https://ntrs.nasa.gov/search.jsp?R=19760011683 2020-03-22T17:15:26+00:00Z

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

NASA CR-144918

Remote Sensing of Submerged Aquatic Vegetation in the Lower Chesapeake Bay

Final Report to

National Aeronautical and Space Administration
Langley Research Center

Contract NAS1-10720

MAR 1976
RECEIVED
NASA STI FACILITY
INPUT BRANCH

by

Robert J. Orth - Principal Investigator
and
Hayden Gordon
Division of Biological Oceanography
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

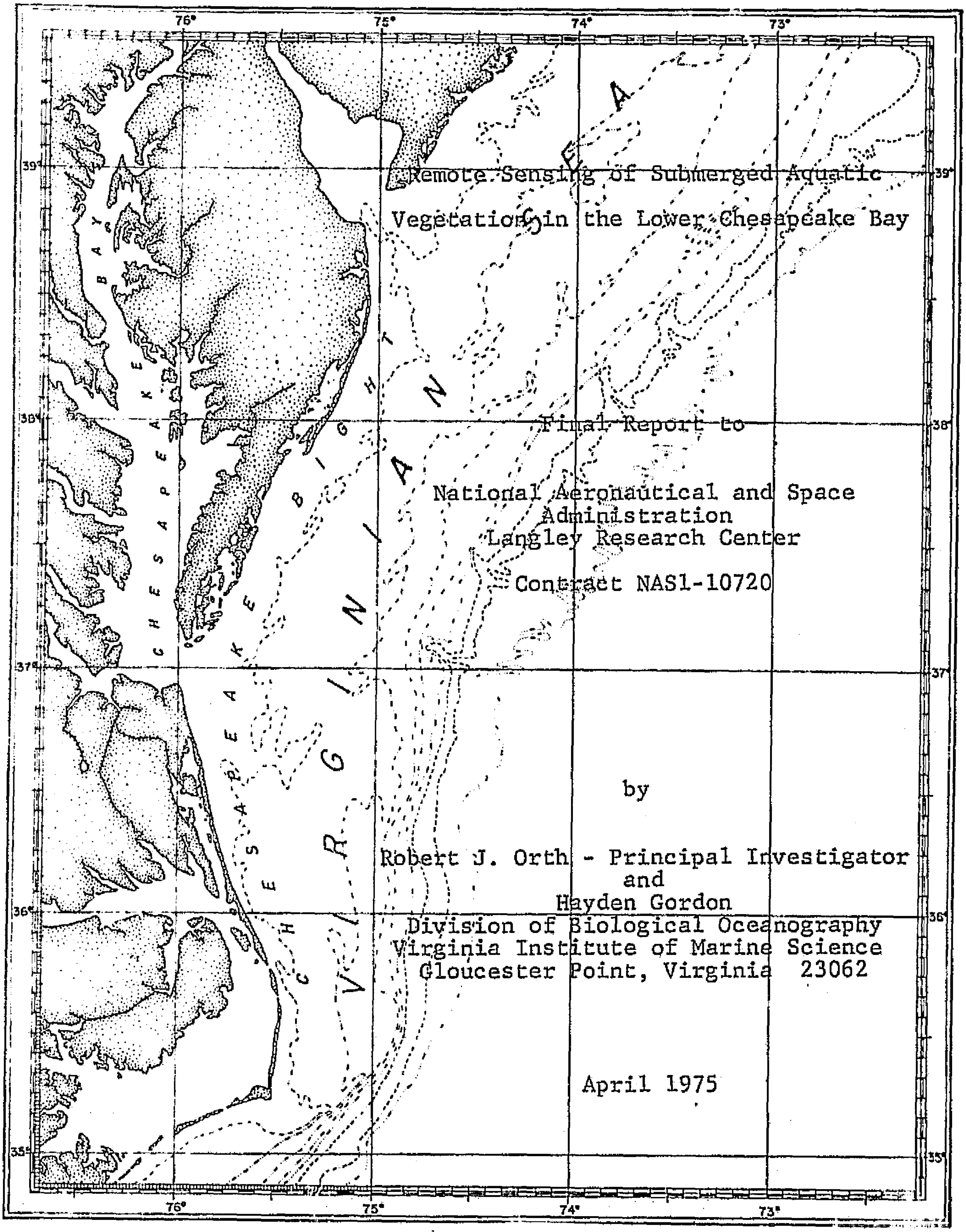
April 1975

(NASA-CR-144918) REMOTE SENSING OF SUBMERGED AQUATIC VEGETATION IN THE LOWER CHESAPEAKE BAY Final Report (Virginia Inst. of Marine Science) 70 p HC $4.50 CSCL 08A

N76-18771

G3/48 Unclas 20603

NASA CR-144918



Remote Sensing of Submerged Aquatic Vegetation in the Lower Chesapeake Bay

Final Report to

National Aeronautical and Space Administration
Langley Research Center

Contract NAS1-10720

by

Robert J. Orth - Principal Investigator
and
Hayden Gordon
Division of Biological Oceanography
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

April 1975

Table of Contents

List of Tables

List of Figures

		Page
Figure 16	Aerial photograph of Allens Island and Sandy Point, May, 1960.	49
Figure 17	Aerial photograph of the Severn River mouth off Long Creek, November, 1974.	50
Figure 18	Aerial photograph of Ware Point, November, 1974.	51
Figure 19	Aerial photograph of Saddlers Neck, Severn River, November, 1974.	52
Figure 20	Distribution of submerged aquatic vegetation in Ware Neck Quadrangle.	53
Figure 21	Distribution of submerged aquatic vegetation in New Point Comfort Quadrangle.	54
Figure 22	Distribution of submerged aquatic vegetation in Mathews Quadrangle.	55
Figure 23	Distribution of submerged aquatic vegetation in Deltaville Quadrangle.	56
Figure 24	Distribution of submerged aquatic vegetation in Wilton Quadrangle.	57
Figure 25	Distribution of submerged aquatic vegetation in Irvington Quadrangle.	58
Figure 26	Distribution of submerged aquatic vegetation in Urbanna Quadrangle.	59
Figure 27	Distribution of submerged aquatic vegetation in Fleets Bay Quadrangle.	60
Figure 28	Aerial photograph of Bluff Point Neck, Fleets Bay, November, 1974.	61
Figure 29	Aerial photograph of cownose ray activity on Poquoson Flats, September, 1974.	62

Abstract

Kodak's experimental water penetration film and black and white near infrared film were used to study the distribution of submerged aquatic vegetation in the lower Chesapeake Bay. The water penetration film was very useful in this study compared to the black and white NIR. Optimal results from this film were obtained with the camera aperture closed 1/2 stop from suggested settings. Detailed description of the grass beds were obtained by flying at an altitude of 5,000 feet, at low tide when wind conditions were minimal.

There was a 36% reduction in the amount of submerged aquatic vegetation in the lower Chesapeake Bay from 1971 to 1974. The greatest losses occurred in the York, Piankatank and Rappahannock rivers. Recovery of some grass beds occurred primarily through seedling recruitment and subsequent vegetative growth. Cownose rays were suspected as a main factor for the decimation of some of the grass beds.

I. Introduction

Many of the shallow water coastal areas of the Chesapeake Bay and its tributaries are covered by dense beds of submerged aquatic vegetation. Past attempts to estimate the abundance and distribution of aquatic vegetation have relied on time consuming, costly and relatively inaccurate ground surveys. Recently, the application of remote sensing techniques verified with ground truth information has proved highly successful as a rapid and accurate means of delineating submerged vegetation (Thomson, Lane and Csallany, 1973; Harwood, Davis and Reed, 1974; Kelly, 1969, 1971; Kelly and Castiglione, 1970; Kelly and Conrod, 1969; Conrod, Kelly, and Boersma, 1968). The objectives of this project were to assess the feasibility of using remote sensing to delineate submerged aquatic vegetation (primarily eelgrass, *Zostera marina*) in the lower Chesapeake Bay, to map the present distribution of submerged aquatics, to determine the extent of loss or recovery of eelgrass in the lower Chesapeake Bay since 1972, and to judge the effectiveness of various photographic films and techniques in delineating submerged aquatic vegetation.

II. Background

Eelgrass (*Zostera marina*) is a resource of underestimated value in the southern Chesapeake Bay area. Highly productive ecosystems, eelgrass beds nourish fishery resources through detrital food webs in much the same way as do salt marshes. Migratory waterfowl extensively feed on eelgrass and associated plants and animals. Eelgrass beds also furnish shelter and food for young fishes and blue crabs. By trapping sediment and absorbing wave energy, grass beds have undoubtedly slowed shore erosion. These observations have led many scientists to believe that the eelgrass community is among our most valuable marine resources on a per acre basis.

Eelgrass has historically been beset with catastrophes. In the 1930's, an epidemic disease destroyed most of the eelgrass on the East Coast of the United States and elsewhere in the world. Many areas, for example seaside Eastern Shore, Virginia, have still not recovered. The demise of eelgrass in the Chesapeake Bay at that time was given as the cause of the extinction of bay scallops in the Bay. During the summer of 1973 vast areas of eelgrass were laid bare, apparently by the foraging activities of cownose rays which dig up bivalves inhabiting the grass beds. These predators worked over bottoms in massive schools, often completely uprooting the eelgrass, leaving no roots or rhizomes for regrowth.

The extensive grass beds in the lower York, Rappahannock, and Piankatank rivers were nearly completely destroyed in 1973. Only sparse beds or isolated patches remained of the vast beds on Poquoson and Drum Island Flats, although the bayside of Eastern Shore were much less affected.

III. Methods

Film

Two types of film were used in the aerial surveys: a new experimental color film developed by Eastman Kodak Company (SO-224), which has "superior water penetration" capabilities (Specht, Needler and Fritz, 1973) and a black and white near infrared film. The water penetration film has two sensitive layers: a bottom layer sensitive to the green spectral region which upon processing forms a green positive image and a top layer sensitive to the blue green spectral region and forms a magenta positive image. A yellow filter layer was placed between these two layers to prevent exposure of the green layer by blue radiation.

Preliminary work with the water penetration film indicated that best results were obtained with the camera aperture setting closed one-half stop from the suggest f-stop ratings (Kodak Aerial Computer) for the camera shutter speed, sun angle, and altitude of flight mission. With the black and white NIR film, camera settings were opened one full f-stop to achieve better water penetration (Bressette and Lear, 1973). Kodak Wratten filters number 2A and 89B were used with the experimental film and NIR film, respectively.

Flight coverage

Three flight missions were planned to photograph Virginia waters along the southwest shoreline from Back River, Hampton to Fleets Bay (Fig. 1). The flights were made in April, June, and November 1974. The April and November missions were conducted with light aircraft by Virginia Institute of Marine Science personnel and the June flight was conducted by NASA Wallops aircraft. The missions were flown with a Hasselblad 500 EL/M camera (50 mm F/4 Distagon lens) mounted on the aircraft and at an altitude of 5,000 feet (1500 meters). The June mission was flown at 10,000 feet using Hasselblad cameras with both natural color (Ektachrome SO-397) and experimental color (SO-224) films. An altitude of 5,000 feet (scale 1:30,000) was chosen for the missions because it allowed for maximum resolution of small scale features in the grass bed and adequate spatial coverage. Flight missions were made during low tides in the morning and when water conditions were calm, allowing for minimal turbidity interference. Flight lines set up for each mission were covered entirely with 50% overlap in adjacent pictures.

Historical Data

NASA aerial photographs (25,000 feet) taken in 1971 (Mission 187), served as baseline information to provide an accurate picture of the distribution of submerged aquatics before any major disturbances occurred. RC-8 cameras (6" lens) with Ektachrome film (SO-397) provided broad band coverage in 9 x 9" format. Historical data for sites in the York River (1937, 1960, 1963, 1968) were also available from photographs taken by the U.S. Department of the Agriculture and Virginia Department of Highways.

Ground Truth Measurements

Small scale surveys of the York River & Mobjack Bay were made by surface observation from small boats and by diving to assess small increases in size and density of grass beds and provide ground truth for the aerial photographs.

Data Analysis

Data for the 1971 and 1974 aerial coverage of submerged aquatics were mapped onto topographic maps (1:24000) using a Zoom Transfer Scope. Area was computed following tracing by an automatic digitizer. There are several limitations in the data analysis. In most areas, grass beds were not uniform. Different degrees of patchiness were present in all areas covered. Sand bars anastomosing through the beds are regular features in localities that were relatively exposed to waves. Within dense areas, patchiness increased toward the lower limit of grass growth. To quantify, in some way, the density of the grass in each area, subjective ratings were applied to grass areas (25% coverage, 50% coverage, 75% coverage, 100% coverage).

Another submerged aquatic plant, Ruppia maritima (widgeon grass), occurs in mixed stands with eelgrass as well as in pure stands. Areas with Ruppia could only be delineated with ground truth information because the two species are inseparable in aerial photographs. The areas mapped from the aerial photographs represent the total of these two species.

Aerial coverage of the lower Chesapeake Bay was limited to the western shore from the James River (Hampton Roads area) to Fleets Bay just above the Rappahannock River. Vegetated areas were summarized in three ways: 1) by topographic map quadrangles (Table 1); 2) by major areas, corresponding to large distinct features within the Bay (Table 2); and 3) by minor areas, corresponding to subdivisions within the major areas (Table 3).

The three aerial surveys conducted in 1974 were used to assess increases or decreases of existing grass beds. Mapping of the 1974 data was made primarily from the November flight since this is the end of the growing season for eelgrass and also represents the latest coverage on the distribution of grass beds. Changes in grass beds during 1974 will be mentioned in the results section.

To facilitate the handling of the data in this report, each of the 13 quadrangles will be described separately with references made to the major and minor areas within each map. Figure 1 shows the position of each quadrangle in the lower Chesapeake Bay.

IV. Results

1. Hampton Quadrangle

Almost all of the submerged aquatics in this section were found in the Back River area (Figure 2; Tables 1, 2, 3). Several small patches (17.9 acres) are located in Hampton Roads and were mapped from the 1974 flights. Aerial coverage in 1971 of these particular areas was of poor quality and it was difficult to tell whether the patches mapped in 1974 were present in 1971. Eelgrass was known to occur in this area but it is not known whether these are the same patches or if there has been an increase or decrease of the present patches.

There was a 46% increase in grass coverage from 1971 to 1974 for Back River with most of this increase occurring between Northend Point and Harris River (51%) and on the north side of the river from the Northwest Branch to Bell's Oyster Gut (123%). The decrease in grass coverage off Plum Tree Island (see also Section 2, Poquoson East Quadrangle) nearly balanced the increase in the Back River area resulting in a small net increase in total grass coverage for the Hampton Quadrangle.

The grass in Back River was very dense (almost 100% ground coverage) for both the 1971 and 1974 data. This is shown in the aerial photograph taken in November, 1974, of an area adjacent to Northend Point (Figure 3).

2. Poquoson East Quadrangle

The shoal areas off Plum Tree Island contained some of the largest and densest grass beds in the Chesapeake Bay in 1971 (Figs. 2, 4; Tables 1, 2, 3). Grass beds ranged from very dense (75-100% coverage near shore) to patchy (25% coverage along edges of the beds and on the Poquoson flats). Sand bars anastomosing through the beds were common features especially off Bennett Creek and Lloyd Bay. However, by 1974, there were dramatic differences in these same beds. On the Poquoson Flats the area occupied by grass was reduced by 75% and off Plum Tree Island by 46%. Also, the grass in many areas appeared more patchy in 1974 than in 1971.

3. Poquoson West Quadrangle

This section was divided into three major areas: 1) Poquoson River, 2) Crab Neck and Goodwin Islands (Chesapeake Bay side), and 3) the York River (Figure 5; Tables 1, 2, 3). All areas contained extensive beds in 1971. Sand bars were very prominent in the beds off Crab Neck, Hunts Neck, Pasture Neck, and Goodwin Islands. Also, as in the Poquoson East section, the densities of grass beds were variable. Many areas had less grass in 1974 than in 1971, but in other areas eelgrass flourished and was as dense as in 1971.

There was a 25% reduction in the total amount of vegetated bottom in this quadrangle but there was much variation depending on the respective area. There was a

58% increase off Hunts and Pasture Neck, a 100% increase off Fish Neck, a 43% decrease off Crab Neck, a 24% decrease off the Goodwin Islands (most of this reduction was confined to the York River side), a 54% decrease off Goodwin Neck, an 82% decrease off Yorktown and the Coast Guard station and a 100% reduction from the Gloucester Point area.

Very little grass was present off Goodwin Islands and Crab Neck during the April, 1974, flight and a preliminary flight in October, 1973, but the distribution of grass from June to November, 1974, appeared as mapped in Fig. 5. It appears that these areas lost all or most of their grass in 1973 but new growth from seedlings probably accounted for the large increase in such a short span of time (see Discussion).

Fig. 6 shows some of the dense grass beds off Lyons Creek and Bennett Creek just off from the Poquoson River.

4. Clay Bank Quadrangle

This section contained several major grass beds in the York River in 1971 (Fig. 7, Tables 1, 2, 3). Eelgrass was the dominant vegetation with some widgeon grass found mixed with eelgrass close to shore. Mumfort Island had a large dense eelgrass bed (100% coverage) and was the site of several eelgrass faunal studies (Marsh, 1973, Orth, 1973). Clay Bank was the upestuary limit of eelgrass growth in the York River and eelgrass was of patchy to moderate density (25-50%) in this area.

The situation in 1974 was entirely different. There was a 90% reduction of eelgrass in this section. What remained of the grass beds at Mumfort Islands were two small patches. Eelgrass was absent from the Carmine and Catlett Islands and only a few small clumps of grass (none larger than 0.1 m^2) were found around the Clay Bank area. Dense (nearly 100%) patches were still present off Blundering Point and behind the Mumfort Islands, and a patchy (50%) area was present off Kings Creek on the South shore.

Figure 8 is an aerial photograph taken in 1971 showing the dense eelgrass bed off Mumfort Islands. Figure 9 shows the complete absence of eelgrass off these islands in 1974.

5. Achilles Quadrangle

Some of the most interesting observations concerning the distribution of eelgrass were made in this section (Fig. 10; Tables 1, 2, 3), for which ground truth information is the most complete.

Eelgrass beds in the lower York River were very dense in 1971 (Fig. 8) but by October, 1973, all eelgrass was gone. The April flight showed no eelgrass also but diving observations of these areas showed numerous seedlings recolonizing many former beds. The flights in June and November, 1974, showed dramatic increases in eelgrass growth in this short period. Ground truth supported these observations. Fig. 11 shows an area off Allens Island in April, 1974, showing no eelgrass. Fig. 12 shows a similar picture off Allens Island taken in November, 1974, but with the presence of a large amount of eelgrass close to shore. Fig. 13 is of an area off Sandy Point taken in April, 1974. Only small patches were present immediately off the island. Fig. 14 shows the same area but in November, 1974. Eelgrass is still patchy but the dramatic increases marked in the photograph have all been from seedling recruitment and subsequent vegetative growth. Observations of this area by diving (this area has been intensely studied during the last four years) substantiated these findings. Numerous seedlings were present in April, 1974, but not detected in the photograph. Their subsequent growth in the following months accounted for the increase of eelgrass.

Despite this increase from April to November, 1974, there was still a 70% reduction in the total amount of eelgrass from 1971 to 1974 in the lower York River.

Historical information was available for these areas from the U.S. Department of Agriculture and Virginia Department of Highways aerial photographs. Fig. 15 shows Allens Island and Sandy Point in 1937 with sparse amounts of eelgrass around each area. Fig. 16 was taken in 1960 with an increase in extent and density of eelgrass during this period. Inspection of 1963 and 1968 photographs taken by the Virginia Department of Highways of these same areas showed the eelgrass to have increased even more. The 1971 data indicate this year as having the maximum extent and density of eelgrass.

The Mobjack Bay grass beds, in contrast to the York River beds, all have increased in area from 1971 to 1974. The beds are very dense (90-100% coverage during both 1971 and 1974) and contain a mixture of eelgrass and widgeon grass. Much of this expansion has been along the inner boundaries of the existing beds.

Several features typical of grass beds in the Bay are found in the Mobjack Bay region. Boat tracks cutting through the beds are typified in Fig. 17, an area at the mouth of the Severn River off Long Creek. Sand bars crossing through the beds are found off Ware Point (Fig. 18).

An example of another human perturbation of grass beds is found off Saddlers Neck in the Severn River. In 1971, there was a dense, continuous grass bed off this area. However, the April, 1974, flight showed a barren patch in the middle of the bed. Upon investigation, it appeared that this area may have been dredged for landfill sometime after December, 1972. The exact date is not known because the dredging is now the subject of litigation and the perpetrator refuses to make this known. Interestingly, the November, 1974, flight showed patches of grass invading this 3.3 acre depression (Fig. 19). Diving observations of this area in December, 1974, showed that these isolated patches were a mixture of eelgrass and widgeon grass and were colonized via seed dispersal.

6. Ware Neck Quadrangle

Most of the submerged aquatics in this section were found in the North River. There was a net increase of grass in 1974 of 23% over 1971 with all minor areas increasing to some extent (Fig. 20; Tables 1, 2, 3). Widgeon grass is much more abundant especially in near shore areas where it occurs in pure stands and becomes mixed with eelgrass in deeper water. Densities of grass for both years were approximately 75% cover.

7. New Point Comfort Quadrangle

This section was divided into 3 areas: the Guinea Marshes, the Mobjack Bay, and the Chesapeake Bay between New Point Comfort and Potato Neck (Fig. 21; Tables 1, 2, 3).

Despite the fact that the grass beds around the Guinea Marshes have similar areas for the two years, the densities were quite different. In 1971, the grass covered 75-100% of the area, with patchiness occurring at the outer limits. In 1974, the April flight and ground truth indicated that the grass was very patchy (25-50% coverage). By November, the grass was still patchy around the outer edges of the bed but inshore in the more shoal areas, the grass flourished. As in the York River, many seedlings were observed in April, 1974, which by November, contributed to the increase in density in these areas. In the Mobjack Bay, there was a very large increase (166%) in submerged aquatics between Bay Shore Point and Peppers Creek. Grasses were much more

ORIGINAL PAGE IS
OF POOR QUALITY

dense (75% in 1974 vs. 25-50% in 1971) not only in this area but also between Peppers Creek and New Point Comfort. There was a 20% increase in grass coverage in this same area.

In the Chesapeake Bay between New Point Comfort and Potato Neck, the amount of grass coverage increased by 9% between New Point Comfort and Horn Harbor and by 95% between Horn Harbor and Potato Neck. This area contains one of the more exposed grass beds but the grass still flourishes and has increased in density and coverage. The presence of sand bars are a common feature in this area.

8. Mathews Quadrangle

One of the largest changes in grass coverage occurred in the Gwynn Island area. The grass was very dense (75-100% coverage) in Milford Haven but patchy (25-50%) in Hills Bay off Gwynn Island in 1971. The April, 1974, flight showed no grass anywhere in this region. However, by November, there were patches of grass in Milford Haven, but they were not nearly as extensive as in 1971 (Fig. 22; Tables 1, 2, 3). Aquatic vegetation was reduced by 84% off Crab Neck, 78% off Whites Creek, Lilleys Neck, 100% off Cow Neck, and 87% around Gwynn Island (this includes a portion of the Deltaville Quadrangle). The patches that were mapped in 1974 were dense (75-100% coverage) and were probably a result of seedling growth.

Aquatic vegetation in the East River increased by 30% (this includes acreage from the New Point Comfort Quadrangle) and grass coverage was moderately dense (50-75%).

Aquatic vegetation was reduced by 82% for this section from 1971 to 1974.

9. Deltaville Quadrangle

In 1971, there were 1,342 acres of grass in this section. Submerged aquatics in the Piankatank River were dense (75-100% coverage) while in the Rappahannock River, the beds were of patchy to moderately dense (25-50% coverage). By April, 1974, not a single patch of grass was observed (Fig. 23; Tables 1, 2, 3). However, by November, 1974, sparse to moderately dense patches were present in sections of the Piankatank River. Total grass coverage was reduced by 96% for this region.

10. Wilton Quadrangle

The portion of the Piankatank River in this quadrangle also lost all submerged vegetation between 1971 and 1974. One fairly large patch was present in November, 1974, just off Horse Point (Fig. 24; Tables 1, 2, 3). Ground truth indicated that this was all eelgrass and the density was moderately dense (50-75%).

All of the submerged aquatics in the Rappahannock River in 1971 were patchy to moderately dense but by 1974 there was no vegetation at all. This was true up to and including November, 1974.

11. Irvington Quadrangle

Eelgrass covered the entire length of the shallows in this section of the Rappahannock River and many parts of the Corrotoman River in 1971 (Fig. 25; Tables 1, 2, 3). No grass was detected in 1974.

12. Urbanna Quadrangle

As in the Irvington Quadrangle, the eelgrass that was present from Towles Point to Greenvale Creek in 1971 (Fig. 26; Tables 1, 2, 3) was completely gone in 1974 with no patches detected in November, 1974.

13. Fleets Bay Quadrangle

Fleets Bay was not covered by the NASA flights in 1971 so no information was obtained for this period. This area was covered by aerial photography in November, 1974, only (Fig. 27; Tables 1, 2, 3).

Grass covering was moderately dense in most areas (50-75% coverage), with noticeable sand bars in all sections. Fig. 28 shows a section of the grass beds in Fleets Bay off Bluff Point Neck.

V. Discussion

Photographic Techniques

Several difficulties in film handling of the black and white near infrared film made interpretation and comparison of this film almost impossible. However, despite this difficulty, it is believed that this film would be of less value than the experimental film. Bressette and Lear (1973) maintain that for water penetration, this film must be overexposed. This does enhance water penetration but it presents several problems which makes its use in studies on the distribution (both spatial and temporal) of submerged aquatics questionable. By overexposing the film, land features are washed out and coastlines are not as well defined as in conventional exposures. Because land features (houses, roads, coastline, etc.) are very important in precise mapping, it would be almost impossible to use the near infrared film for this purpose. Also, many areas having submerged aquatics have fringing marshes and unstable shorelines. By using more conventional films, here the water penetration film, a record of not only the submerged aquatics is obtained, but also of shoreline condition and marsh development which could prove very useful in related studies (e.g. coastal zone management, shoreline erosion, and impingement on marshlands). With the loss of the submerged aquatics from many areas, detection of shoreline erosion (grass beds stabilize bottom sediments and baffle waves) would be very important. All this information would be lost by using the black and white near infrared film.

For example, examination of the marsh adjacent to the unvegetated area in the midst of a dense grass bed off Saddlers Neck in the Severn River indicated that the marsh had been filled in and that dredging may have been the cause for this bare area. A check of records kept by the Army Corps of Engineers and state and local agencies could reveal the exact cause and date of the operation. The overexposed NIR film would depict the bare spot but the land would be washed out and it would be more difficult to discover the reason for this bare area.

In another remote sensing study using the "water penetration film" (SO-244), Lockwood, et al. (1974) indicated that the depth penetration of this experimental film with a Wratten 3 filter was comparable to SO-397 (Ektachrome EF Aerographic Film) with a Wratten 3 filter, but its color contrast (magenta and near neutral) was not as good. They concluded that SO-397 with a Wratten 12 filter was better for differentiating surface and subsurface vegetation.

The ability to detect and delimit submerged aquatics from the experimental film in this study was excellent. At an altitude of 5000 ft., features within grass beds were very distinct and coverage of the entire width of the bed was possible. However, flying at this altitude would present problems in areas where grass flats extend more than 1/2 mile from shore. It is recommended that in future studies of other areas containing submerged aquatics, test flights be made at different altitudes for information on coverage of the beds including a significant portion of land (this is stressed because it is very important for precise mapping).

Distribution of Submerged Aquatics

Comparison of the distribution patterns of submerged aquatics in the lower Chesapeake Bay between 1971 and 1974 indicated a tremendous net loss during this time period. In October, 1973, no grass was seen from overflights in the Rappahannock, Piankatank, and York rivers (there were small patches near the mouth of the York from Sandy Point to the Guinea Marshes) and there were considerable reductions in the Chesapeake Bay between Goodwin Islands and Back River. This was still the condition until the first flight in 1974 (April). By November, 1974, there were significant increases of eelgrass in the York River but it was still reduced in the Piankatank River and none was present in the Rappahannock River. By November, 1974, there was 36% less area of submerged aquatic vegetation than in 1971 in the areas surveyed in the lower Chesapeake Bay (11,978 acres in 1971 vs. 7,669 acres in November, 1974. This includes areas covered both in 1971 and in 1974).

It appears that the major loss of aquatic vegetation occurred during the summer of 1973. Grass beds were still flourishing by the end of July but by the end of August, many grass beds were completely gone. Several explanations may be posed for such a great loss and the real causes may be complex.

Personal observation of one particular area in the lower York River (Sandy Point to the Guinea Marshes) indicated that the loss was principally due to a large influx of cownose rays (Orth, in press). In their foraging for infaunal bivalves, they uprooted large areas of eelgrass. Whether this can account for the massive and almost complete decimation is debateable. The rays activity is quite intense as shown in Fig. 29, a photograph taken in September, 1974, in the Poquoson Flats area. Ray activities were also seen in September and October, 1974, in the lower York River and around the Severn River and Browns Bay, but there was no total loss of eelgrass. However, it appears that much of the patchiness in grass beds, at least in the Mobjack Bay, can be attributed to the cownose rays. Rays use the Bay as summer feeding grounds and are more abundant in some years than others, whether 1973 represented a year of unusual ray abundance is not known.

A second cause of the extensive loss of grass beds might be climatological. Hurricane Agnes reduced salinities in the rivers during July, 1972, perhaps stressing the plants. However, the disappearance of eelgrass was not until the following year. Rasmussen (1974) believes that mild winter temperature and very hot summers may induce death and he has correlated such conditions in Denmark with the disappearance of eelgrass. There has been a warming trend within the last few years, the winters being more mild. It may be the case that Agnes stressed the plants which, followed by another warm winter, caused a sudden die off of all the grass. One interesting problem is why was the loss concentrated in the 3 major rivers whereas in the Mobjack Bay, the grass remained relatively stable and has even increased in abundance. Whether the grass in the Mobjack Bay is genotypically different than the other areas or physiologically more able to withstand greater environmental flucutations remains to be answered.

With the loss, it was surprising to see an increase in grass coverage just in a few short months. Most of the increase was from seeds which are produced by mature plants in the spring and remain in the sediment until the fall when temperatures decline and then germinate (personal observation). As mentioned, seedlings were observed in many parts of the York River from January to April, 1974, which gave rise to the increase in grass in these areas. Thus seedlings may play a very important role in the establishment of new grass beds.

VI. Conclusions

The following conclusions are made from this study:

1. Remote sensing is an useful tool for studying the spatial distribution and temporal variation of submerged aquatic vegetation.

2. The new water penetration film yielded excellent results in revealing details of the grass beds. It would prove more profitable for this type of work rather than the black and white near infrared film.

3. Optimal results from this film were obtained with camera aperture closed 1/2 stop from suggested settings. Flying at an altitude of 5,000 feet, at low tide, and in the morning when wind conditions were minimal, allowed for detailed description of the grass beds with minimum turbidity interference.

4. There was a 36% reduction in the amount of submerged aquatics in the western portion of the lower Chesapeake Bay from 1971 to 1974. The York, Piankatank and Rappahannock rivers experienced the greatest loss.

5. Cownose rays were suspected as a main factor for the decimation of some of the grass beds and may be a prime factor causing patchiness within remaining beds.

6. Recovery of some grass beds occurred primarily through seedling recruitment and subsequent vegetative growth.

VII. Recommendations

1. Surveillance should continue in those areas that lost all or most of their submerged aquatic vegetation to judge the success of natural recolonization in these areas.

2. Census new areas that contain submerged aquatic vegetation, e.g. the Delmarva peninsula.

3. Detailed work should be initiated on some sand bars within the grass beds to see if they remain stationary or are in a dynamic state of movement, and, if so, if the grass follows the moving of the sand bars.

4. The long term effects of boat traffic through grass beds should be assessed. The recolonization of swaths denuded by boats should be documented.

5. Attempts should be made to transplant grass (seed and whole plants) as a means of increasing the rate of recolonization in damaged areas and introducing vegetation to previously unvegetated areas.

6. Attempts should be made to use remote sensing to detect other features of shallow bottoms.

7. Attempts should be made to relate optical film density and productivity of submerged aquatic vegetation.

Acknowledgments

We thank Eastman Kodak Company for making available their experimental water penetration film for trial use in the Chesapeake Bay and NASA Wallops for development of the film. We appreciate the support of Langley Research Center personnel and equipment which made this study and the data analysis possible. Helpful discussions with Dr. Donald Boesch concerning the eelgrass problem aided the senior author during the course of the study. We wish to thank Mrs. Shirley Sterling for typing the manuscript.

Literature Cited

Bressette, W. E. and D. E. Lear, Jr. 1973. The use of near-infrared reflected sunlight for biodegradable pollution monitoring.

Conrod, A. C., M. G. Kelly, and A. Boersma. 1968. Aerial photography for shallow water studies on the west edge of the Bahama Banks. Experimental Astronomy Laboratory, Mass. Inst. of Technology, Publ. No. RE 42.

Harwood, J. E., G. J. Davis, & S. E. Reed. 1974. Aerial remote sensing of benthic aquatic macrophytes in the Pamlico River Estuary, North Carolina. ASB Bull. 21(2):60.

Kelly, M. G. 1969. Applications of remote sensing to the study of coastal ecology in Biscayne Bay, Florida. Contract Report, U.S. Naval Oceanographic Office, Contract N62306-69-C-0032. 52 pp.

__________. 1971. Studies of benthic cover in near-shore temperate waters using aerial photography. New York Ocean Science Laboratory Technical Report No. 0007. 18 pp.

Kelly, M. G. and L. Castiglione. 1970. Aerial photographic studies of the coastal waters of New York and Long Island. Contract Report, U.S. Naval Oceanographic Office, Contract N62306-70-A-0073-0003. 48 pp.

Kelly, M. G. and A. C. Conrod. 1969. Aerial photographic studies of shallow water benthic ecology. In: P. Johnson, ed., Remote Sensing in Ecology, Univ. of Georgia Press, pp. 173-183.

Marsh, G. A. 1973. The Zostera epifaunal community in the York River, Virginia. Chesapeake Sci. 14:87-97.

Orth, R. J. 1973. Benthic infauna of eelgrass, Zostera marina, beds. Chesapeake Sci. 14:258-269.

Orth, R. J. 1975. Destruction of eelgrass, Zostera marina, by the cownose ray, Rhinoptera bonasus, in the Chesapeake Bay. Chesapeake Sci. (in press).

Rasmussen, E. 1973. Systematics and ecology of the Isefjord marine fauna (Denmark). Ophelia 11:1-495.

Specht, M. R., D. Needler, and N. L. Fritz. 1973. New color film for water penetration. Photogrammetric Engineering 39(4):359-369.

Thomson, K. P. B., R. K. Lane, and S. C. Csallany. 1973. Use of remote sensing for mapping of aquatic vegetation in the Kawartta Lakes. Remote Sensing & Water Resources Management. Proc. No. 17:331-336.

Table 1. Total coverage of submerged aquatics in square meters and acres for the 13 topographic maps used for mapping in this study for the years 1971 and 1974.

	1971		1974	
TOPOGRAPHIC MAP	Square Meters	Acres	Square Meters	Acres
Hampton	2,958,100	730.9	3,064,600	757.2
Poquoson, East	9,456,000	2,336.6	4,355,900	1,076.3
Poquoson, West	4,892,900	1,209.0	3,681,700	909.7
Clay Bank	1,134,100	280.2	120,770	29.8
Achilles	7,450,900	1,841.1	7,417,200	1,832.8
Ware Neck	1,535,600	379.4	1,890,000	467.0
Mathews	3,401,100	840.4	608,910	150.5
New Point Comfort	7,254,200	1,792.5	9,662,600	2,387.6
Deltaville	5,432,900	1,342.4	230,000	56.9
Wilton	2,960,700	731.6	79,014	19.5
Irvington	1,133,300	280.0	none in 1974	
Urbanna	845,050	208.8	none in 1974	
Fleets Bay	not covered in 1971		1,975,600	488.2

Table 2. Total coverage of submerged aquatics in square meters and acres for the major sections of the Chesapeake Bay for the years 1971 and 1974.

Major Areas	1971 Square Meters	1971 Acres	1974 Square Meters	1974 Acres
Back River	1,448,900	358.0	2,119,300	523.7
Chesapeake Bay off Plum Tree Island	8,682,300	2,144.8	4,664,700	1,152.6
Poquoson Flats	2,337,800	577.5	598,860	148.0
Poquoson River	661,300	163.4	1,117,300	276.1
Chesapeake Bay off Crab Neck & Goodwin Islands	3,066,800	757.8	2,193,700	542.1
York River	4,931,200	1,218.5	1,407,800	347.9
Mobjack Bay	12,939,300	3,196.5	15,926,000	3,935.2
Chesapeake Bay between New Point Comfort and Potato Neck	1,683,500	416.0	2,330,200	575.8
Gwynn's Island Area	2,667,500	659.1	433,010	107.0
Piankatank River (includes Cow Neck)	3,069,000	758.3	211,620	52.3
Rappahannock River	6,996,300	1,728.3	36,075	8.9
Fleets Bay	not covered in 1971		1,975,600	488.2
Hampton Area	not covered in 1971		72,445	17.9

Table 3. Total coverage of submerged aquatics in square meters and acres for minor areas within major areas and topographic maps for the years 1971 and 1974.

	1971		1974	
Minor Areas	Square Meters	Acres	Square Meters	Acres
Back River between Harris River and Northend Point	945,580	233.6	1,423,000	351.6
Back River between Harris River and including S. W. Branch	330,920	81.7	311,830	77.4
Back River - North side including N. W. Branch to Bell's Oyster Gut	172,400	42.6	384,420	95.0
Chesapeake Bay off Plum Tree Island (Poquoson W., Poquoson E., and Hampton Quadrangle)	8,682,300	2,144.8	4,664,700	1,152.6
Poquoson Flats	2,337,800	577.5	598,860	148.0
Hunt's and Pastures Neck on Poquoson River, South side	527,910	130.4	829,680	205.0
Fish Neck (Poquoson West)	76,751	19.0	159,930	39.5
Crab Neck (Poquoson West)	1,466,100	362.3	836,020	206.6
Goodwin Islands (Chesapeake Bay side and York River side)	2,165,500	535.1	1,646,500	406.8
Goodwin Neck - York River side	188,910	46.7	65,887	16.3
Goodwin Neck - Chesapeake Bay side	89,741	22.2	63,241	15.6

Table 3 (Continued)

Minor Areas	1971 Square Meters	1971 Acres	1974 Square Meters	1974 Acres
York River - Coast Guard Area and Yorktown	255,440	63.1	45,558	11.3
York River - Clay Bank to Blundering Pt.	195,510	48.3	71,414	17.6
York River - Catlett Islands	391,650	96.8	none in 1974	
York River - Carmine Islands	263,340	65.1	none in 1974	
York River - Mumfort Islands	242,750	60.0	44,772	11.1
York River - Gloucester Point area from Clay Bank map	40,871	10.1	none in 1974	
York River - Gloucester Point area drawn onto Poquoson W. map and also from Achilles map	67,394	16.6	16,499	4.1
York River - Sarah's Creek to Ellen Island	1,383,200	341.7	404,600	100.0
York River - Jenkins Neck	933,090	230.6	307,500	76.0
Guinea Neck - Achilles & New Point Comfort maps	5,425,100	1,340.5	5,197,800	1,284.3
Severn River - Brown's Bay to Rocky Point, Cedar Neck	1,513,300	373.8	1,763,300	435.7
Severn River - Saddler's Neck	100,540	24.8	219,470	54.2

Table 3 (Continued)

Minor Areas	1971 Square Meters	1971 Acres	1974 Square Meters	1974 Acres
Severn River - North side to Caucus Bay	252,110	62.3	307,720	76.0
Ware River - Caucus Bay to Windmill Point	1,559,500	385.3	2,173,800	537.1
Ware River - North side to right off Ware Point; Achilles & Ware Neck map	440,720	108.9	1,210,500	299.1
North River - From Ware Point including East side of river	675,570	166.9	718,460	177.5
North River - off Blackwater Creek	125,200	30.9	169,550	41.9
North River - West side from Ware Neck New Point Comfort and Mathews maps	1,487,700	367.5	1,574,500	389.1
East River (New Point Comfort and Mathews maps)	142,070	35.1	184,600	45.6
Mobjack Bay - Bay Shore Point to Pepper's Creek	501,360	123.9	1,336,100	330.1
Mobjack Bay - Pepper's Creek to New Point Comfort	1,087,000	268.5	1,297,300	320.6
Chesapeake Bay - New Point Comfort to Horn Harbor	1,105,500	273.1	1,204,200	297.6

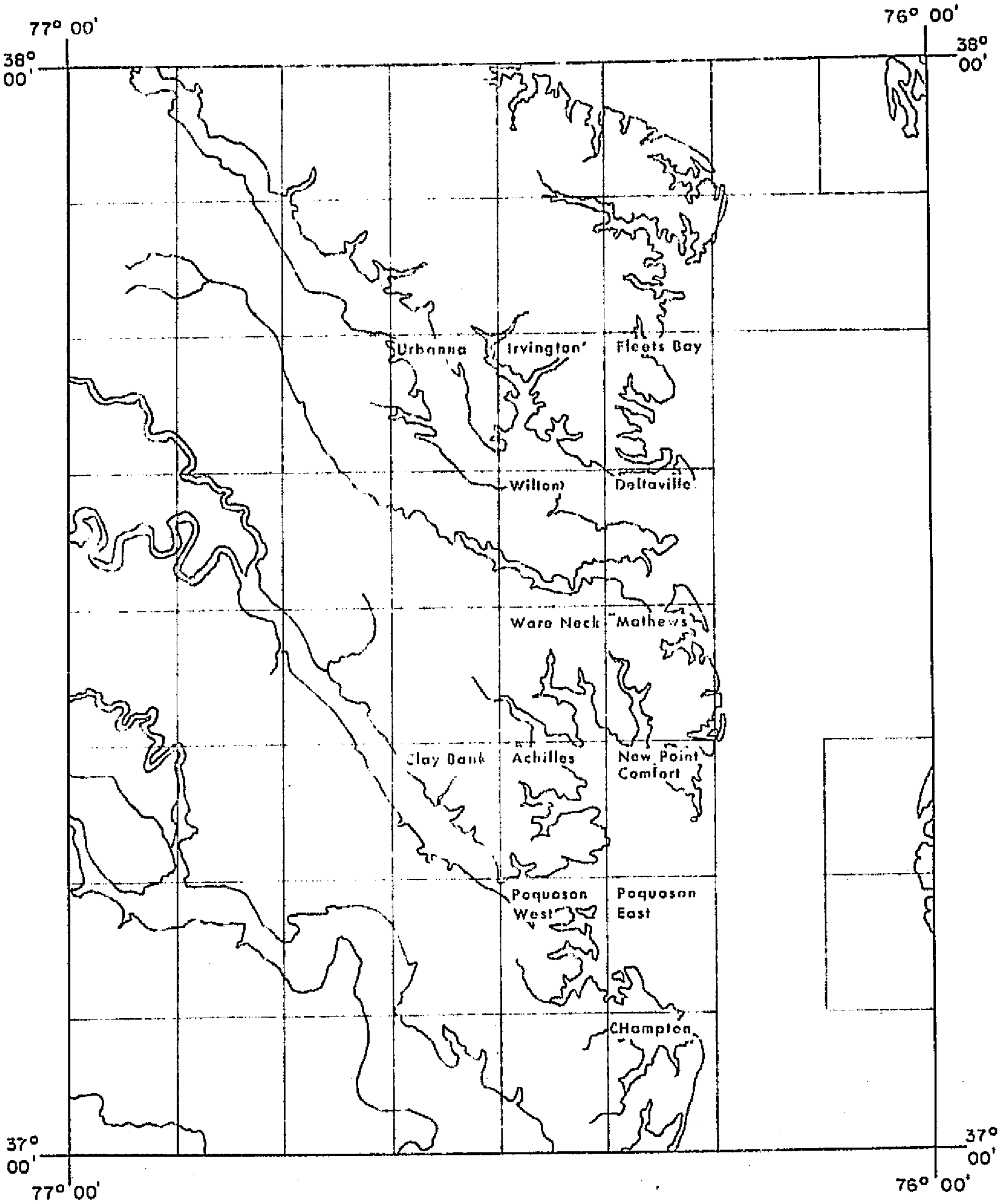
Table 3 (Continued)

Minor Areas	1971 Square Meters	1971 Acres	1974 Square Meters	1974 Acres
Chesapeake Bay - Horn Harbor to Potato Neck	577,940	142.8	1,126,000	278.2
Crab Neck (Mathews map)	388,250	95.9	60,762	15.0
Lilly's Neck, Whites Creek (Mathews map)	792,910	195.9	176,980	43.7
Gwynn's Island (Mathews & Deltaville maps)	1,486,300	367.2	195,270	48.3
Cow Neck (Mathews map)	1,033,500	255.3	none in 1974	
Piankatank River - South side, Iron Pt. to Roane Point	377,240	93.2	12,405	3.1
Piankatank River - North side, Stove Point to Horse Point	463,340	114.5	97,541	24.1
Piankatank River - Stingray Point to Stove Point	1,195,000	295.3	101,670	25.1
Rappahannock River - South side, Stingray Point to Whiting Creek (Deltaville & Wilton maps)	4,492,100	1,109.7	none in 1974	
Rappahannock River - North side (Deltaville map)	525,930	129.9	36,075	8.9
Rappahannock River - North side to Corrotoman River (Irvington map)	675,580	166.9	none in 1974	

Table 3 (Continued)

Minor Areas	1971 Square Meters	1971 Acres	1974 Square Meters	1974 Acres
Corrotoman River	182,190	45.0	none in 1974	
Rappahannock River - Corrotoman River to Greenvale Creek (Irvington and Urbanna maps)	1,120,500	276.8	none in 1974	
Fleets Bay - North Point, Antipoisson Neck, Poplar Neck	not covered in 1971		1,010,500	249.7
Fleets Bay - Fleets Bay Neck	not covered in 1971		709,390	175.3
Fleets Bay - Bluff Point Neck, Indian Creek side	not covered in 1971		134,130	33.1
Dividing Creek (Fleets Bay map)	not covered in 1971		121,590	30.0
Hampton area (Hampton map)	not covered in 1971		72,445	17.9

Fig. 1. Map of lower Chesapeake Bay showing position of topographic maps used for this study.



77° 00'
76° 00'
38° 00'
Urbanna
Irvington
Fleets Bay
Wilton
Deltaville
Ware Neck
Mathews
Clay Bank
Achilles
New Point Comfort
Poquoson West
Poquoson East
Hampton
37° 00'
77° 00'
76° 00'

34-a

Figure 2. Distribution of beds of submerged aquatic vegetation in the Hampton Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).

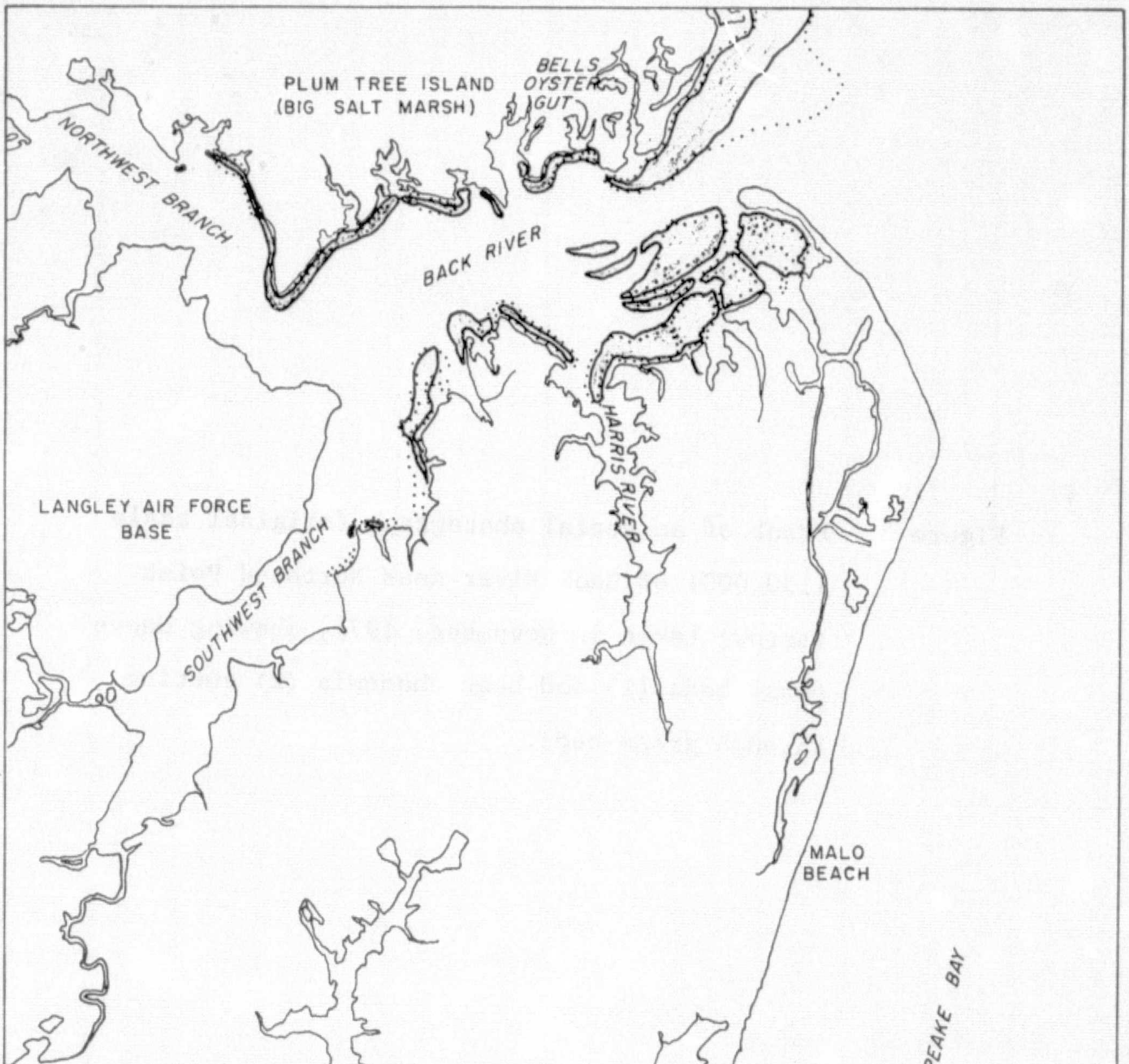

PLUM TREE ISLAND
(BIG SALT MARSH)
BELLS
OYSTER
GUT
NORTHWEST BRANCH
BACK RIVER
HARRIS RIVER
LANGLEY AIR FORCE
BASE
SOUTHWEST BRANCH
MALO
BEACH
CHESAPEAKE BAY
HAMPTON
N

Figure 3. Print of an aerial photograph (original scale 1:30,000) of Back River near Northend Point (arrow) taken in November, 1974, showing dense grass beds (1) and boat channels (2) cutting through grass beds.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 4. Distribution of beds of submerged aquatic vegetation in the Poquoson East Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).

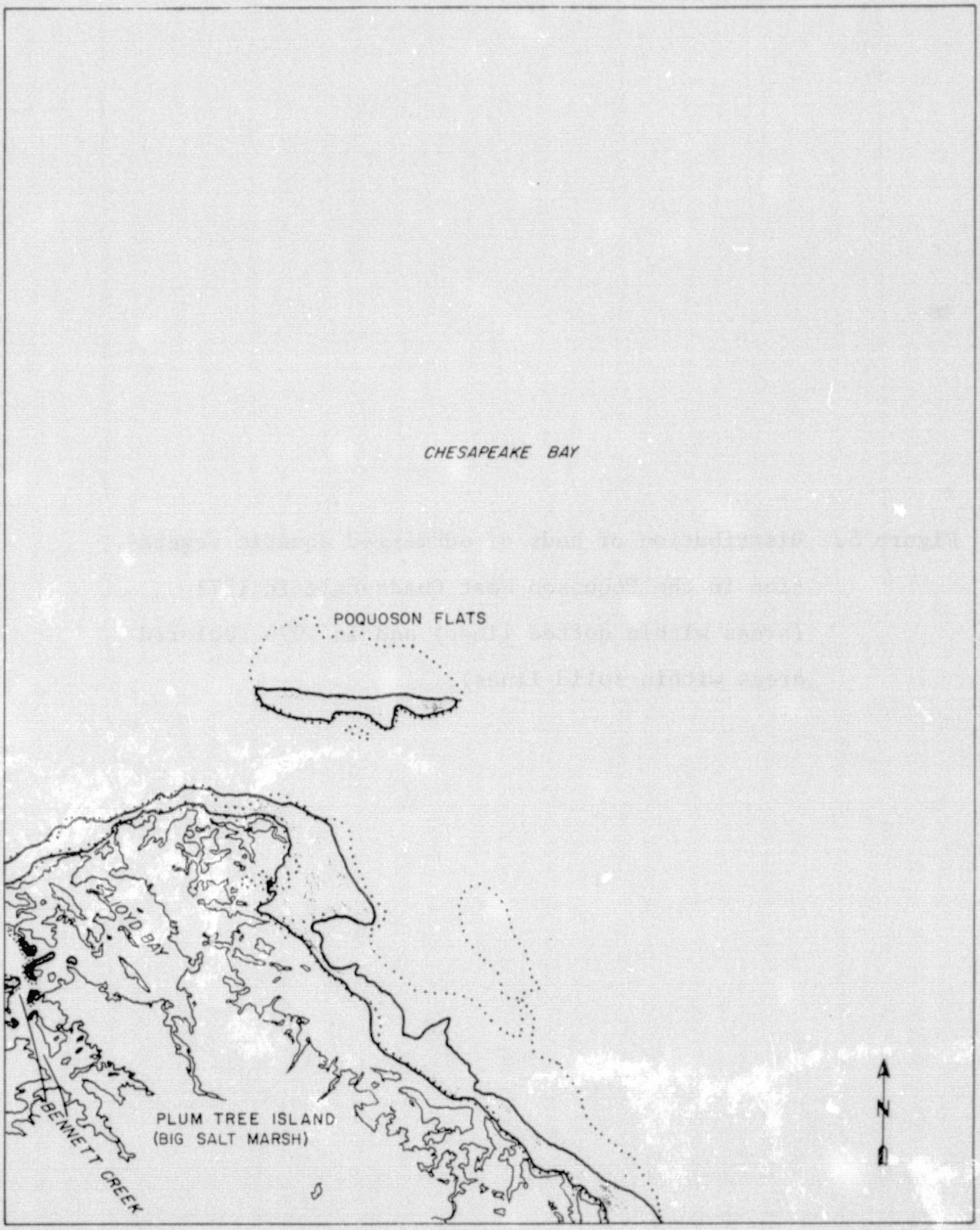

CHESAPEAKE BAY
POQUOSON FLATS
LLOYD BAY
PLUM TREE ISLAND
(BIG SALT MARSH)
BENNETT CREEK
N

Figure 5. Distribution of beds of submerged aquatic vegetation in the Poquoson West Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).

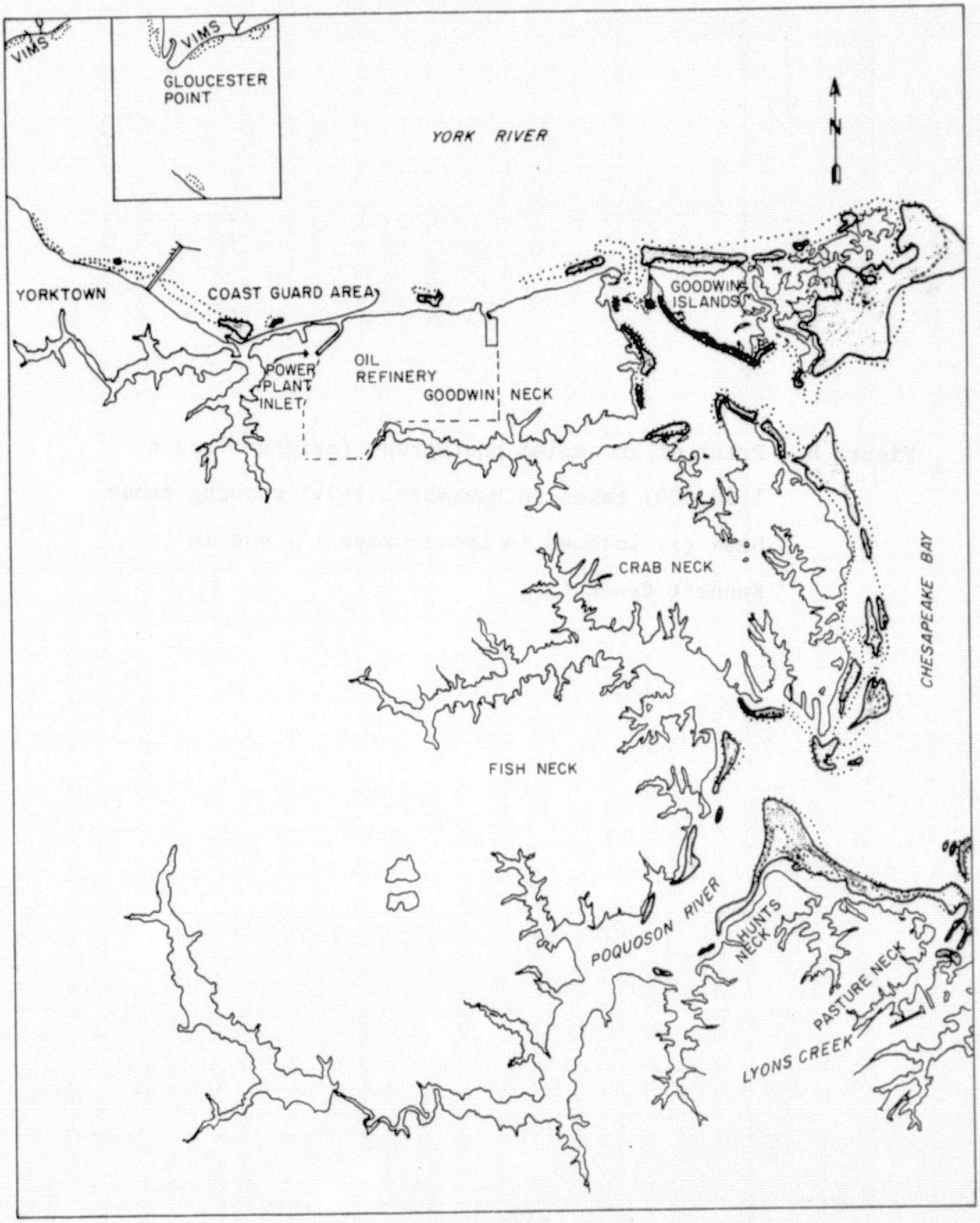
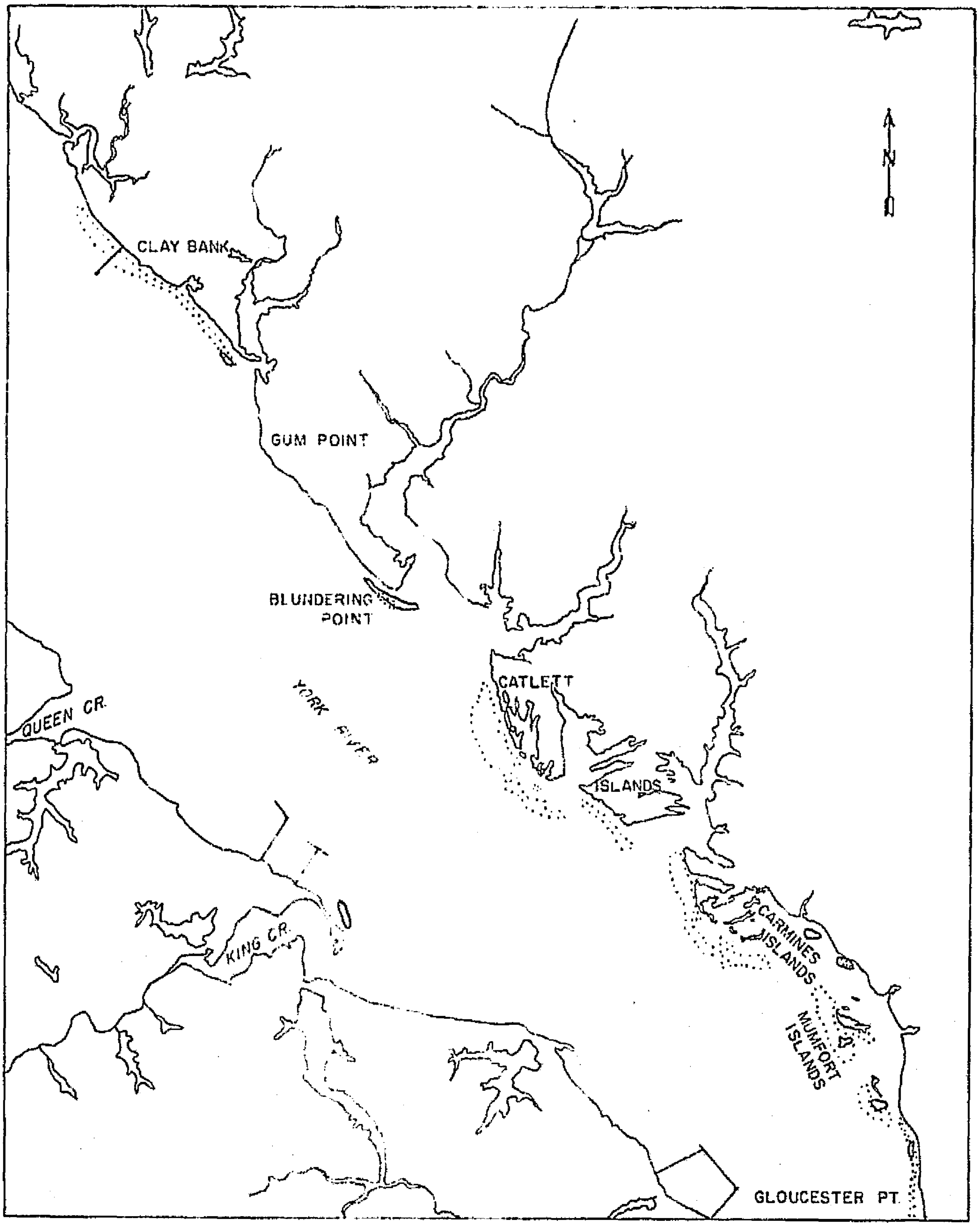

VIMS
VIMS
GLOUCESTER
POINT
YORK RIVER
N
YORKTOWN
COAST GUARD AREA
POWER
PLANT
INLET
OIL
REFINERY
GOODWIN NECK
GOODWIN
ISLANDS
CRAB NECK
CHESAPEAKE BAY
FISH NECK
POQUOSON RIVER
HUNTS
NECK
PASTURE NECK
LYONS CREEK

Figure 6. Print of an aerial photograph (original scale 1:30,000) taken in November, 1974, showing dense beds (1) located in Lyons Creek (L) and in Bennett Creek (B).

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 7. Distribution of beds of submerged aquatic vegetation in the Clay Bank Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).



N
CLAY BANK
GUM POINT
BLUNDERING
POINT
YORK RIVER
QUEEN CR.
KING CR.
CATLETT
ISLANDS
CARMINES
ISLANDS
MUMFORT
ISLANDS
GLOUCESTER PT.

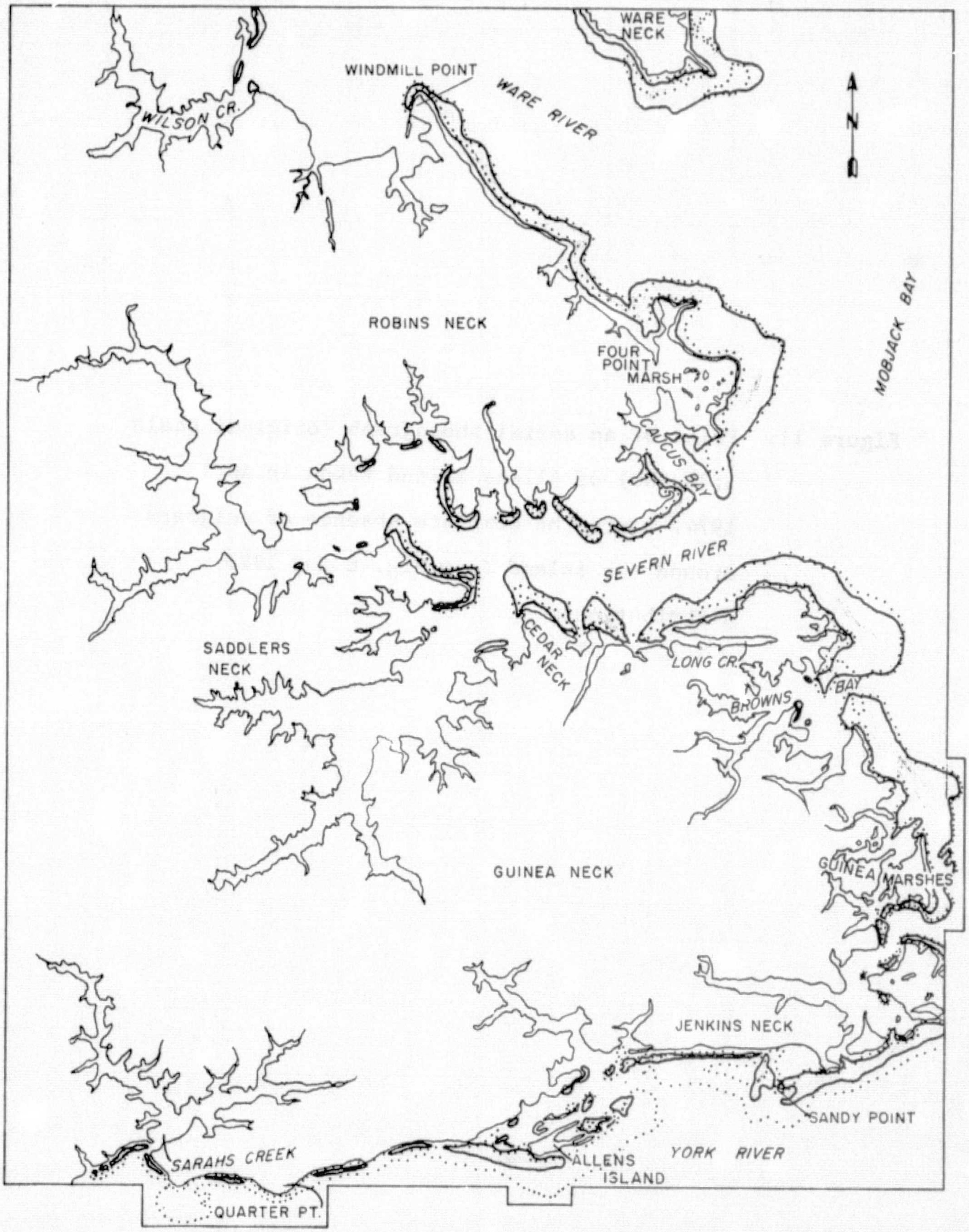
Figure 8. Print of an aerial photograph (original scale 1:50,000) taken in 1971 showing dense grass beds off Mumfort Islands (1), Quarter Point (2), Allens Island (3), and Sandy Point (4) in the York River.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 9. Print of an aerial photograph (origincal scale 1:30,000) of Mumfort Island taken in April, 1974, showing complete absence of eelgrass off these islands.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 10. Distribution of beds of submerged aquatic vegetation in the Achilles Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).



WARE NECK
WINDMILL POINT
WARE RIVER
WILSON CR.
N
ROBINS NECK
FOUR POINT MARSH
CAUCUS BAY
MOBJACK BAY
SEVERN RIVER
CEDAR NECK
SADDLERS NECK
LONG CR.
BROWNS
BAY
GUINEA NECK
GUINEA MARSHES
JENKINS NECK
SANDY POINT
SARAHS CREEK
ALLENS ISLAND
YORK RIVER
QUARTER PT.

Figure 11. Print of an aerial photograph (original scale 1:30,000) of Allens Island taken in April, 1974. Note the complete absence of eelgrass around the island (see Fig. 8 for 1971 distribution).

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 12. Print of an aerial photograph (original scale 1:30,000) of Allens Island taken in November, 1974, showing eelgrass beds (1) present off the island. The light lines cutting across the grass bed are boat tracks.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 13. Print of an aerial photograph (original scale 1:30,000) of Sandy Point taken in April, 1974. Note small patches of eelgrass to the lower right of the island (1). Arrow points to Monday Creek where no eelgrass is evident.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 14. Print of an aerial photograph (original scale 1:30,000) of Sandy Point taken in November, 1974, showing grass beds (1) and large beds of algae (2). Arrow points to eelgrass in Monday Creek which was not seen in Fig. 13.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 15. Print of an aerial photograph (original scale 1:20,000) of Allens Island and Sandy Point taken in July, 1937. Note sparse patches of grass (1) around these areas.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 16. Print of an aerial photograph (original scale 1:20,000) of same areas as in Fig. 15, taken in May, 1960. Eelgrass is much more dense in these areas.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 17. Print of an aerial photograph (original scale 1:30,000) of the Severn River off Long Creek, showing boat tracks (2) cutting across the dense grass beds (1).

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 18. Print of an aerial photograph (original scale 1:30,000) of Ware Point taken in November, 1974. Note the sand bars (3), and boat tracks (2) cutting across the dense grass bed (1).

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 19. Print of an aerial photograph (original scale 1:30,000) of an area off Saddlers Neck in the Severn River taken in November, 1974. Note the light area (arrow) in the center of a dense grass bed (1). This area of 3.3 acres appeared to have been dredged to fill in the adjacent marsh. Small dark specks in the area are very small patches of eelgrass and widgeon grass.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 20. Distribution of beds of submerged aquatic vegetation in the Ware Neck Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).

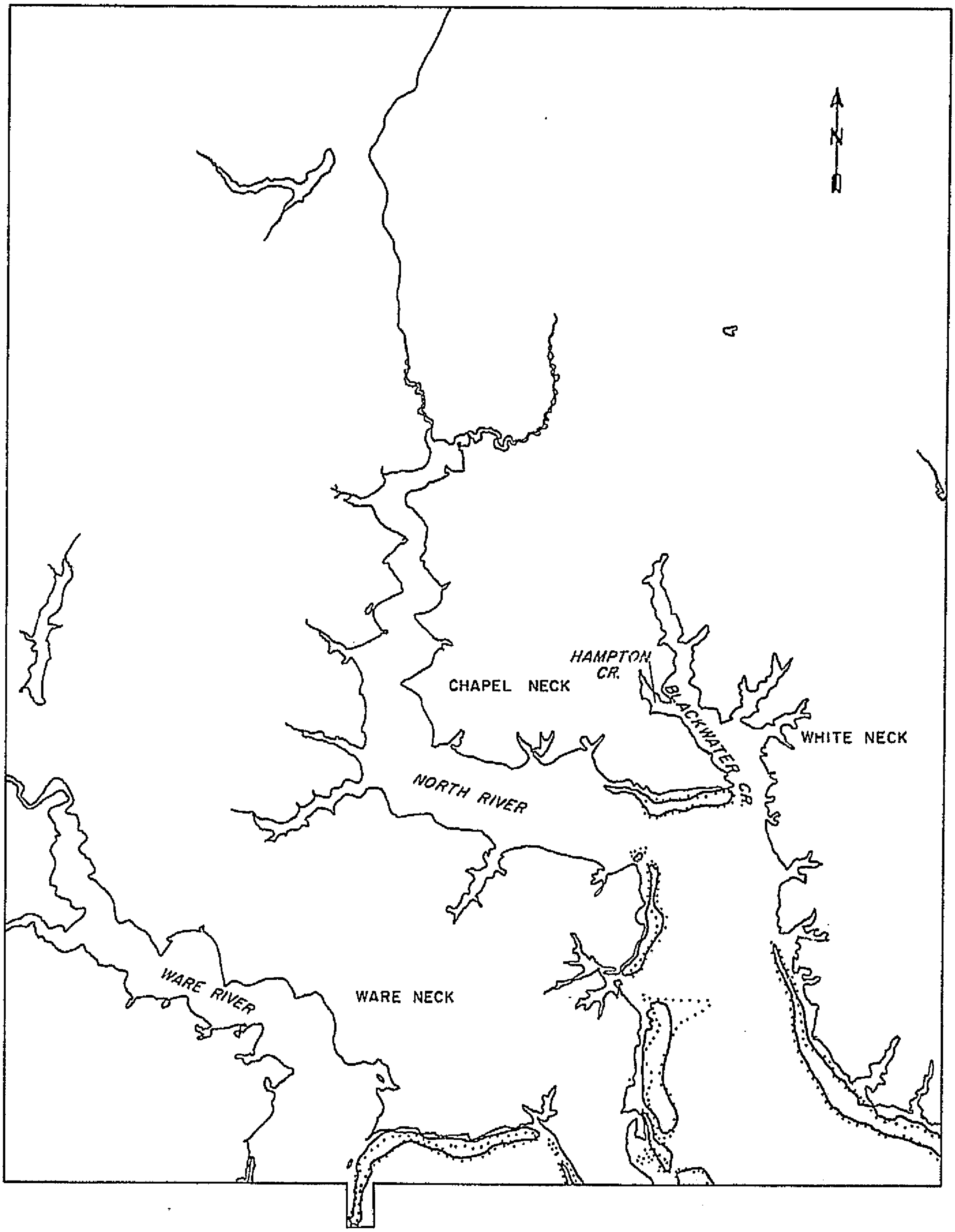
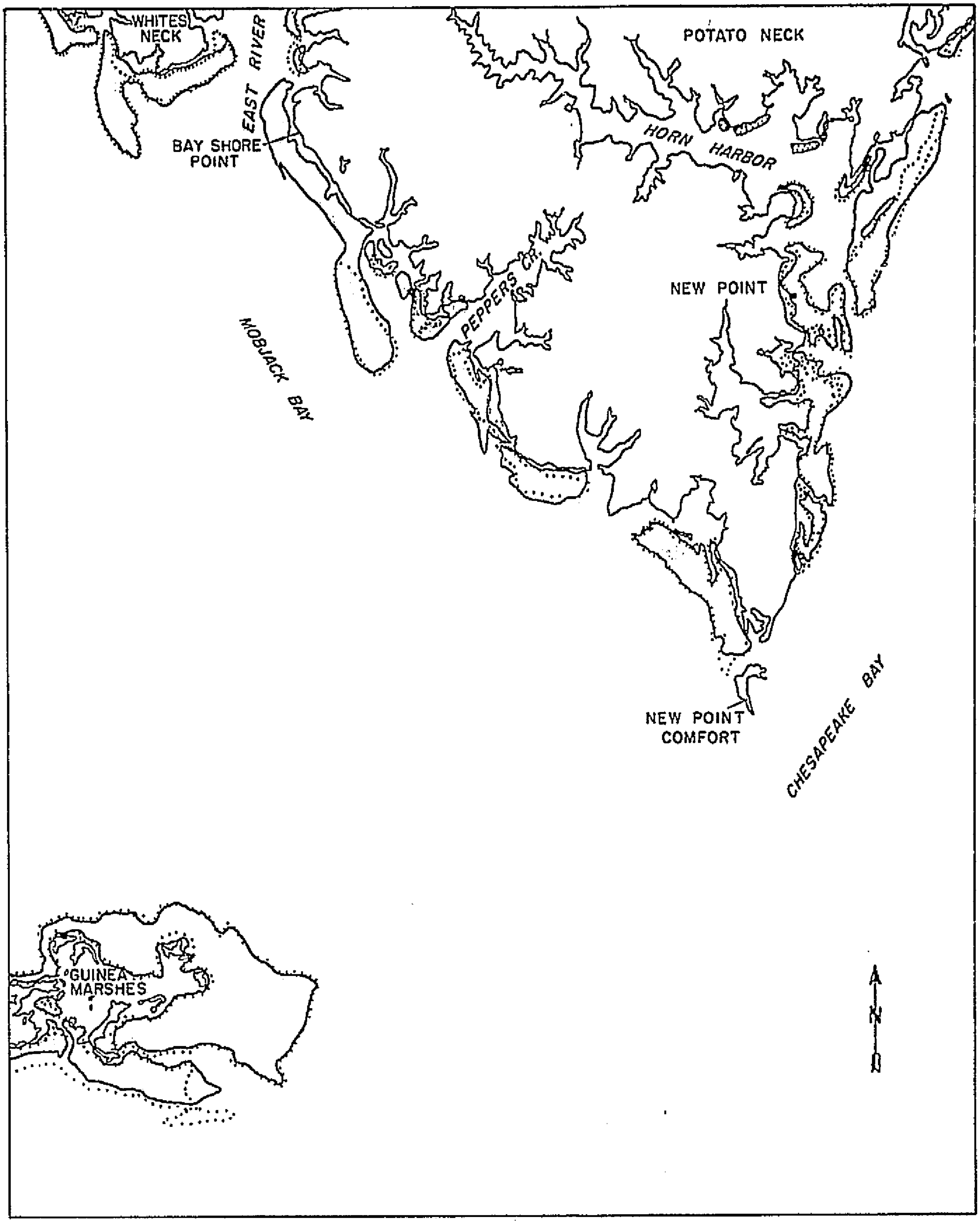

N
HAMPTON CR.
CHAPEL NECK
BLACKWATER CR.
WHITE NECK
NORTH RIVER
WARE RIVER
WARE NECK

Figure 21. Distribution of beds of submerged aquatic vegetation in the New Point Comfort Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).


WHITES NECK
EAST RIVER
BAY SHORE POINT
POTATO NECK
HORN HARBOR
PEPPERS CR.
NEW POINT
MOBJACK BAY
NEW POINT COMFORT
CHESAPEAKE BAY
GUINEA MARSHES
N

54-A

Figure 22. Distribution of beds of submerged aquatic vegetation in the Mathews Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).

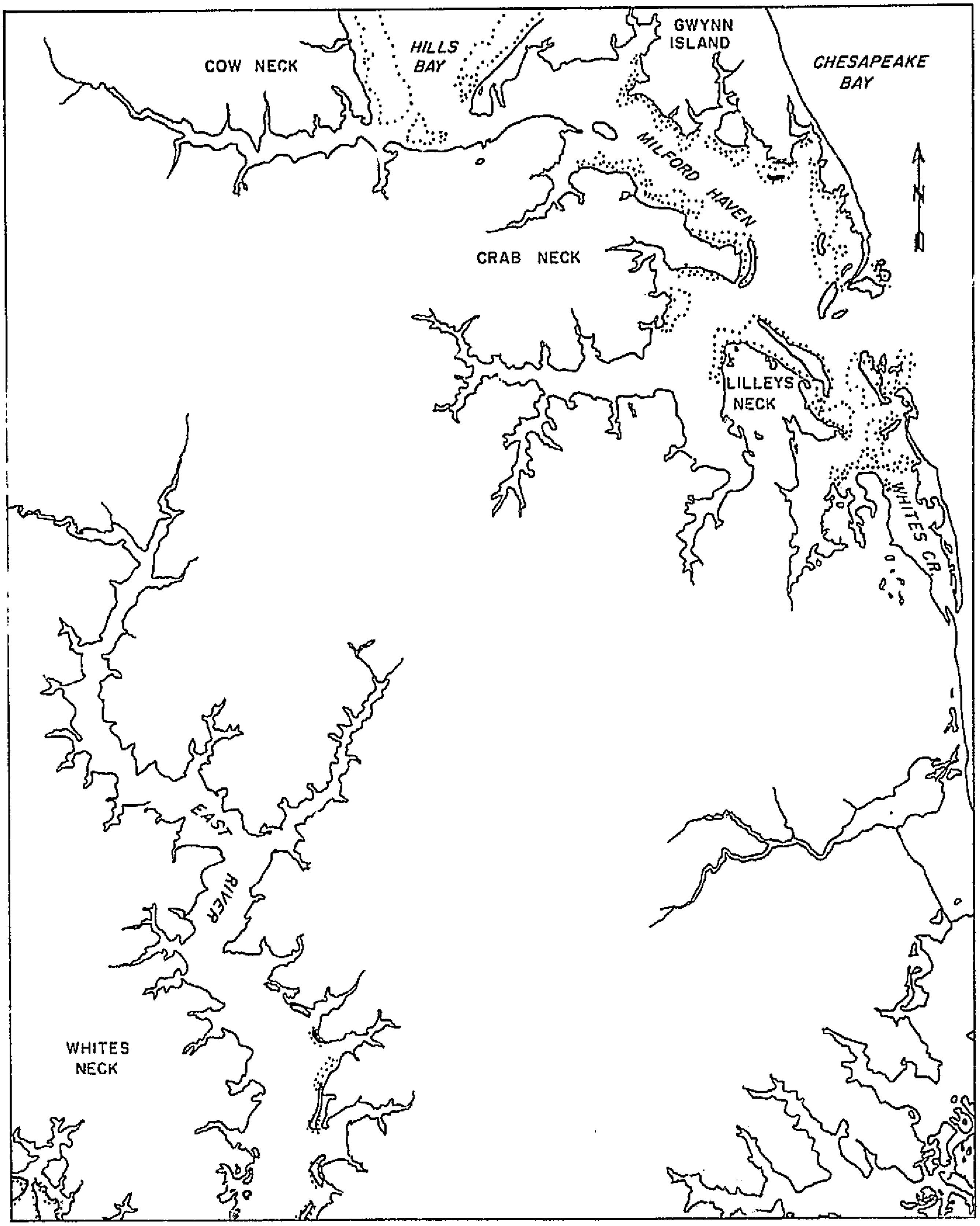

GWYNN
ISLAND
HILLS
BAY
COW NECK
CHESAPEAKE
BAY
MILFORD HAVEN
CRAB NECK
LILLEYS
NECK
WHITES CR.
EAST
RIVER
WHITES
NECK

Figure 23. Distribution of beds of submerged aquatic vegetation in the Deltaville Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).

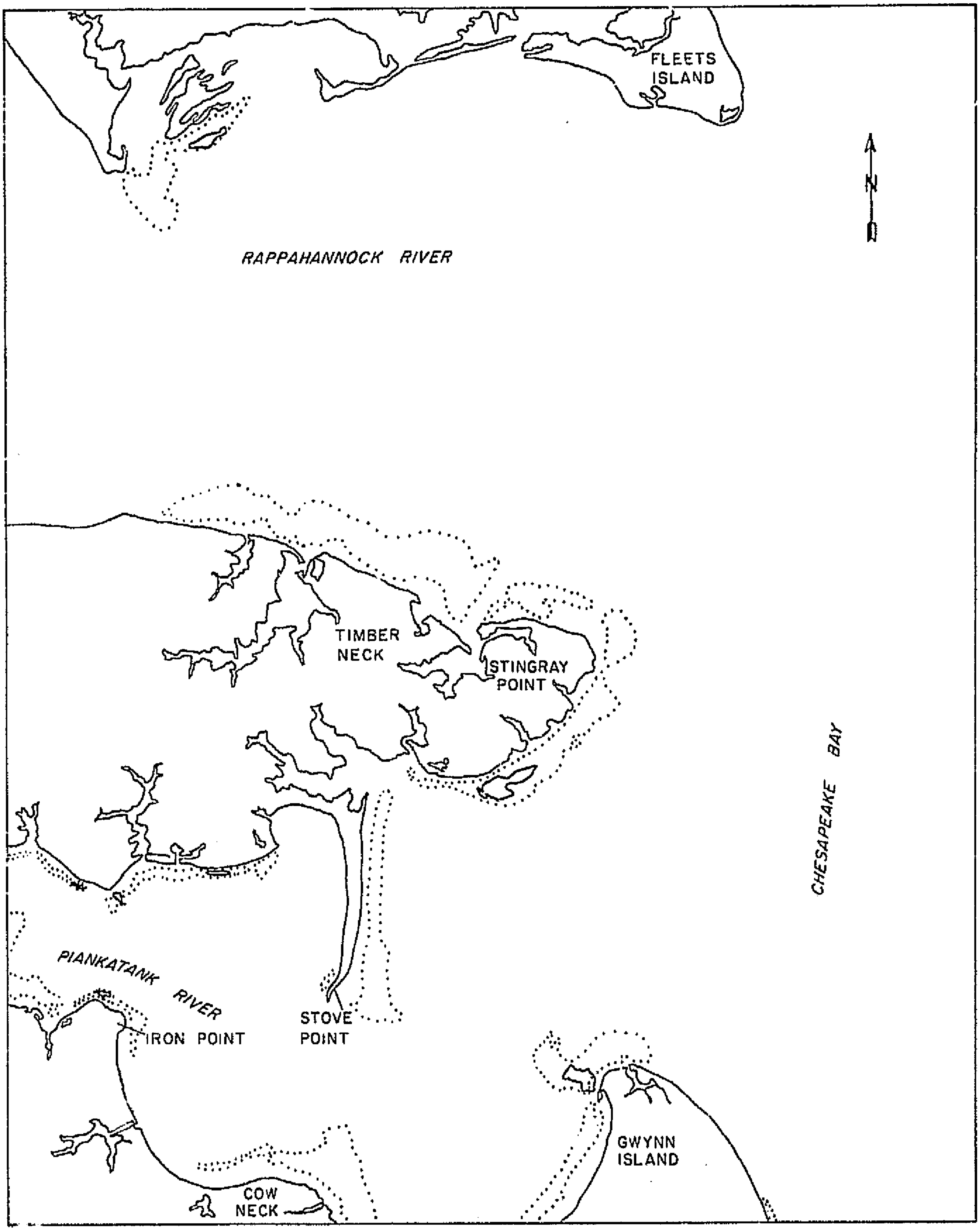
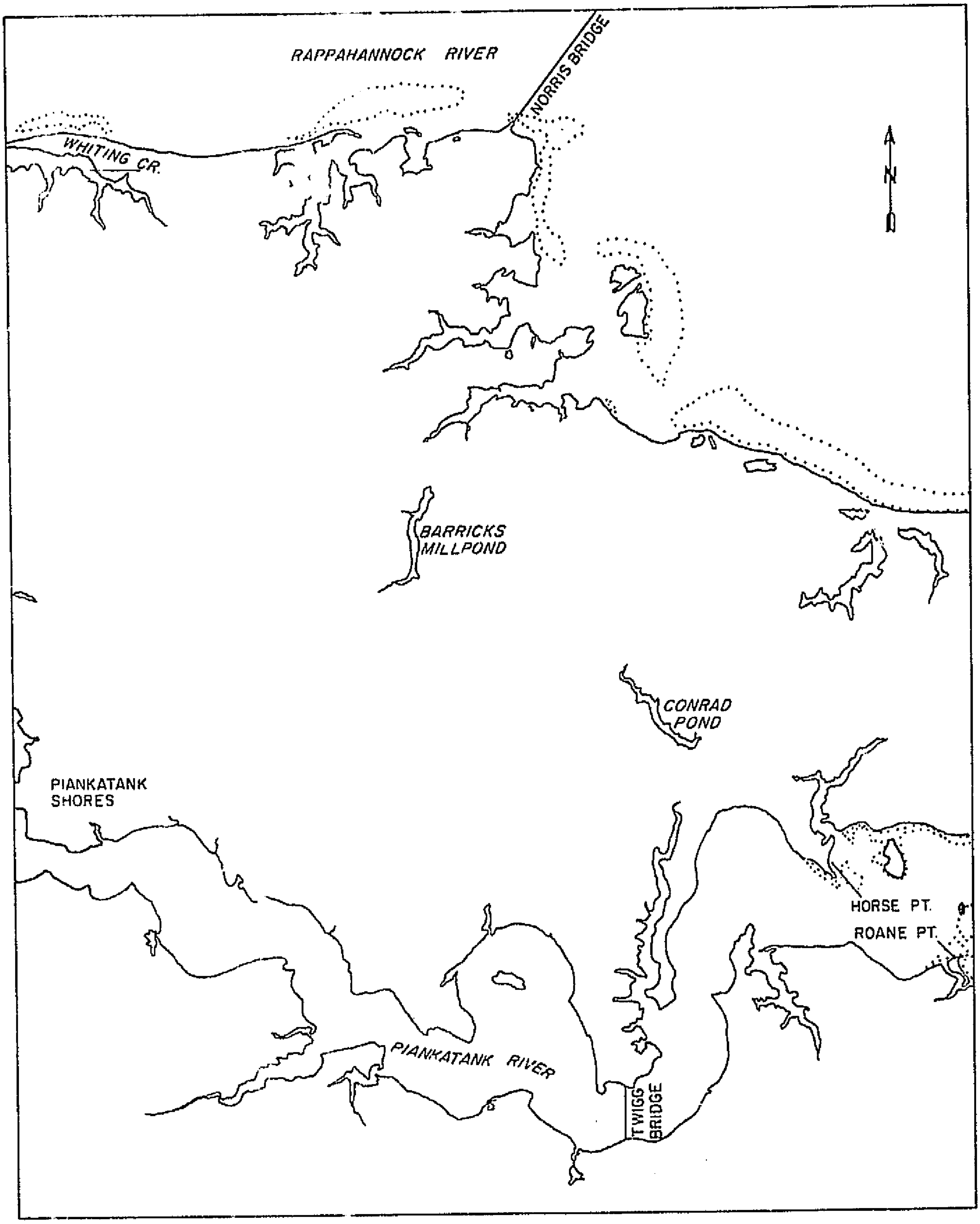

FLEETS ISLAND
RAPPAHANNOCK RIVER
N
TIMBER NECK
STINGRAY POINT
CHESAPEAKE BAY
PIANKATANK RIVER
STOVE POINT
IRON POINT
GWYNN ISLAND
COW NECK

Figure 24. Distribution of beds of submerged aquatic vegetation in the Wilton Quadrangle in 1971 (areas within dotted lines) and in 1974 (colored areas within solid lines).


RAPPAHANNOCK RIVER
NORRIS BRIDGE
WHITING CR.
N
BARRICKS MILLPOND
CONRAD POND
PIANKATANK SHORES
HORSE PT.
ROANE PT.
PIANKATANK RIVER
TWIGG BRIDGE

57-A

Figure 25. Distribution of beds of submerged aquatic vegetation in the Irvington Quadrangle in 1971 (areas within dotted lines). There were no submerged aquatics in this section in 1974.

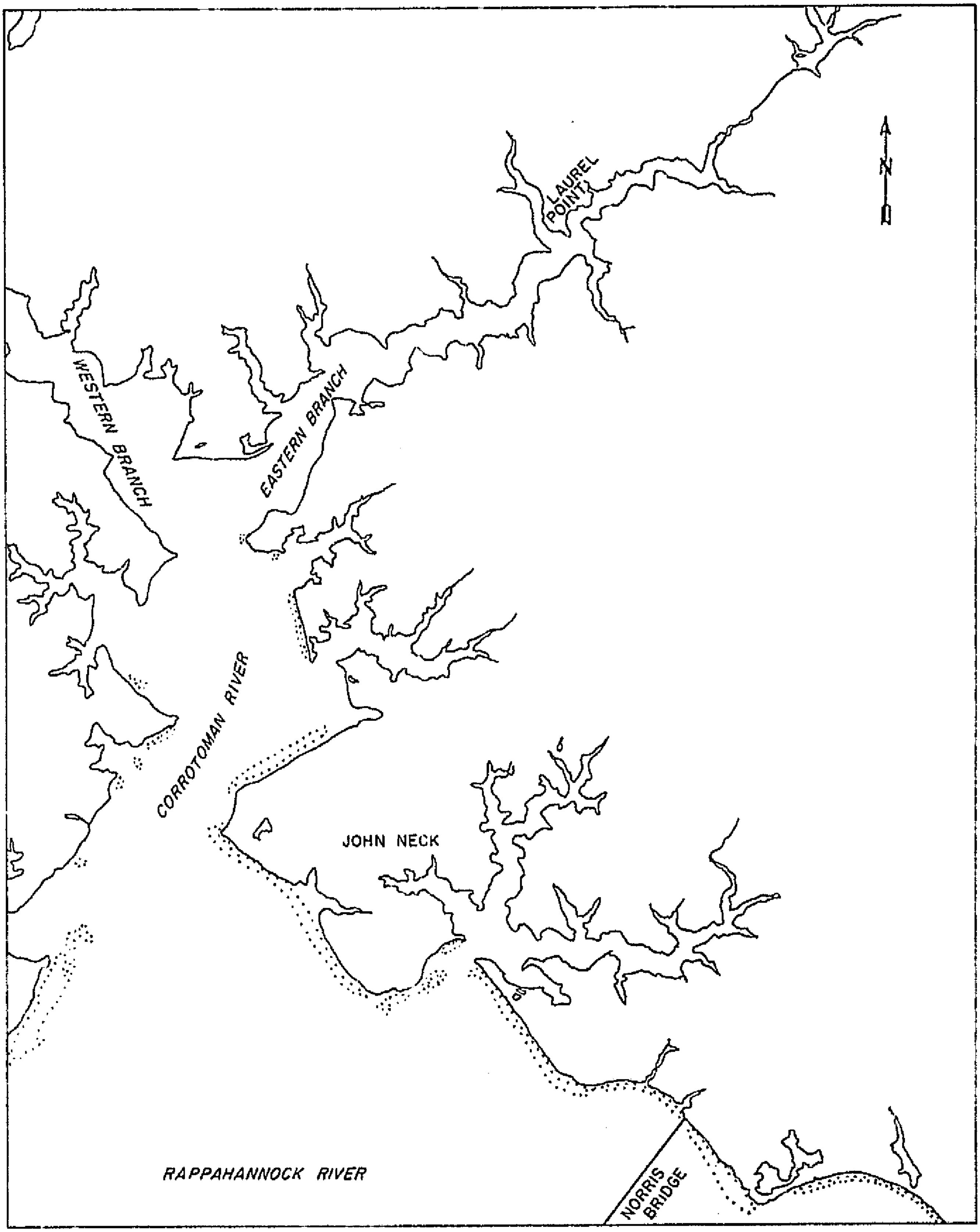
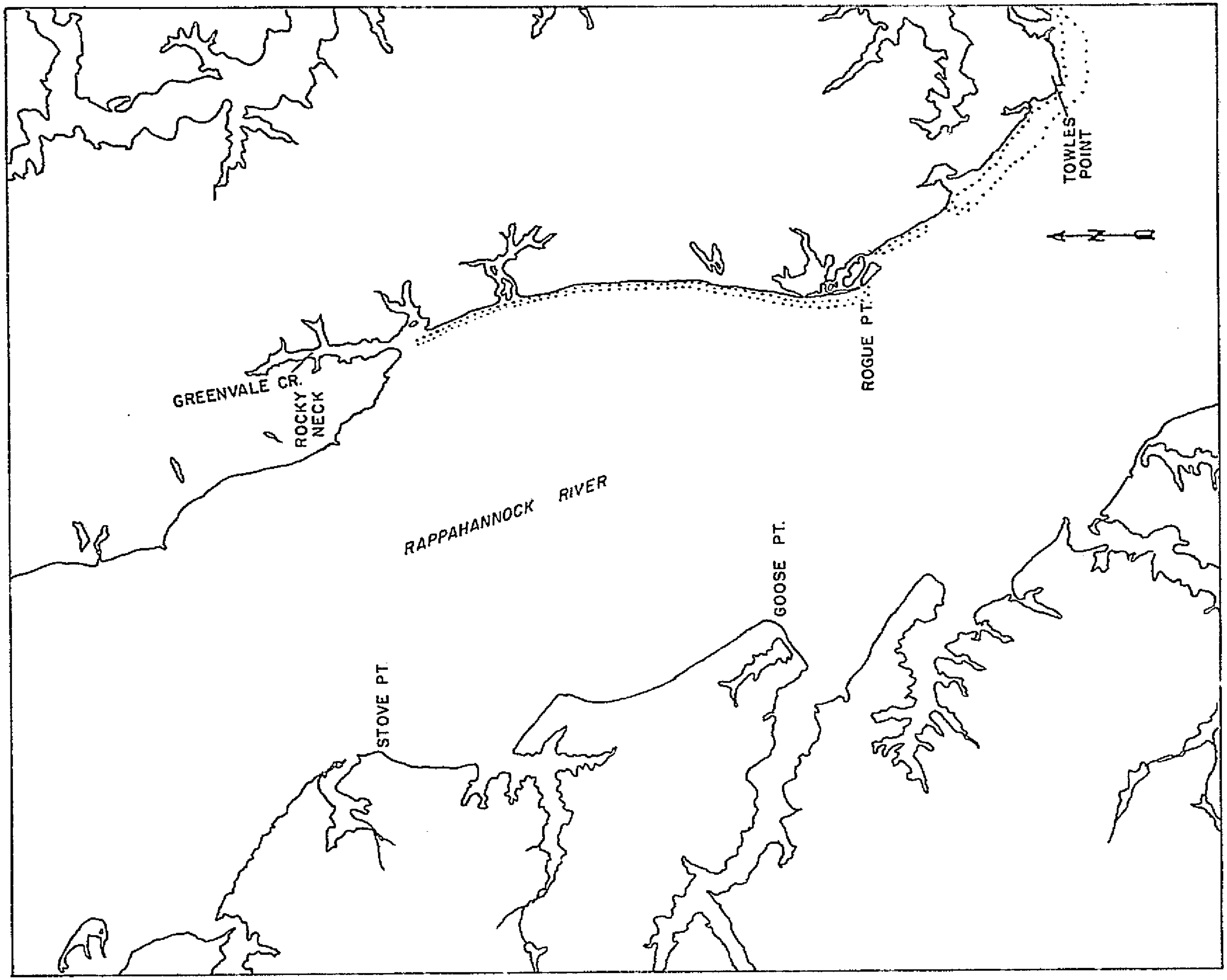

LAUREL POINT
WESTERN BRANCH
EASTERN BRANCH
CORROTOMAN RIVER
JOHN NECK
RAPPAHANNOCK RIVER
NORRIS BRIDGE

Figure 26. Distribution of beds of submerged aquatic vegetation in the Urbanna Quadrangle in 1971 (areas within dotted lines). There were no submerged aquatics in this section in 1974.



TOWLES POINT
N
ROGUE PT.
GREENVALE CR.
ROCKY NECK
RAPPAHANNOCK RIVER
GOOSE PT.
STOVE PT.

Figure 27. Distribution of beds of submerged aquatic vegetation in the Fleets Bay Quadrangle in 1974 (colored areas within solid lines). This section was not covered in the 1971 survey.

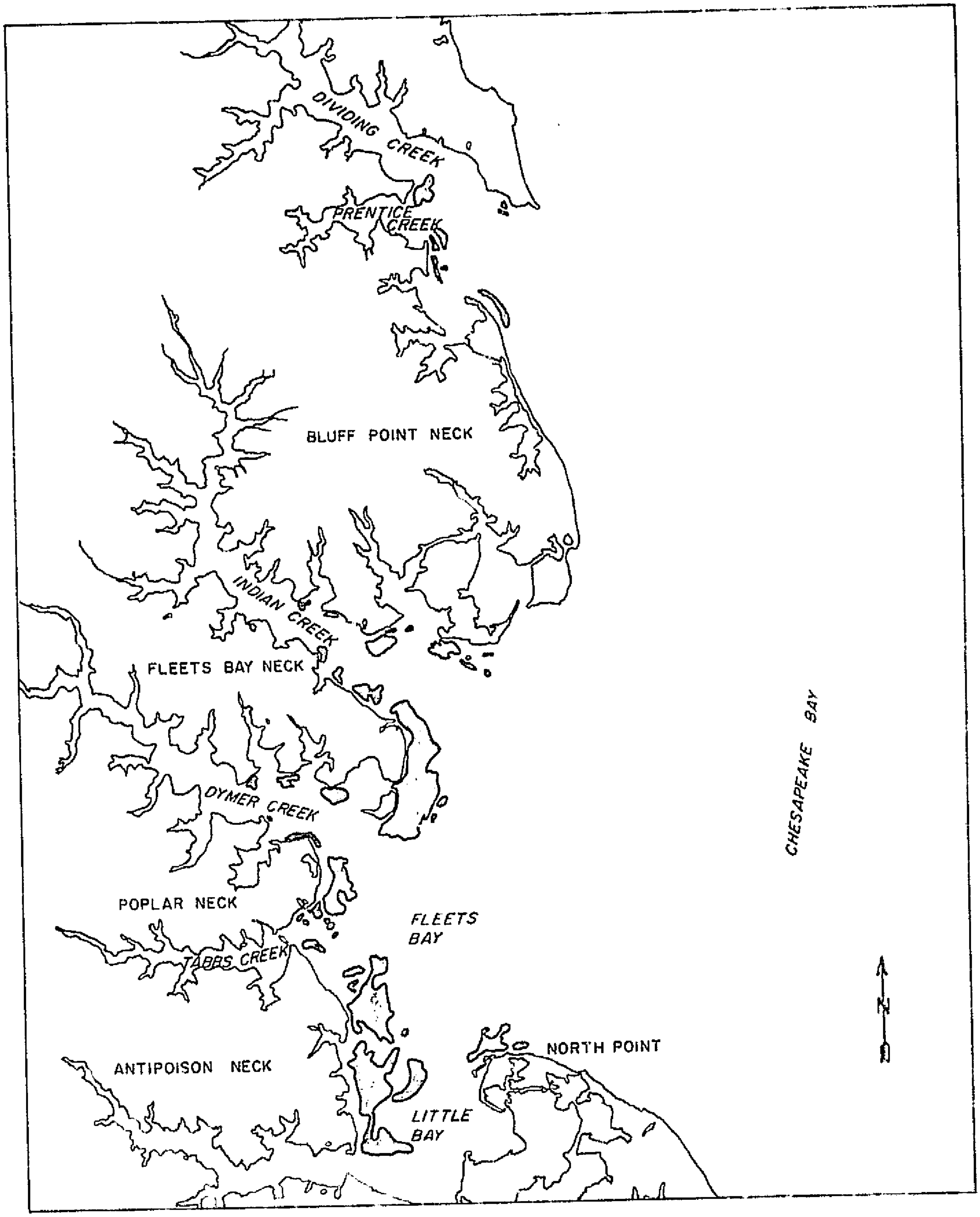
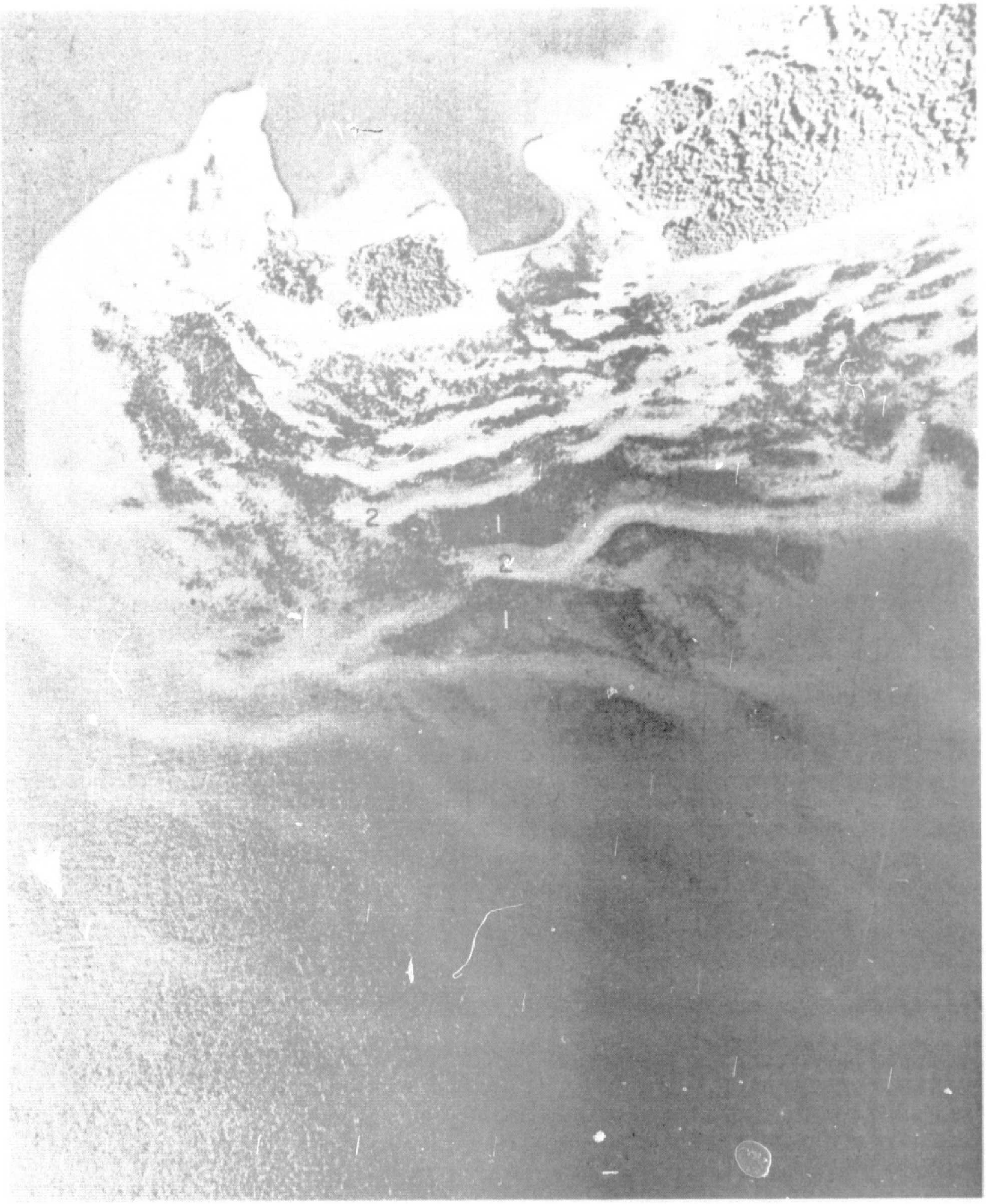

DIVIDING CREEK
PRENTICE CREEK
BLUFF POINT NECK
INDIAN CREEK
FLEETS BAY NECK
CHESAPEAKE BAY
DYMER CREEK
POPLAR NECK
FLEETS BAY
TABBS CREEK
NORTH POINT
ANTIPOISON NECK
LITTLE BAY
N

Figure 28. Print of an aerial photograph (original scale 1:30,000) taken in November, 1974, off Bluff Point Neck, Fleets Bay, showing submerged aquatics (1) and sand bars (2) between the grass areas.



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 29. Print of an aerial photograph (original scale 1:30,000) taken in September, 1974, off the Poquoson Flats showing results of digging activities of the cownose rays (arrow points to where rays are and the light trails are sediment plumes which are approximately 1 to 1.5 miles long).

ORIGINAL PAGE IS
OF POOR QUALITY

C 2