U.S.-Marine Corps at Cherry Point, N. C., photographed all of the area for us in 1958. Photographs were taken at 20,000 ft. with a 12 inch focal length. These photographs provided base maps for more detailed description of the vegetation by means of ground inspection and low flying, small aircraft.

The Piper Super Cub P-18 on floats was particularly useful for this cover mapping. Vegetation types were mapped as long as I could definitely recognize the dominant vegetation. When a sizeable unit of unrecognized vegetation was encountered I would land the seaplane adjacent to the marsh and walk into the unrecognized unit to determine its identity and characteristics. that would permit recognition from:the air.

This rapid mapping procedure permitted completion of first-draft cover maps of the entire area in about 2 days of flying.

Back Bay and portions of upper Currituck Sound have an extremely heterogeneous marsh that defies small-scale illustration.. This heterogeneous marsh is normally dominated by cattail, three-squares, spikerushes, marshmallow, and smartweeds.

Frequent burning every 2 or 3 years, and use by snow geese are major factors in determining annual dominance. The succession after a set-back appears to be from Cyperus spp., Eleocharis palustris, and Polygonum spp., to Scirpus olneyi, S. americanus, S. robustus, and S. validus, to a climax of Typha spp. and Hibiscus sp. When many of these heterogeneous marshes become dominated by rank growths of cattail the muskrat-trappers burn them and the succession starts anew.

Because of the relatively dynamic character of this heterogeneous marsh, and their complexity, they were so illustrated on the accompanying maps. The maps may thus be considered as generally depicting dominant marsh types during the period 1958-1964.

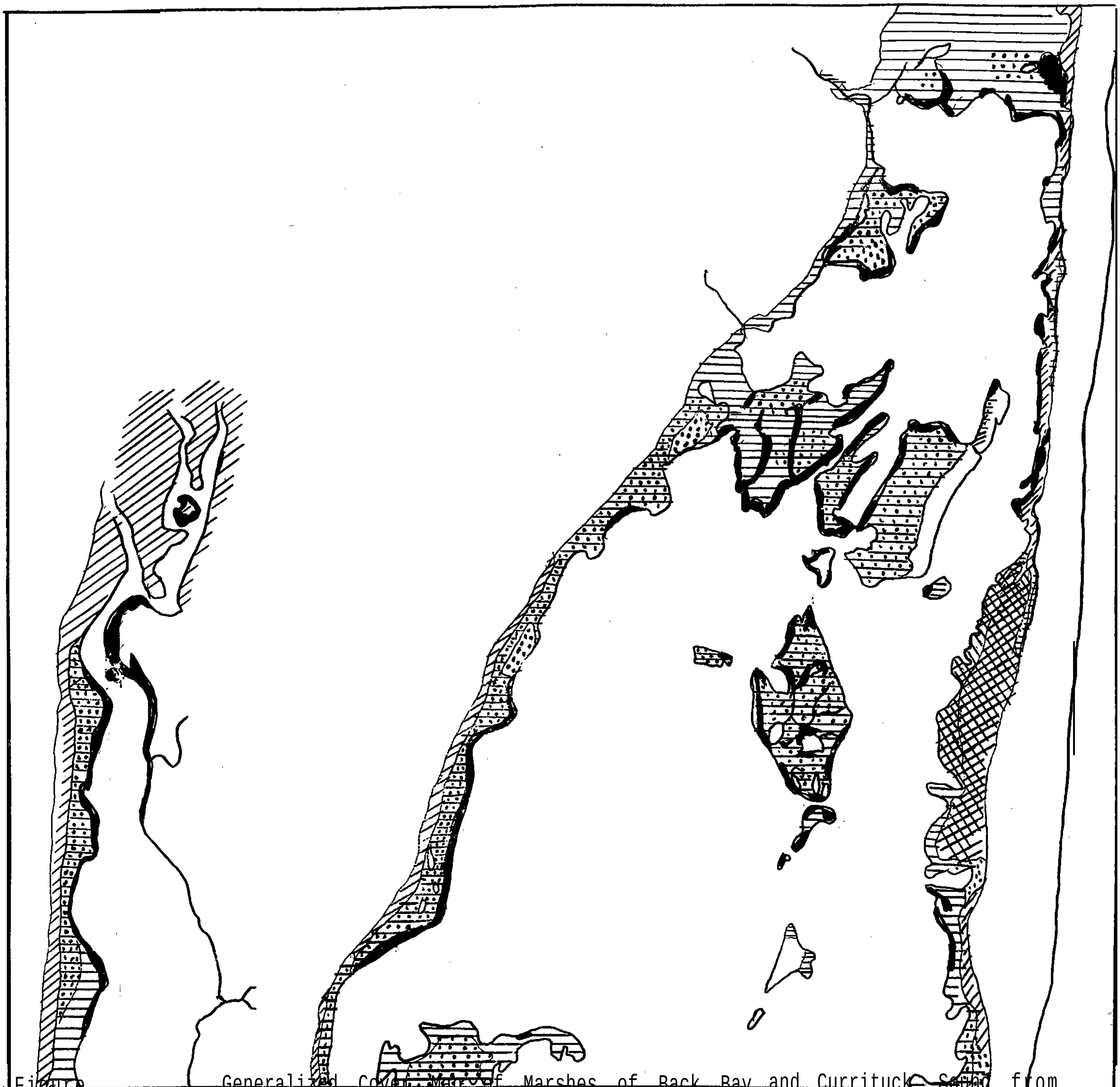

Figure ______ Generalized Cover Map of Marshes of Back Bay and Currituck Sound from Aerial Reconnaissance and Photograph Interpretation.

- Needlerush
- Big Cordgrass
- Cattail
- Sawgrass
- Mixed Waxmyrtle, Needlerush, and Saltgrass
- Heterogeneous Marsh of Cattail, Three-squares, Spikerushes, Marshmallow, and Smartweeds
- Three-squares (*Scirpus americanus*, *S. olneyi*, and *S. robustus*)

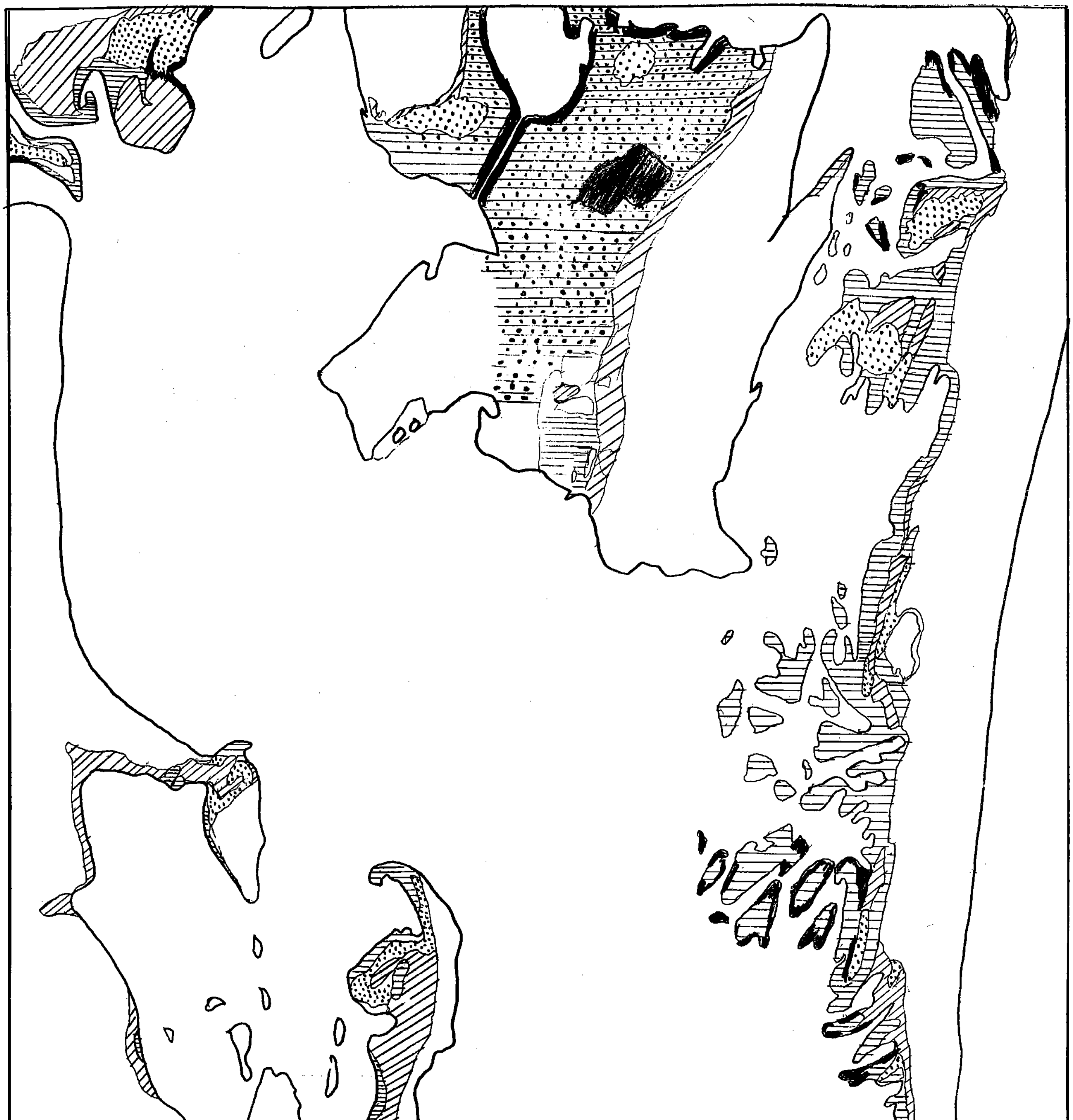

Figure ________ Generalized Cover Map of Marshes of Back Bay and Currituck Sound from Aerial Reconnaissance and Photograph Interpretation.

- Needlerush
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- Heterogeneous Marsh of Cattail, Three-squares, Spikerushes, Marshmallow, and Smartweeds
- Three-squares (<u>Scirpus americanus</u>, <u>S</u>. <u>olneyi</u>, and <u>S</u>. <u>robustus</u>)

The marshes of Currituck Sound, south of Church's Island and Monkey Island, are more homogeneous than those to the north. They are composed primarily of needlerush (*Juncus romerianus*), big cordgrass (*Spartina cynosuroides*), with some cattail, and s-awgrass (*Cladium jamaicense*). These marshes are far less productive of waterfowl foods than are the heterogeneous marshes to the north.

Chamberlain (1947) and Wilson (1962) discuss certain aspects of the marsh composition and wildlife value of Back Bay and Currituck Sound, respectively, in somewhat greater detail. Further reference to marsh composition and management aspects will be found in this report in the volume dealing with waterfowl.

EXPERIMENTAL STUDIES OF AQUATIC PLANTS

If our attempts to conduct experimental studies in this estuarine habitat did nothing else they did make us acutely aware of the difficulties of such experiments, particularly with limited budgets and equipment.

Several apparently well conceived studies involving considerable effort and ingenuity resulted in disappointing failure; frequently, the failures resulted from destruction by wave action in the bay or ocean. Among our more notable failures were the attempt to maintain water salinities in the Sandbridge ponds, the destruction of carp exclosures and enclosures by wave action, the destruction of a large test box in Back Bay designed to permit studies of turbidity, the drowning of several waterfowl in enclosures by abnormally high wind tides, the loss of a continuous water level recorder and the the data by hurricane wave action, the breaking of several 500-gallon test tanks midway in a 5-month vegetation bioassay, the loss of several soil transfer boxes from wave action midway in a study, and several others not worthy of mention. The objectives, designs, and data from these studies are not presented or discussed further in this report. The assistance of all who participated in those studies was, nevertheless, greatly appreciated.

The principal experimental vegetation studies that were wholely or partially successful were the 1960 and 1961 bioassays of aquatic plantsinvarious water salinities, the soil-vegetation transfer study, the depth-vegetation yield study, the artificial light-vegetation yield study, the fungus disease study, and related aspects of these.

Although we cannot take credit for the ocean water introduction resulting from the March 7, 1962, Ash Wednesday Storm, it most certainly provided the finest possible experimental study of the effects of ocean water on this habitat, and it could be thought of as an experimental study.

The large-scale ocean water pumping operation conducted by the City of Virginia Beach started in May 1965 and continuing to the present time is truly the most extensive experimental study attempted in the area. This habitat management attempt is presently being evaluated by our transect surveys and preliminary discussion is made in the section dealing with transect surveys and major environmental factors.

Ocean Water Introductions Into Sandbridge Marsh Ponds

In March 1959 experimental introduction of ocean water into 110 acres of ponds on the Sandbridge marsh was attempted to determine its effect on aquatic plants. The Sandbridge Gun Club generously permitted the construction of gut plugs in canals between the ponds and the pumping of ocean water into them. Several Virginia Game Commission officers assisted the study personnel in gut plug construction, and the month-long job of pumping 2 million gallons of ocean water across the beach. The City of Virginia Beach assisted greatly in the loan of pumps, pipe, etc.

Numerous tables were prepared on water chemistry, plant abundance, etc., and has been presented in past quarterly reports. Because of extremely high water in North Bay and a marsh fire that permitted fresh water access across the marsh and also damaged key gut plugs, our attempts to maintain the desired salinity of 10 percent sea strength were futile. For this reason the study was inconclusive and the data are not repeated in this report.

During the month-long period of pumping ocean water, study personnel distributed live boxes containing large mouthed black bass, pumkinseed, white crappie, and carp in several of the connecting ponds where they were exposed to various concentrations of ocean water. The results of this exploratory study are discussed in the volume on fish.

Bioassays of Aquatic Plants in Water Salinities of 0 to 40 Percent Sea Strength

The history of ocean water as a factor in the ecology of the area was frequently referred to in the literature review. Ocean water introduction into Back Bay and Currituck Sound has been damned by some, and recommended as a panacea by others. It was of paramount importance to determine the optimum and tolerance limits of the principal aquatic plants of the area to various concentrations of ocean water. These studies were conducted on the site, at Nawney Creek, where it was possible to most closely simulate local conditions of climate, soil type, water chemistry, and planting stock.

Initial-studies in 1960 sought to determine plant response in a fairly broad range of 0 to 40 % SS (percent of sea strength). Later studies in 1961 sought to refine the tolerance estimates in a more practical range of management from 0 to 17 % SS.

The study in 1960 involved testing plant response from 0 to 40 % SS on 2 types of soil: loam soil taken from the bottom of the productive Salingers Cove area, and silty soils from the non-productive area in the middle of Back Bay.

One hundred twenty 24 gallon plastic cans were buried in the ground to the top of can. This proved successful in maintaining temperatures within 1 or 2 degrees Fahrenheit of the adjoining bay.

There were 6 double rows of cans with 10 cans to the row. Approximately three gallons of loam soil was placed in the cans on one side of each double row. About two and one-half gallons of silt soils, which had been collected with the oyster tongs, were added to the other rows of cans. One week after water levels and salinity concentrations were attained two quarts of specially collected soft surface silt were added to the silt cans. This process helped to duplicate the natural conditions in the middle of Back Bay.

Water was pumped directly from Back Bay into all 120 cans and ocean water from Sandbridge was used to adjust salinity concentrations. Each double row of 10 cans was used to test an aquatic plant. The first 4 tanks in each double row were control tanks of bay water designated as 0 percent, but actually the water tested about 1.86 % SS. The successive cans, in each row after the controls, were adjusted to 5 % SS increments from 5 % SS to 40 % SS. Bay water was added as needed during the summer to maintain the salinities specified. Sheets of clear polyethelene were suspended in a framework over the rows of tanks to prevent excessive dilution by rainfall, or contamination of various types.

As seedling stock of sago pondweed, wildcelery, southern naiad, redheadgrass, and widgeongrass became available in May, 100 uniform-size plants of each species were selected. The seedlings were only 2 or 3 inches in size and were considered, as a-negligible quantity in later computation of yields. Plantings of most species were made between May 7-9, 1960, but sago pondweed was not planted until May 31, and the muskgrasses were not planted until mid-July.

Each plant species was tested in 20 cans in water salinities in 5 percent increments from 0 to 40 % SS, on silt and loam soils. Ten plants of the test species were planted per can, except only five Chara and five Nitella plants were planted in one series of cans.

Numerous observations, photographs, and water and soil chemical determinations were made throughout the summer and fall. Specific notes were made on aquatic fauna, plant coloration, plant vitality, seeding, competition, -and water clarity. Many of these incidental observations are interesting but not significant enough for repetition here. It is worthwhile noting that a few test cans, particularly two used for redheadgrass, were ruined because rodents drowned in the tanks. Even though these were removed within 24 hours the pH was lowered and the ammonical nitrogen increased; algal growth increased and the test plants died out in a few days time.

Competition from invading species was a problem even though every effort was made to remove plant parts from the soils when the study was started. Oogonia of muskgrasses and seeds of several other plants could not be removed. The subsequent bioassay in 1961 used sand soils to alleviate competition from invading species.

Each of the 120 cans was removed on December 5, 1960, and the contents were washed out over a one-fourth inch wire mesh rack. All plant. parts were measured by volume displacement. The number of tubers and winter buds of certain plants were determined and individually measured by volume displacement.

Results of 1960 Bioassay

Tabular material accompanies this narrative; graphs depicting yields are in the appendix.

Sago Pondweed

The silt soils that were non-productive in the bay were by far the most productive of sago pondweed, and most other species, in the still waters of the test cans. Considering the high

Table____

Volumes of' Each Species of Vegetation Grown in Various Salinities on Loam a&Silt Soil.

Loam:

% of Sea Strength	Sago	Najas	Celery	Widgeon Gram,	Redhead Grass	Chara	Nitella	Total
#1 0	7.0	35.0			1.0			83.0
#2 0		97.5			1.0			98.5
#3 5%		50.0	3.0	1.5	23.0	0.3	0.2	78.0
#4 10%		30.0	1.5		140.0	106.9	28.5	306.9
#5 15%		13.0		2.0	1.0			16.0
#6 20%		4.0	10.5	210.0	6/0			230.5
#7 25%	30.0		3.0	17.0	150.0			200.0
#8 30%	3.0			37.5	142.5			183.0
#9 35%	2.0			60.0	20.0	90.0		172.0
#10 40%	6.5			150.0	9.0			165.5
Total	48.5	269.5	18.0	478.0	493.5	197.2	28.7	1533.4

Silt:

% of Sea Strength	Sago	Najas	Celery	Widgeon Gram,	Redhead Grass	Chara	Nitella	Total
#1 0		120.0	3.0	2.0	187.5			332.5
#2 0	6.0	150.5	1.0	7.0	102.5	12.0	150.0	429.0
#3 5%	62.0	142.5	3.0	8.0	90.0	22.5		328.0
#4 10%	2.0	9.0	8.0		125.0			144.0
#5 15%	46.5	67.5	7.0	135.0	105.0	60.0	20.0	441.0
#6 20%	135.0	45.0	10.0	90.0		25.0	35.0	340.0
$7 25%	69.5		4.0	150.0	115.0			338.5
#8 30%	189.0		17.0	120.0	120.0			446.0
#9 35%	174.0		30.0	135.0	75.0			414.0
#10 40%	167.1		30.0	112.5	105.0			414.6
Total:	851.1	534.5	113.0	759.5	1025.0	119.5	205.0	3607.6

T a b l e

Total Volume of Each Species of Vegetation in Loam and Silt Tanks.
(includes).

LOAM:

% of Sea Strength		Sago	Najas	Celery	Widgeon Grass	Redhead Grass	Nitella	Chara	Eleo-charis	Sagit-taria	Berch-toldi	Total
#1	0	7.0	100.0	0.1		1.0	137.5	76.0	Tr.	52.5		374.1
#2	0		162.6			1.0	328.5		17.1			509.2
#3	5%		350.0	7.5	1.5	23.0	1.2	20.3	33.0	22.5		459.0
#4	10%		32.8	1.5		140.0	357.5	256.9	17.3		Tr.	806.0
#5	15%		63.0	4.5	2.0	1.0	95.5		78.5			244.5
#6	20%	39.0	4.0	40.5	210.0	6.0	1.0		65.5			366.0
#7	25%	30.0		5.0	17.0	150.0		90.0	202.5			494.5
#8	30%	3.0		0.5	172.5	142.5		7.0	117.0			442.5
#9	35%	47.5		0.8	127.5	20.0		I.42.5	215.5			553.8
#10	40%	34.5			170.0	9.0		62.0	159.5			435.0
Total:		161.0	712.4	60.4	700.5	493.5	921.2	654.7	905.9	75.0	Tr.	4684.6

SILT:

% of Sea Strength		Sago	Najas	Celery	Widgeon Grass	Redhead Grass	Nitella	Chara	Eleo-charis	Sagit-taria	Berch-toldi	Total
#1	0		166.0	3.0	2.0	187.5		0.5		15.0	20.0	394.0
#2	0	6.0	327.0	1.0	7.0	102.5	162.0	35.0	8.0	10.0		658.5
#3	5%	62.0	297.5	3.0	8.0	90.0	10.0	32.5	7.0	30.0		540.0
#4	10%	7.0	2U.5	8.0	11.0	125.0		22.0	0.5	17.0		402.0
#5	15%	46.5	84.5	7.0	135.0	105.0	20.0	66.0	9.0	Tr.		473.0
#6	20%	135.0	49.0	10.0	90.0		50.0	35.0	29.0	1.0		399.0
#7	25%	69.5	Tr.	4.0	150.0	115.0		10.0				348.5
#8	30%	189.0		17.0	120.0	120.0						446.0
#9	35%	174.0		30.0	135.0	75.0						414.0
#10	40%	167.1		30.0	112.5	105.0		3.0				W7.6
Total:		856.1	1135.5	113.0	770.5	1025.0	242.0	204.0	53.5	73.0	20.0	4492.0

Table ____. Total Invasion by Each Species of Vegetation in all Tanks (excludes species test tanks).

% of Sea Strength		Sago	Najas	Celery	Widgeon Grass	Redhead Grass	Nitella	Chara	Eleocharis	Sagittaria	Berchtoldi	Total
#1	0		71.0	0.1			137.5	76.5	Tr.	67.5	20.0	372.6
#2	0		241.6				340.5	23.0	25.1	10.0		640.2
#3	5%		455.0	4.5			11.0	30.0	40.0	52.5		593.0
#4	10%	5.0	205.3	Tr.	11.0		329.0	172.0	17.8	17.0	Tr.	757.1
#5	15%		67.0	4.5			95.5	6.0	87.5	Tr.		260.5
#6	20%	39.0	4.0	30.0			16.0	10.0	94.5	1.0		X94.95
#7	25%			2.0				100.0	202.5			304.5
#8	30%			0.5	135.0			7.0	117.0			259.5
#9	35%	45.5		0.8	67.5			52.5	215.5			381.8
#lo	40%	28.0			20.0			65.0	159.5			272.5
Total:		117.5	1043.9	42.4	233.5	0	929.5	542.0	959.4	148.0	20.0	4036.2

Table.____ Total Volume of Bach Species of Vegetation in all Tanks (incl. Invasion)

% of Sea Strength		Sago	Najas	Celery	Widgeon Grass	Redhead Grass	Nitella	Chara	Eleocharis	Sagittaria	Berchtoldi	Total
#1	0	7.0	266.0	3.1	2.0	188.5	137.5	76.5	Tr.	67.5	20.0	768.1
#2	0	6.0	489.6	1.0	7.0	103.5	490.5	35.0	25.1	10.0		1167.7
#3	5%	62.0	647.5	10.5	9.5	113.0	11.2	52.8	40.0	52.5		999.0
#4	10%	7.0	244.3	9.5	11.0	265.0	357.5	278.9	17.8	17.0	Tr.	1208.0
#5	15%	46.5	147.5	11.5	137.0	106.0	115.5	66.0	87.5	Tr.		717.5
#6	20%	174.0	53.0	50.5	300.0	6.0	51.0	35.0	94.5	1.0		765.0
#7	25%	99.5	Tr.	9.0	167.0	265.0		100.0	202.5			843.0
#8	30%	192.0		17.5	292.5	262.5		7.0	117.0			888.5
#9	35%	221.5		30.8	262.5	95.0		l-42.5	215.5			967.8
#10	40%	201.6	-	30.0	282.5	114.0		65.0	159.5			852.6
Total:		1017.1	1847.9	173.4	1471.0	1518.5	1163.2	858.7	959.4	148.0	20.0	9177.2

Table . Yield of Sago Pondweed (in cc.) from the 1960 Bioassay from Late May to Early December in Various Concentrations of Sea Water to 40% Sea Strength on Loam and Silt Soils.

Percent Sea Strength	Number of Tubers	Volume of Tubers (cc.)	Volume of Vegetation	Total Volume	Average Tuber Volume	Condition of Plants	Plant Color	Remarks
Loam Soil								
0	0	0	7.0	7.0	--	Poor	Chlorotic and Yellow-green	Fallen to bottom
0	2	Trace		Trace	--	Poor	Chlorotic	
5	0	0	0	0	--	Dead	Chlorotic	
10	0	0	0	0	--			No vegetation
15	0	0	0	0	--			No vegetation
20	0	0	Trace	Trace	--	Poor	Yellow-green	Small sprig
25	1	Trace	30.0	30.0	--	Poor	Brown	Sago standing; algae heavy
30	1	Trace	3.0	3.0	--	Poor	Brown-green spots	Partially standing, appears dead, algae heavy
35	17	2.0	0	2.0	0.118	Fair	Yellow-green	Slight
40	17	1.5	5.0	6.5	0.088	Fair	Yellow-green	
Silt Soil								
0	0	0	0	0	--	--		Dead - no vegetation
0	0	0	6.0	6.0	--	Poor	Chlorotic - few green leaves	At surface, competition heavy
5	25	2.0	60.0	62.0	0.080	Good	Pale green	Medium competition
10	0	0	2.0	2.0	--	Poor	Chlorotic to pale green	Very slight competition
15	12	1.5	45.0	46.5	0.125	Fair	Pale green	Saphrophytic fungus heavy
20	121	15.0	120.0	135.0	0.124	Excellent	Green-some brown	One of best stands
25	26	2.0	67.5	69.5	0.077	Poor	Pale green	Heavy algae
30	113	9.0	180.0	189.0	0.080	Excellent	Green-some brown	Heavy sago at surface
35	146	9.0	165.0	174.0	0.062	Excellent	Green to brown	Heavy sago at surface
40	41	2.1	165.0	167.1	0.051	Good	Pale green with brown	Moderate sago at surface

Table . Yield of Wildcelery (in cc.) from the 1960 Bioassay from Early May to Early December in Various Concentrations of Sea Water to 40% Sea Strength on Loam and Silt Soils.

Percent Sea Strength	Number of Tubers	Volume of Tubers (cc.)	Volume of Vegetation	Total Volume	Condition of Plants	Remarks
Loam Soil						
0	2	Trace	0	Trace	Dead	
0	2	Trace	0	Trace	Dead	
5	16	3.0	Trace	3.0	Dead	1 seed pod; floating dead leaf
10	5	0.5	1.0	1.5	Dead	
15	0	0	0	0	Dead	
20	52	6.5	4.0	10.5	Dead	
25	28	3.0	0.0	3.0	Dead	
30	3	Trace	0.0	Trace	Dead	
35	2	Trace	0.0	Trace	Dead	
40	0	0	0	0	Dead	
Silt Soil						
0	15	1.5	1.5	3.0	Poor	2 seed pods
0	6	1.0	Trace	1.0	Dead	
5	25	3.0	Trace	3.0	Dead	
10	60	8.0	0.0	8.0	Dead	
15	37	7.0	Trace	7.0	Dead	1 seed pod
20	66	10.0	0.0	10.0	Dead	
25	39	4.0	Trace	4.0	Dead	
30	88	17.0	Trace	17.0	Dead	
35	32	5.0	25.0	30.0	Dead	
40	134	20.0	10.0	30.0	Dead	

Table . Yield of Widgeongrass (in cc.) from the 1960 Bioassay from Early May to Early December in Concentrations of Sea Water to 40% Sea Strength on Loam and Silt Soils,

Percent Sea Strength	Volume of Vegetation (cc.)	Condition of Plant	Plant Color	Remarks*
Loam Soil				
0	0.0	--	--	Najas competition
0	0.0	--	--	Slight competition
5	1.5	Good	Green	Najas competition
10	0.0	--	--	Chara competition
15	2.0	--	--	Nitella competition
20	210.0	Excellent	Yellow-Brown	No competition
25	17.0	Good	Pale Green	Slight competition
30	37.5	Good	Pale Green to Yellow	Slight competition
35	60.0	Excellent	Pale Green	No competition
40	150.0	Excellent	Medium Green	No competition
Silt Soil				
0	2.0	Good	Green	Moderate Najas competition
0	7.0	Good	Green	Moderate Najas competition
5	8.0	Fair	Pale Green	Heavy Najas competition
10	0.0	Fair	Pale Green	Heavy Najas competition
15	135.0	Good	Yellow-Brown	No competition
20	90.0	Good	Yellow-Brown	Seeds numerous, No competition
25	150.0	Good	Yellow-Brown	Seeds numerous, No competition
30	120.0	Good	Yellow-Brown	Seeds numerous; Heavy roots, No competition
35	135.0	Good	Reddish--Yellow	Seeds numerous; Heavy roots, No competition
40	112.5	Good	Reddish-Yellow	Heavy roots, No competition

* Competition in some tanks appears to limit growth.

Table . Yield of Redheadgrass (in cc.) from the 1960 Bioassay from Early May to Early December in Concentrations of Sea Water to 40% Sea Strength on Loam and Silt Soils,

Percent Sea Strength	Volume of Roots and Winterbuds (cc.)	Volume of Vegetation (cc.)	Total Volume (cc.)	Condition of Plant	Color	Remarks*
Loam						
0	0.0	1.0	1.0	Fair	Green	'Heavy Nitella competition
0	0.0	1.0	1.0	Fair	Greea	Heavy Nitella competition
5	3.0	20.0	23.0	Good	Green	Medium Najas competition
10	65.0	75.0	140.0	Good	Green	
15	0.0	1.0	1.0	Poor	Pale Green	
20	Trace	6.0	6.0	Fair	Pale Green	Few roots, Small leaves
2.5	60.0	90.0	150.0	Good	Green-Brown	
30	75.0	67.5	142.5	Good	Green-Brown	
35	Trace	20.0	20.0	Poor	Green-Brown	
LO	Trace	9.0	9.0	Poor	Green-Brown	Short stems
Silt						
0	60.0	127.5	187.5	Excellent	Green	
0	20.0	82.5	102.5	Good	Pale Brow-n-Green	
5	15.0	75.0	90.0	Good	Pale Brown-Green	
10	20.0	105.0	125.0	Good	Green	
15	15.0	90.0	105.0	Good	Brbwn-Green	
20	Destroyed	--	--	--	--	Rat in Tank
25	10.0	105.0	115.0	Fair	Brown	
30	45.0	75.0	120.0	Fair	Brown	
35	30.0	45.0	75.0	Fair	Brown	
40	60.0	45.0	105.0	Fair	Brown-Green	

Table . Sago Pondweed Tuber Production from the 1960 Bioassay (from early May to late November) Under Indicated Conditions of Water Salinities and Soil Types.

		1960 Bioassay*			
		Number Tubers on Each Soil			
Percent Sea Strength	Tank No.	Silt	Loam	Total	Average
2%	1 2	0 0	0 2	(2)	0.5
5%	1	25	0	25	12.5
10%	1	0	0	0	0.0
15%	1	12	0	12	6.0
20%	1	121	0	121	60.5
25%	1	26	1	27	13.5
30%	1	113	1	114	57.0
35%	1	146	17	163	81.5
40%	1	41	17	58	29.0
Total		484	38		

* 1960 Bioassay involved two soil types and water salinities to 40 percent sea strength.

cation exchange capacity of these silt soils this is not too surprising; but it does demonstrate that the physical nature of these soils and the conditions of turbidity where these soils occur are more suspect of limiting plant growth than the chemical composition of the soils.

In the proper receptacles, excluding invasion, the yield of sago pondweed from all 10 cans with loam soil was 48.5 cc.; however, 851.1 cc. were grown in the 10 cans with silt soils. Also the total number of tubers was only 38 in the loam soils, but there were 484 tubers in the silt soils. Tuber production also increased in the higher salinities; this conforms to numerous observations and surveys of field conditions.

The volumetric yield of sago pondweed tended to increase on the silt soils with increased salinity. Several of the tanks with loam soil between 0 and 20 % SS were non-productive; this is believed to have resulted from a fungal disease.

Although there were not suitable replicates,the evidence from this range-finding bioassay indicated that plant and tuber production were greatly enhanced by water salinities of 20 to 40 % ss. Water salinities of 5 to 15 % SS increased plant and tuber production of sago pondweed, although competition by invading species and possibly fungal disease are presumed to have been of importance and obscure definite conclusion.

As shown in the table documenting invasion, sago pondweed invasion tended to increase in all salinity concentrations above 0 % SS.

Najas, southern naiad, or bushy pondweed

Najas production was 269.5 cc. on the loam soils and 534.5 cc. on the silt soils. No najas survived concentrations of 25 % SS or more. Yield was progressively reduced in concentrations of 10 to 20 % SS in the test tanks for that species. However, the invasion of najas in silt soils in other tanks was highest in 10 % SS, but much reduced in higher concentrations. The high cation exchange of the silt soils probably serves to buffer the salts that might be harmful to the roots of najas and other species more than in other soiltypes.

Wildcelery

The yield of wildcelery was 113 cc. in the silt soil cans, but only 18 cc. in the loam soil cans.

In the series of silt cans the yield of wildcelery vegetation and tubers tended to increase with increasing salinity. The greatest number of tubers, 134, occurred in the can with 40 % SS. I believe this increased tuber production of wildcelery and sago pondweed in higher salinities may result from the increased potassium level. Potassium contributes to the storage of starches in plants.

Practically all wildcelery leaves disintegrated in late October. Fragmentation of leaves of plants in loam soil began in early June. Through August the best stand of wildcelery occurred in the can with silt soils on 10 % SS.

On August 3 good healthy stands of wildcelery were recorded on silt soils in cans with 0, 10, 30, 35, and 40 % SS. Fair stands were recorded on silt soils in 0, 15, 20, and 25 % SS, and on loam soils in 5, 20, and 25 % SS. Poor stands occurred on silt soils in 5 % SS, and on loam soils in both fresh cans, 10, 15, 30, 35, and 40 % SS.

A red coloration of wildcelery leaves was first noted June 23 in cans of 15 to 25 % SS. By August 3 the red coloration of leaves was noted on loam soils in fresh water, 10, 20, and 25 % SS, and on silt soils in 10, 15, 20, and 25 % SS. The red coloration was most noticeable in the 20 to 25 % SS but some fresher and some more saline cans contained normal green wildcelery. Possibly a nutrient imbalance, e.g., phosphorus, might account for the odd red coloration.

Throughout the summer a definite diminution in individual plant size was observed in 20 % SS and above.

Invasion by wildcelery occurred on loam soils in all salinities from 0 to 35 % SS; however, none invaded other test cans on silt soils at any salinity.

Widgeongrass

The yield of widgeongrass from the silt cans was 759.5 cc. compared to only 478 cc. from the loam cans.

The yieldsvery definitely increased at 15 % SS or more, and seeds were more numerous and root structure was heavier. On July 26 only 6 flowering heads were seen in the 8 cans of 10 % SS or less, but from 15 to 40 % SS between 95 and 500 flowering heads were counted per can with higher numbers in the higher salinities. Competition from invading species was much less at 15 % SS and higher.

Most of the invasion by widgeongrass occurred in loam soil at salinities of 30, 35, and **40** % SS.

The peak yield of widgeongrass, as both a test and invading species, occurred in 20 % SS; however, this was not significantly different from similar yields in salinities up to 40 % SS. Quite possibly the optimum salinities for widgeongrass are higher than 40 % SS.

Redheadgrass

The yield of redheadgrass on silt soils was 1025 cc. compared to only 493.5 cc. on loam soils.

Reasonably good yields have occurred at all salinities tested and no particular significance could be assumed for any of the variations. The 20 % SS can with silt soil was destroyed by decomposition of a drowned rat.

Unlike all other species no redheadgrass invaded any of the other test cans. This was surprising in view of the relatively good seed production of redheadgrass in the bay and the likelihood of contamination of the test soils. It was also surprising that there was no invasion of redheadgrass on silt soils by other species.

On June 23 the best stands occurred in waters of 5 to 25 % SS, with the 15 % SS can rated as the best. The ratings remained about the same through mid-July. However, the pH of the water in the cans with loam soil and 15, 20, and 35 % SS dropped to a low of 4.2 and a calcium precipitant appeared on the plant leaves. An iron-like brown spotting also appeared on some leaves.

Between July 12 and July 25 the M.O. alkalinity of the water in the loam soil cans at 15, 20, and 35 % SS dropped from an average of 20 part per million (ppm) to 6 ppm. The pH of the water in these 3 cans remained very low until October 11 when it had climbed to a pH of about 8.5. During the period of July, August, and September when these low pH readings occurred in the cans, the pH averaged about 9 in the other cans.

Although the reason for the increased acidity is unknown, it might have resulted from a calcium precipitating bacteria.

By September 9 the best stands were on silt soils from 0 to 15 % SS; although good ratings were assigned to the 25 and 30 % SS cans on silt soil.

On December 5 the observation was made that redheadgrass appeared to make the best growth on silt soils at salinities of 0 to 15 % SS; and it appeared only fair to poor on silt soils at 25 to **40** % ss.

Muskgrasses (Chara sp. and Nitella sp.)

An insufficient number of test receptacles was available for all plant species, so in the last row of 20 cans 5 Chara plants and 5 Nitella plants were planted in each can.

These were identified by Dr. Zaneveld, of the College of William, and Mary, as Chara hydropitys (Reich.) and Nitella hyalina (D.C.) Ag.

Although the muskgrasses readily invaded cans used for other species, establishment of Chara and Nitella in the proper test cans was never very satisfactory. Turbid water developed in this series of cans in mid-summer and further complicated results by preventing observation on the plants.

Perhaps, the best index of the response of these two plants is found in the table showing total volume in all tanks including invasion. This indicates Nitella did not survive salinities in excess of 20 % SS, and possibly it was retarded by salinities above 10 % SS. Chara was also erratic but it survived salinities of 0 to 40 % SS, with no significant preference demonstrated, considering the variability.

Eleocharis parvula was an invading species of all levels of salinity on loam soils; it tended to occur in greater abundance with increased salinity, but this may have resulted from lesser competition in the higher salinities. On silt soils it invaded water salinities of 0 to 20 % SS.

Sagittaria subulata invaded loam soils at salinity levels of 0 and 5 % SS; it invaded silt soils in water salinities of 0, 5, 10, 15, and 20 % SS, but decreased in quantity above 5 % SS.

Potamogeton berchtoldi invaded one fresh silt can to the greatest degree; only a trace was found in a loam can at 10 % SS.

Total Vegetation

Including the invasion the greatest quantity of vegetation grew in the loam soils, which apparently had much seed and root stock. Considering 'the advantage of this there was not much difference in total vegetation on the two soil types. However, the yields from the proper test cans for each species show the silt soils were more than twice as productive as the loam soils.

Indeed, the lesser competition on the silt soils probably contributed to higher yields on those soils, but the fertile character of the silt soils was demonstrated. Certainly the chemical composition of the soils was absolved as a factor in their non-productivity in the habitat.

Including invasion the greatest yield of total vegetation occurred in 10 % SS. We do not consider this to be significantly higher than that of any other level tested.

In attempting to relate the results of the bioassay to what might be expected to happen in the habitat under different levels of salinity the first assumption would be that species composition changes would be the most dramatic result; changes in total plant abundance would be secondary.

However, plant abundance is a function of many complex ecological factors and the influence of salinity on these factors, e.g., water turbidity, soil cohesion, etc., cannot:be judged from this bioassay.

Spectrochemical analyses were made of the major nutrientsin most plant specimens from this bioassay. The results of those analyses are discussed in the volume on water and soil chemistry, in conjunction with discussion of chemical content of plant samples taken in the habitat.

Bioassays of Aquatic Plants in Water Salinities of 2 to 17 Percent Sea Strength

Further tests were made of the response of the principal aquatics to various concentrations of ocean water in 1961, following the range-finding tests in 1960. The objective was to determine yields of aquatics from a complete growing season in salt water concentrations that were possibly compatible with fresh water fish management.

The 24-gallon plastic cans used in the 1960 study were again used in 1961; they were set in the ground in double rows and the rows were covered with frames of polyethelene plastic.

Each of 7 species ofaquatic was tested in 16 cans at ocean water concentrations of 2, 7, 12, and 17 % SS. Four cans were assigned to each concentration. The species tested were sago pondweed, widgeongrass, wildcelery, southern naiad, redheadgrass, Chara sp. (Presumably Chara hydropitys), and Nitella hyalina.

Three gallonsof coarse sand collected near Nawney Creek from a natural levee were washed several times and placed in each can. This helped to overcome the difficulty of invasion of other species in the test cans; further, the sand soils were low in all major nutrients and the direct response to salt water could more clearly be determined than with other soils.

Ten uniform size plants were planted per can in the first week in May, except Nitellaand Chara were not planted until June 9 and 12, respectively.

Water salinities were maintained within 1 or 2 percent of the assigned concentrations throughout the test. Water temperatures were virtually the same as the adjacent bay. Water used in the test was pumped directly from Back Bay and hauled from the ocean. The assigned concentration of 2 % SS was bay water that tested 1.87 % ss.

The tanks were removed on November 27, 1961, and the contents were washed out over a one-fourth inch wire mesh frame. Volume displacement measurements were of individual plant parts.

The contents of certain cans were destroyed by decomposition of rodents, as indicated in:the accompanying tables, and these are not included in the averages per test.

Results of the 1961 Bioassay

Sago Pondweed

Sago pondweed yield was highest in 17 % SS, but not significantly different from that in 7 or 12 % SS. The average number of tubers also increased in the higher salinities; averaging 10.5, 18, 28.8, and 30.5 in the cans of 2, 7, 12, and 17 % SS, respectively, Seed production was heaviest in the cans of 17 % SS.

Widgeongrass

Widgeongrass yield also was highest in 17 % SS. At least 1 can at 2, 7, and 12 % SS was ruined by decomposition of rodents. Relatively good growth was made by widgeongrass in all concentrations and the plant condition was good. Seeding occurred only in 17 % SS.

Wildcelery

Wildcelery yield of tubers and vegetation tended to decline in higher salinities, although the yields from 2 and 7 % SS are not significantly different. Plant condition at 17 % SS was distinctly worse than at lower salinities. It is interesting to note the results from this study with sand soil are converse to the results of the 1960 bioassay with silt soil. The wildcelery tuber and vegetation tended to increase in the higher salinities in this general range on the silt soils. I believe the high cation exchange of silt soils protects the root structure from harmful salt concentrations, whereas sand has little buffering effect.

Najas

Southern naiad yield was about equal at 2 and 7 % SS, but declined progressively at 12 and 17 % SS.

Redheadgrass

The yield of redheadgrass was about equal and highest at 12 and 17 % SS; yield at 2 and 7 % SS was about equal but considerably lower than at the higher salinities. The volume of the root structure and winter buds was obviously enhanced at the two higher salinities. Plant condition also was better at the higher salinities.

Table . Volumes (in cc.) of Each Species of Vegetation Grown in Various Water Salinities on Sand Soil During the 1961 Bioassay Extending from May 2, 1961, to November 27, 1961.

Percent Sea Strength	Tank No.	Sago	Widgeon	Celery	Najas	Redhead	Chara	Nitella	Total Vegetation	No. of Tanks
2	1	1.5	19.0	17.0	21.0	3.0	Trace	0.0		
	2	5.5	9.0	15.0	7.0	5.0	0.0	0.0		
	3	4.0	18.0	7.0	87.0	5.0	0.5	2.0		
	4	5.5	0.0*	27.0	32.0	3.0	0.0	1.0		
	Total:	16.5	46.0	56.0	147.0	16.0	0.5	3.0	285.0	27
	Average:	4.13	15.33	14.00	36.75	4.0	0.13	0.75	10.56	
7	1	38.0	3.0	7.0	31.0	3.0	0.5	3.0		
	2	20.0	9.0	14.0	40.0	4.0	0.0	1.0		
	3	24.5	Trace	18.0	49.0	Trace	Trace	0.0*		
	4	8.5	0.0	14.0	32.0	6.0	Trace	3.0		
	Total:	91.0	12.0	53.0	152.0	13.0	0.5	7.0	328.5	27
	Average:	22.75	3.0	13.25	38.00	3.25	0.13	2.33	12.17	
12	1	7.5	0.0*	5.0	19.0	16.0	0.0	6.0		
	2	49.0	23.0	13.0	23.0	42.0	0.0	0.0*		
	3	12.5	9.0	5.0	10.0	35.0	0.0	8.0		
	4	15.5	18.0	8.0	11.0	0.0*	1.0	1.0		
	Total:	85.5	50.0	31.0	63.0	93.0	1.0	15.0	338.5	25
	Average:	21.38	16.67	7.75	15.75	31.0	0.25	3.0	13.54	
17	1	17.5	22.0	4.0	1.0	14.0	0.0	5.0		
	2	14.0	12.0	4.0	5.0	51.0	0.0	0.0		
	3	19.0	22.0	5.0	3.0	35.0	0.0	0.0		
	4	61.5	28.0	6.0	4.0	46.0	0.0	2.0		
	Total:	112.0	84.0	19.0	13.0	156.0	0.0	7 .	391.0	28
		28.00	21.00	4.75	3.25	39.00	0.0	1.75	14.00	

* Destroyed by decomposition of rodents and not included in averages.

Table . Yield of Sago Pondweed (in cc.) from the 1961 Bioassay from Early May to Late November in Concentrations of 2%, 7%, 12%, and 17% Sea Strength.

Percent Sea Strength	Tank Number	Number of Tubers	Volume Of Tubers (cc.)	Volume of Vegetation (cc.)	Total Volume	Condition of Plants	Plant Color	Remarks
2	1	10	1.0	0.5	1.5	Fair	Pale Green	
	2	11	1.0	4.5	5.5	Good	Pale Green	
	3	6	0.5	3.5	4.0	Good	Pale Green	
	4	15	1.0	4.5	5.5	Fair	Pale Green	
	Total	42	3.5	13.0	16.5			
	Average	10.50	0.875 (0.083)*	3.250	4.125			
7	1	13	1.5	36.5	38.0	Good	Green	
	2	15	1.0	19.0	20.0	Good	Green	
	3	31	1.5	23.0	24.5	Good	Green	
	4	13	1.0	7.5	8.5	Good	Green	
	Total	72	5.0	86.0	91.0			
	Average	18.00	1.250 (0.069)*	21.500	22.750			
12	1	10	0.5	7.0	7.5	Good	Green	
	2	52	6.0	43.0	49.0	Excellent	Green & tan	
	3	27	2.5	10.0	12.5	Good	Green	
	4	26	2 .	13.5	15.5	Good	Green & tan	
	Total	115	11.0	73.5	84.5			
	Average	28.75	2.750 (0.096)*	18.375	21.125			
17	1	22	2.0	15.5	17.5	Fair	Green & blanched	
	2	32	2.5	11.5	14.0	Fair	Green & blanched	
	3	21	2.0	17.0	19.0	Fair	Green	
	4	47	6.0	55.5	71.5	Excellent	Green	Seeds numerous; about 60 seeds
	Total	122	12.5	99.5	122.0			
	Average	30.50	3.125 (0.102)*	24.875	30.500			

* Average volume (cc.) per tuber.

Table . Yield of Redheadgrass (in cc.) from the 1961 Bioassay from Early May to Late November in Concentrations of 2%, 7%, 12%, and 17% of Sea Strength.

Percent Sea Strength	Tank Number	Volume of Roots and Winter Buds (cc.)	Volume of Vegetation (cc.)	Total Volume (cc.)	Condition of Plants	Color
2	1	1.0	2.0	3.0	Fair	Light Green
	2	1.0	4.0	5.0	Fair	Light Green
	3	Trace	5.0	5.0	Fair	Light Green
	4	Trace	3.0	3.0	Good	Medium Green
	Total	2.0	14.0	16.0		
	Average	0.50	3.50	4.00		
	1	Trace	3.0	3.0	Fair	Light Green to Medium Green
	2	Trace	4.0	4.0	Fair	Medium Green
	3	0	Trace	0.0	Poor	Light Green
	4	1.0	5.0	6.0	Fair	Light Green
	Total	1.0	12.0	13.0		
	Average	0.25	3.00	3.25		
12	1	5.0	11.0	16.0	Excellent	Light Green
	2	13.0	29.0	42.0	Excellent	Light Green
	3	6.0	29.0	35.0	Good	Green & Tan
	4	Destroyed	--	--	--	
	Total	24.0	69.0	93.0		
	Average	8.00	23.0	31.00		
17	1	2.0	12.0	14.0	Good	Medium Green
	2	13.0	48.0	61.0	Excellent	Medium Green
	3	8.0	27.0	35.0	Good	Light Green
	4	5.0	41.0	46.0	Excellent	Green
	Total	28.0	128.0	156.0		
	Average	7.00	32.00	39.00		

Miscellaneous Bioassays of Aquatic Plants in 1961

In conjunction with the aforementioned bioassays, and under identical procedures, certain miscellaneous aspects of the study were explored and are presented in the accompanying table.

Footnote No. 1 refers to the sago pondweed tuber production from the regular bioassay.

Footnote No. 2 refers to an identical series of 16 cans with sago pondweed to which we introduced the root rot fungus, Rhizoctonia solani. One can at each concentration was free from fungus introduction and served as a control. Complete results of this study are discussed in the accompanying publication by Ellis, Lumsden, and Sincock (1963). These tanks were not established until early June and this may explain the slightly lower tuber production than occurred in the May series. Tuber production increased with increasing salinity from 2 to 17 % SS.

Footnote No. 3 refers to a late introduction of ocean water into 2 series of 4 cans with established sago pondweed stands growing in 2 percent sea strength water. Salinities were raised to 12 and 17 % SS on August 20 to simulate introduction time of late summer hurricanes. The yields from the 4 cans raised to 12 % SS were 2.5 cc., 30.0 cc., 23.0 cc., and 8.5 cc. The yields from the 4 cans raised to 17 % SS were 3.0 cc., 8.0 cc., trace, and 13.5 cc. The plant condition was poor on all but the second and third cans at 12 % SS, which were rated as good in November 1961.

The average sago pondweed yield from the cans raised to 12 % SS was 16 cc. compared to 4.1 cc. from the 2 % SS controls in the regular bioassay. This yield of 16 cc. compares to 22.8 cc. yield from the cans maintained at 12 % SS throughout the summer.

The average sago pondweed yield from the cans raised to 17 % SS was 6.1 cc.; this could be compared to the aforementioned 2 % SS control yield of 4.1 cc., and the yield of 28.0 cc. from the constant salinity cans of 17 % SS.

Tuber production in this series was apparently not enhanced. Some plasmolysis seemed to occur to the plants within a week after the late salt water introduction.

This small scale study would need to be repeated with numerous replicates and varying salinity concentrations before definite conclusions could be made. However, at face value the late introductions in August increased the total yield above that of the constant 2 % SS yield. Tuber production was neither conclusively enhanced nor detracted from by the late introduction of ocean water at 12 % SS, but was apparently inhibited by the increase to 17 % SS. This inhibition may have resulted from plasmolysis of the plant tissue; some slow recovery in plant vitality was noted in the final 2 weeks.

The yields from the cans at constant summer salinities of 7, 12, and 17 % SS were higher than those resulting from the late introductions that increased salinities from 2 % SS to 12 and 17 % SS.

Footnote No. 4 refers to the 3 series of 2 tanks in which potassium sulfate was added to bay water to increase the potassium level to the quantity that would occur in ocean water concentrations of 7, 12, and 17 % SS.

It was theorized that the potassium in ocean water was possibly responsible for increasing tuber production. These cans were set up in late June and satisfactory stands were never attained; the results are inconclusive. The, yields from the concentrations of potassium sulfate were: 30 ppm - trace and trace; 60 ppm - 16.5 cc. and trace; 90 ppm - 0 and 0 cc. In this instance as in all of the bioassays the extent to which plant disease confounds the results is not know.

A SURVEY OF FUNGI ASSOCIATED WITH LESIONED AND CHLOROTIC SAGO PONDWEED (POTAMOGETON PECTINATUS)[1]

R. D. Lumsden, D. E. Ellis, and J. L. Sincock[2]

Summary

Isolations from 1000 Potamogeton pectinatus plants collected from six major stands in Back Bay, Virginia and 13 in Currituck Sound, North Carolina yielded Pythium spp. consistently and in relatively high frequency. Although specific determination of these isolates was unsuccessful, they were separated into three groups according to morphological and cultural characteristics. Rhizoctonia solani Kuehn was isolated in rare instances. In inoculation studies, isolates of R. solani were pathogenic to P. pectinatus, whereas inoculations with Pythium spp. proved inconclusive, even though one group of isolates exhibited pathogenic tendencies.

Sago pondweed (Potamogeton pectinatus), an aquatic plant which serves as a source of food for waterfowl, has undergone a severe decline in recent decades in Back Bay, Virginia and Currituck Sound, North Carolina. It has been postulated that the decline of this species, as well as certain other duck-food plants, has been partially responsible for the reduction in waterfowl populations in these areas.

In 1928 Bourn and Jenkins (1) described a disease of P. pectinatus from the waters of Back Bay and Currituck Sound. Pure cultures of a physiological strain of Rhizoctonia solani Kuehn were isolated repeatedly from diseased plants. Isolates of the fungus caused disease symptoms identical with those seen under natural conditions when P. pectinatus plants were inoculated in aquaria in the greenhouse.

During the summer and fall of 1961, a study of the Back Bay and Currituck Sound areas was undertaken to determine the distribution and severity of P. pectinatus decline, the incidence of R. solani and certain other fungi associated with the disease, and the influence of different levels of salinity on disease development.

MATERIALS AND METHODS

A total of 1000 plant samples was collected from 19 areas representative of the major P. pectinatus stands in Back Bay and Currituck Sound. Collections were made at random in each area. The number of plants collected from each area was determined by the abundance of P. pectinatus in relation to the total area of each stand. Plants were packaged separately and each day's collection was shipped without delay to North Carolina State College, Raleigh. Upon arrival, each plant was thoroughly washed in tap water, and rinsed repeatedly in sterile distilled water, after which stem sections were transferred aseptically to plates of potato-dextrose agar (PDA) medium. Readings were made after 2 to 5 days' incubation at room temperature and representative cultures were transferred to test tubes containing PDA medium.

Salinity measurements were made in each of the 19 stands during the summer of 1961; using the field method of Denny (2).

In all inoculation studies, apparently disease-free P. pectinatus plants from comparatively healthy stands in lower Currituck Sound were used.

R. solani inoculation studies were conducted using P. pectinatus plants established in June 1961 in each of 16 tanks (20-gallon capacity) sunken in the ground at Back Bay, Virginia. The tanks contained bay water adjusted with ocean water to salinity levels of 2, 7, 12, and 17% of sea strength[3]. Four inches of sand served as the substratum in all tanks. Nine plants in each of three replicate tanks at each salinity level were inoculated in June 1961. One plant was removed prior to inoculation to determine the initial presence of fungi. Inoculum consisted of

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[1]A cooperative study conducted by the Plant Pathology Department, North Carolina State College; the Bureau of Sport Fisheries and Wildlife, United States Department of the Interior; the Virginia Commission of Game and Inland Fisheries; and the North Carolina Wildlife Resources Commission.
[2]Graduate Assistant, Professor, Department of Plant Pathology, North Carolina State College, Raleigh, and Biologist, Bureau of Sport Fisheries and Wildlife, Laurel, Maryland, respectively.
The assistance of Drs. J. N. Couch and C. S. Hodges in identification of fungi is acknowledged.
[3]One hundred percent of sea strength equivalent to 19,381 ppm chlorinity.

Table 1. Frequency of isolation of fungi and bacteria from Potamogeton pectinatus plants and salinity measurements from major Plant stands in Back Bay, Virginia and Currituck Sound, North Carolina in 1961.

Plot no.	No. plants from which platings were made	% sea strength[a]	No. lesioned plants	Pythium sp. 1	Pythium sp. 2	Pythium sp. 3	Rhizoctonia solani	Curvularia sp.	Phoma sp.	Pullularia pullulans	Hyalo-florae sp.	Misc.	No. plants from which bacteria isolated
Back Bay													
1	30	1.25	24	0	6	9	0	1	a	3	6	a	12
2	30	1.06	23	2	6	7	0	4	4	6	8	12	23
3	50	1.47	33	3	6	5	0	6	1	2	5	a	48
4	30	1.52	22	0	3	9	0	2	5	2	4	11	12
5	30.	1.45	18	5	10	4	0	0	0	1	1	3	11
6	30	1.68	11	0	10	a	0	3	1	3	2	13	19
Currituck Sound													
7	50	1.68	26	2	14	16	0	9	1	0	3	a	39
a	30	1.33	la	2	6	4	0	2	0	4	2	16	27
9	100	1.56	42	2	a	la	1	12	10	2	11	16	a2
10	50	1.72	39	3	6	14	0	4	0	0	0	0	42
11	50	2.00	16	0	3	4	1	2	0	1	0	3	43
12	100	2.48	52	3	9	18	0	1	5	7	0	5	a5
13	100	2.48	22	2	20	21	0	1	4	2	0	4	85
14	100	2.86	43	2	10	33	0	0	0	0	0	19	88
15	100	2.81	32	4	12	36	2	a	2	7	4	30	91
16	30	3.79	6	1	1	10	0	0	2	0	3	10	25
17	30	3.56	4	4	6	11	0.	6	0	1	0	3	28
18	30	3.93	4	0	4	11	1	2	0	0	0	11	7
19	30	5.82	7	3	6	13	0	1	0	0	0	3	23
Totals:	1000		442	38	146	251	5	64	43	41	49	la3	790
% occurrence			44	4	15	25	0.5	6	4	4	5	18	79

[a]100% sea strength = 19,381 ppm chlorinity.

Table 2. Influence of various salinity concentrations on vigor of Potamogeton pectinatus inoculated in the summer of 1961 with Rhizoctonia solani in 20-gallon containers sunken in the ground at Back Bay, Virginia,

Tank no.	% sea strength	Presence of lesions	Seed production	No. of tubers	General plant condition	R. solani	Pythium spp.	Misc	Bact.
1	2	P	0	6	Good[a]	P	A[b]	P	P
2	2	P	0	5	Poor	P	P	A	A
3	2	P	0	10	Very poor	--[c]	--	--	--
4 (control)	2	P	0	6	Fair	A	P	P	P
5	7	P	0	16	Fair	P	P	P	P
6	7	P	0	7	Poor	P	P	P	P
7	7	P	0	9	Poor	P	P	P	A
6 (control	7	P	0	16	Fair	P	P	P	P
9	12	P	0	21	Fair	P	P	P	P
10	12	P	0	26	Good	P	P	P	P
11	12	P	0	23	Fair	A	P	P	P
12 (control)	12	P	P	16	Poor	A	P	P	A
13	17	P	0	37	Fair	P	P	P	A
14	17	P	P	39	Good	A	P	P	A
15	17	P	P	39	Good	A	P	P	P
16 control)	17	A	P	32	Good	A	A	P	P

[a]Good = Green; Fair = Partly green, partly chlorotic; Poor = Entirely chlorotic; Very poor = Plant collapsed.
[b]P = Present; A = Absent.
[c]Plants not suitable for isolations.

certain conditions, thus confirming the studies of Bourn and Jenkins (1), but it appears from this study that its importance is minimal and that some other factor or factors are involved in the disease complex.

One or more of the Pythium spp. frequently isolated from plant samples may be the pathogen involved. Specific identification of these Pythium isolates was not achieved since no single culture could be induced to produce both sexual and asexual fruiting structures. The three groups appeared to be distinctly different from one another, especially groups 1 and 3, as evidenced by the strikingly different sporangial types, and the respective slow and rapid growth rates on PDA. Group 2 produced only oogoniaand antheridia, but its intermediate growth rate distinguished it from the other two groups. The frequency of natural occurrence of the third group along with the results of one inoculation test suggests that it may be involved in the disease complex.

Unsuccessful isolation of Pythium from some lesioned plants may have resulted from either an advanced stage of deterioration of the plants and consequent inhibition of Pythium growth by secondary fungi, or possibly an inability to detect primary lesions. Colonies of iron bacteria growing at the base of many plants often made it difficult to distinguish lesions. Isolation of Pythium spp. from apparently healthy tissue could have resulted from an early stage of infection when lesions were incipient, or from mechanical adhesion of mycelial fragments to plant stems despite the disinfestation procedure. The possibility also exists that the Pythium spp. isolated are saprophytic and some other unknown organism, or causal factor or factors, or both, are involved.

A correlation between increased water salinity and improved plant condition was suggested from field survey, as well as Rhizoctonia inoculation data. Plants in lower Currituck Sound, where average salinity was as high as 5.62% of sea strength, were generally more vigorous than in northern Back Bay, where percentage of sea strength was as low as 1.06. Plants grown in tanks also showed improvement with increase in salinity. Improved plant condition may have been a consequence of increased resistance to disease due to more favorable environmental conditions. Bourn and Jenkins (1) reported increased virulence of R. solani in concentrations

from 7 to 20% normal sea water. In this study, however, *R. solani* appears to be inhibited at the higher salinity levels, since it was reisolated only occasionally from inoculated plants grown
3 at 12 and 17% of sea strength. Salinity increase did not appear to interfere with the isolation of *Pythium* spp. either from natural material or plants in inoculation experiments.

We conclude from the study that *R. solani* was not the primary causal organism of the disease affecting *P. pectinatus* during the summer of 1961, but rather that one or more species of *Pythium* in combination with environmental factors may have been responsible for plant decline.

Literature Cited

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Transplant of Soil and Vegetation Boxes to Different Locations

As indicated by numerous vegetation surveys certain areas, e.g., Back Bay Proper and the North Landing River, consistently do not produce aquatic vegetation. Other areas consistently do produce aquatics. The reason for the lack of production in certain areas could result from a variety of factors, e.g., soil chemistry, water chemistry, turbidity, and physical characteristics of the soil.

To clarify this, soils were transferred in boxes planted with individual species of plants between productive and non-productive sites. In May 1959, 4 wooden boxes measuring 36" x 12" x 9" were filled with silt soil from the second station of transect D, in Back Bay. Water depth averages about 6½ feet in this non-productive area.

Fifty plants of sago pondweed, busy pondweed, and wildcelery were each planted in individual boxes. They were moved to a cove at the north end of Back Bay that was normally heavily vegetated. The boxes were placed at the bottom in a depth of approximately 3 feet of water. The fourth box was left unplanted and merely returned to the original site to determine if disturbance of soils was a factor affecting plant growth.

At the second productive site an identical operation was repeated and the, "so-called," productive soils were planted and transferred to the; non-productive area.

Observations were made at irregular intervals throughout the summer using SCUBA equipment.

Although the boxes were eventually lost due to storms in late summer and the yields could not be measured, the results were that the soils from the non-productive site were very productive of all three species in the shallower protected cove.

The so-called productive soils from the cove area did not support plant life in the deeper site of Back Bay. Sago pondweed and wildcelery both died back at the deeper site in about 2 weeks time and bushy pondweed gradually diminished to a minute quantity by mid-July. At the last check, prior to loss of the boxes in August, no vegetation was found in any of the four boxes at the deeper site.

At the shallow cove area, the unplanted box was invaded by various species; however, the unplanted box at the deep non-productive site had no vegetation.

A similar test was conducted in the North Landing River area but most boxes were lost in the first few days.

The conclusion was that the soil chemistry was not the primary factor affecting survival and growth of these three species. Apparently lack of light was the principal limiting factor.

Transplant of Soil and Vegetation Boxes to Different Depths

The objective of this test was to determine the yield of redheadgrass and wildcelery planted in boxes at one site in Back Bay at three different depths. Soils from the site were added to three boxes that measured 36" x 12" x 9". Paper erosion netting with one-quarter inch mesh was tacked to the top of the boxes to assist in anchoring the vegetation in the soils.

On June 8, 1961, 72 redheadgrass and 72 wildcelery seedlings were planted in each of the three boxes. Each plant species was separated to one side of each box.

The boxes were supported by wooden legs at both ends and fastened securely in stepladder fashion against a 6-inch vertical pipe that had been jetted into the bottom of the bay. The boxes were placed at depths of 1 foot, 3 feet, and 5 feet.

Observations on August 3 were as follows:

Top Box
- 30 wildcelery plants, yellow-green in fair condition
- 5 redheadgrass plants, greenish-tan in fair condition

Middle Box
- Wildcelery side solid cover of plants in good condition
- about 75 redheadgrass. plants in good condition

Bottom Box
- 1 wildcelery plant in good condition

On September 7, 1961, the boxes were removed and the yield from each box was as follows: top box 8 cc. wildcelery, 1 cc. redheadgrass; middle box 28.8 cc. of wildcelery, 302.4 cc. redheadgrass; bottom box no wildcelery and no redheadgrass.

On Back Bay the average precentages of total sunlight at the depths of 1, 3, and 5 feet were 49, 18, and 8 percent, respectively, during the summer of 1961.

The conclusion was that the amount of light at the 5 ft. level is insufficient for the growth and survival of wildcelery and redheadgrass. The lower yield of the box at the 1 foot depth than the one at 3 feet might be accounted for by increased wave action uprooting the plant or by sun-scorch on a few occasions when bay levels were lower.

Neither soil nor water chemistry were limiting factors for production of these two species.

Underwater Lights and Aquatic Growth

In further effort to determine the reasons for the lack of aquatic plant growth in the deeper waters of Back Bay, 2 300-watt underwater lights were installed 200 yards southeast of Warden's Headquarters in a non-productive site. The depth of the water averaged 6 feet. The bottom soils were the typical soft, semi-liquid silt that occurred over much of Back Bay. At two locations underwater flood lights were mounted 18 inches above the bottom and tilted at a 45 degree angle.

The soil beneath one light was planted with sago pondweed, redheadgrass, widgeongrass, and wildcelery. The other site was not planted. No aquatic vegetation naturally existed in the general vicinity.

The study was initiated during the first week of June 1961. The lights were on between 7 a.m. and 5 p.m. each day.

Final observations were made on August 3, and no-vegetation remained in the area under the light that had been planted, and only a few small sprigs of bushy pondweed were growing under the light 'that had not been planted. The surrounding area was still lacking vegetation.

No submarine photometer readings of the quantity of light were taken because of the potential harzard of electric shock.

One observation of importance was made during the process of planting the various aquatics in the bottom of the bay. The buoyancy of a handful of sago pondweed plants, or wildcelery plants, was surprising and could be compared to holding several gas-filled ballons on a string. This fact, in relationship to the extremely soft, semi-liquid silt bottoms of the deeper bays is limiting growth of aquatic plants in the area. Even if a plant was supplied with adequate light, it normally would not be sufficiently well anchored in the soft soils to survive normal wave action.

In addition to that conclusion, the light study indicated some response by bushy pondweed to additional light, and also further confirmed the opinion regarding the relationship between buoyancy of the plants and the bottom type.