An Ecological Study of the Muskrat in Constitution Marsh

FINAL REPORT
to the
Hudson River Foundation

James P. Rod
November 1990

NATIONAL AUDUBON SOCIETY
Constitution Marsh Sanctuary
Garrison, N.Y.

An Ecological Study of the Muskrat in Constitution Marsh

FINAL REPORT

Prepared under contract for

The Hudson River Foundation
for Science and Environmental Research, Inc.
New York, NY

Hudson River Foundation Grant No. 020/85B/023

Prepared by

James P. Rod
Constitution Marsh Sanctuary
National Audubon Society
Garrison, NY

November 1990

Principal Investigator, James P. Rod
Co-Investigator, John Allen
Statistical Consultants, Ronald J. Sloan
Dolores Hughes

ACKNOWLEDGEMENTS

The research contained in this report was financed through research grant No. 020/85B/023 from the Hudson River Foundation for Science and Environmental Research, Inc., a New York not-for-profit corporation with its offices located in New York City. The views expressed herein do not necessarily reflect the beliefs or opinions of the Foundation, which assumes no responsibility or liability for the contents or use of the information herein.

The principal investigator wishes to thank Frank Dunstan, Norman Brunswig and John Anderson of the Sanctuary Department, National Audubon Society, for their encouragement and support of this research. John Allen, Justin Allen and Mark Sramek assisted with field and laboratory work. Steve Nack and Everett Nack trapped the muskrats from Tivoli Marsh and assisted with the trapping in Constitution Marsh, as did Kenneth Trimble. Ronald Sloan performed most of the statistical analyses and assisted with all phases of the project. My wife, Dolores Hughes, assisted with the field collection of data and performed the rest of the statistical analyses. She also contributed substantially to the design of the study. Eric Lind, Audubon intern at Constitution Marsh, prepared the maps of Constitution Marsh and plotted the locations of muskrat lodges.

Milton Weller, Erik Kiviat, Ben Tullar, Peter Ward and Harvey Smith provided valuable input during the design of this project. Robert Boyle and John Cronin assisted with the preparation of the grant application to the Hudson River Foundation. Ward Stone was of great assistance, spending several weekends with the authors examining muskrat livers for Hepaticola infestation, and providing insights regarding the effects of cadmium on other organisms. The U.S. Army Photo Services at West Point Military Academy provided a helicopter, photographer and laboratory services for the spring, 1990, re-survey of muskrat lodge locations. Cadet Bob Maindell field-checked the photos.

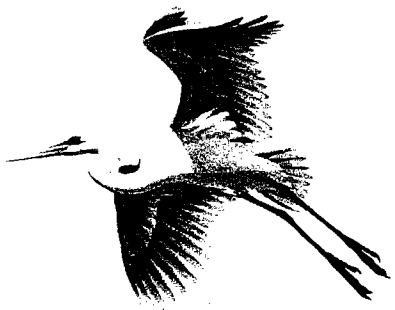
The authors wish to thank the Hudson River Foundation for making laboratory space available at the Castle Rock Field Station in Garrison, NY. The staff of the Hudson Riverkeeper Fund at Castle Rock were helpful in many ways. New York State Department of Environmental Conservation provided the necessary scientific permits to conduct the project, and Glenn Cole and Richard Henry were helpful with comments on the study. Cadmium analyses were performed by Hazleton Laboratories, Madison, Wisconsin. Personnel from consulting firms performing Superfund studies under contract to NYSDEC and USEPA, including Acres American, Princeton Aqua Science, Ebasco Services and Malcolm Pirnie assisted with comments and by providing data.

The primary inspiration for this study was provided by the late Paul Errington whose exhaustive muskrat studies laid the groundwork necessary to understand the ecology of the muskrat and to suggest additional topics for research.

National Audubon Society
RFD 2, ROUTE 9-D, GARRISON, NEW YORK 10524 (914) 265-3119

ABSTRACT

Constitution Marsh is a National Audubon Society Sanctuary on the Hudson River 50 miles north of New York City. The 270-acre tidal marsh is contaminated with cadmium from a battery plant discharge into adjacent Foundry Cove, where sediment levels reach 171,000 ppm. Constitution Marsh, Foundry Cove and the nearby Hudson River are an EPA Superfund Site. Cadmium contamination in Constitution Marsh ranges from near background to 1,600 ppm, with a clear demarcation between two areas of moderate to high contamination and low contamination. Substantial declines in muskrat Ondatra zibethicus populations were observed which coincided with the operation of the battery factory. In 1986, a year-long study of the muskrat was conducted to assess the effects of cadmium. Four seasonal aerial photographic flights were made to record muskrat lodges. Each was visited, measured, numbered and mapped. Following the last lodge survey in the fall, muskrats were trapped from Constitution Marsh (two areas of significantly different contamination) and from Tivoli Marsh (the control) fifty miles upriver with background cadmium levels. Livers, kidneys and femurs were weighed and analyzed for cadmium, placental scars were counted, livers were examined for lesions and parasites, standard measurements were obtained and age and sex ratios were determined. Lodge counts ranged from 31 (summer: one lodge per 8.7 acres) to 70 (fall: one lodge per 3.9 acres). Fall lodges were largest. Mean cadmium in kidneys ranged from .222 to 15.485ppm and was significantly greater in the most contaminated area. Liver cadmium ranged from .04 to 3.127ppm and was significantly greater in the most contaminated area. 93% of muskrats from the most contaminated area had liver lesions compared to 22% from the control area. In the two contaminated areas, juveniles comprised 17% of female population compared to 86% from the control area. There were no significant differences in placental scar counts between areas. Among all areas, the male sex ratio was 53%. Muskrats from the contaminated areas were significantly heavier and longer. Cadmium contamination appears to be responsible for greatly reduced muskrat populations in Constitution Marsh.

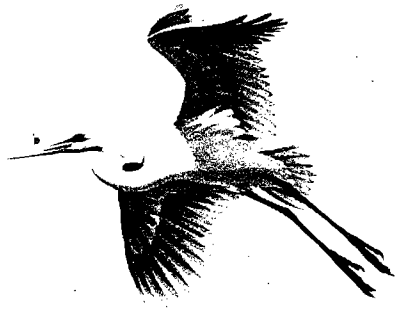


CONTENTS

NOTE: Figures 4,23,24,25 are from EBASCO Services Inc., Final Remedial Investigation Report, Marathon Battery Site, August, 1986 and are used with the permission of the United States Environmental Protection Agency, Region II, New York, NY.

LIST OF TABLES

LIST OF FIGURES



AN ECOLOGICAL STUDY OF THE MUSKRAT IN CONSTITUTION MARSH

Principal Investigator, James P. Rod
Co-Investigator, John Allen
Statistical Consultants, Ronald J. Sloan
Dolores Hughes

INTRODUCTION

Muskrats, Ondatra zibethicus, are semi-aquatic rodents found over most of the United States and Canada. They are the most important mammal, both ecologically and economically, living in Hudson River marshes. No other animal, except humans, exerts as much direct influence on Hudson River tidal wetlands as muskrats. They have been called "marsh managers," because of the effects of their burrowing, feeding and lodge-building activities. Openings created by lodge construction increase the amount of "edge," create nesting, feeding and loafing areas for many marsh birds, permit plant succession and increase diversity. The lodges themselves are used as resting, nesting or feeding sites by more than 70 vertebrate species. Abandoned lodges decay and become ideal substrates for pioneering plants. Muskrats are the major consumer of living plant materials in a marsh, and uneaten plant fragments undergo mechanical and biological breakdown and contribute to the detritus food web. Substantial declines in the Constitution Marsh muskrat population were observed to coincide with the operation of a nickel/cadmium battery factory which operated for 27 years, discharging nickel and cadmium wastes into Foundry Cove, adjacent to Constitution Marsh. Those declines were not quantified. The purpose of this research was to provide as many baseline data as possible regarding the ecology of the muskrat in Constitution Marsh and to assess the effects of cadmium upon their reproductive success in order that valid comparisons may be made after remediation of the site as part of the scheduled Superfund cleanup.

SITE BACKGROUND AND PURPOSE OF THE RESEARCH

Constitution Marsh is a tidal, primarily freshwater 270 acre marsh located on the east shore of the Hudson River approximately fifty miles north of New York City and directly opposite the West Point Military Academy. National Audubon Society has managed this estuarine marsh, which is owned by New York State, as a public wildlife sanctuary since 1970, and employs a full-time manager who was the principal investigator for this study.

Primary emergent vegetation in the marsh is cattail Typha angustifolia, pickerelweed Pondeteria cordata, arrow arum Peltandra virginica and arrowhead Sagittaria sp. Constitution Marsh is bounded on the west by Constitution Island and the Metro North Railroad tracks; on the east by deciduous forest and at the north and south ends by breached dikes constructed in the 1830's. In addition to natural tide channels, the marsh contains more than four miles of level ditches constructed during the same period in an attempt to farm wild rice. Dredge spoils from that operation form the base of a 5 acre island in the northwest corner of the marsh which now supports mature trees. (Figs. 4,5).

Immediately north of Constitution Marsh, and connected to it through a breached dike, is Foundry Cove, the site of heavy-metal contamination resulting from the operation of a nickel/cadmium battery factory from 1952 to 1979. Initially constructed and operated by the U.S. Army, the plant was later operated by a succession of private companies. During that period, contaminated wastes were discharged into both the Hudson River and Foundry Cove. Cadmium was the primary constituent of the effluent, which also included large quantities of nickel and small amounts of cobalt. Estimates of the total discharges from the plant range up to 100 tons. (See Appendix B).

Limited dredging of a small area of Foundry Cove was undertaken in 1972 to satisfy a federal court order, but more than 90% of the cadmium wastes remained in the Cove following the completion of the dredging operation. In 1983, Constitution Marsh, Foundry Cove, the battery plant and the adjacent Hudson River became an Environmental Protection Agency Superfund Site. In 1984, with the New York State Department of Environmental Conservation as lead agency, comprehensive studies of the site were initiated to determine the extent of cadmium contamination. With the USEPA as lead agency, those studies have continued through 1990 and have cost approximately $8 million. Remediation plans have been approved for most of the Superfund Site and they entail the physical removal of cadmium contaminated sediments and soils. Remediation is projected by USEPA to cost $75 million. Some of the data collected during the course of the Superfund studies have been utilized in this research.

THE MUSKRAT

The most important mammal, both ecologically and economically, living in Hudson River marshes is the muskrat. No other animal, except humans, can exert as much direct influence on Hudson River tidal wetlands. In most marshes, the muskrat is the major consumer of living plant material and its importance to marsh systems has been described by Kiviat (1978).

Uneaten plant fragments cut by muskrats undergo mechanical and biological breakdown and contribute to the detritus food webs in the marsh. Rotting lodges and feeding platforms, enriched by feces, become compost heaps and provide substrates for pioneering plants. Cleared areas around lodges, where building and food materials have been cut, provide feeding and loafing areas for rails, waterfowl and other birds, and increase the amount of "edge" available in the marsh. These edges are favored nesting sites for species such as the marsh wren and red-winged blackbird. Plant succession in such cleared areas contributes to the richness and the diversity of both animal and plant life. Scores of vertebrate and invertebrate species are known to use muskrat lodges and burrows as resting, nesting and feeding places.

Therefore, broadly speaking, "normal" muskrat populations contribute to maximum diversity within the marsh system, while very high or very low populations may have the opposite effect.

In addition to their ecological importance, muskrats are valuable furbearers, and provide both income and recreation to trappers. During the 1980-81 season, New York State trappers harvested 800,000 muskrats which they sold for $6 million (Carroll, 1981). See Appendix for additional information.

MUSKRAT POPULATION DECLINES

Despite the fact that it has been closed to public trapping for 20 years, muskrat populations in Constitution Marsh have remained low for at least that long. According to local trappers who trapped muskrats in Constitution Marsh during the 1940's and 1950's, high muskrat populations were not unusual and in some years muskrat lodges could be seen "everywhere" in the marsh. The observed but unquantified decline appears to coincide with the operation of the battery factory and subsequent discharges of cadmium into Foundry Cove.

Muskrats, the sediments in which they burrow and the vegetation on which they feed are known to be contaminated with cadmium, with the highest concentrations from Foundry Cove. For example, according to Acres International (1985), muskrats collected from Foundry Cove during the Superfund study showed maximum kidney and liver cadmium concentrations of 15.0 ppm and 2.60 ppm (expressed as wet weight) respectively. Tivoli Marsh maxima were 0.370 ppm and 0.065 ppm.

In Foundry Cove, cadmium concentrations reached 171,000 ppm (dry weight) in a restricted area adjacent to the outfall pipe. Nickel levels reached 156,000 ppm. Cadmium levels in the rest of the 44-acre cove were generally between 500 and 10,000 ppm.

In Constitution Marsh, cadmium concentrations are related to tidal flow patterns (Acres Int. op cit). Incoming flood tides from Foundry Cove meet incoming tides from the cove south of Constitution Marsh at a point near the dredge spoil island mentioned earlier. Outgoing tides recede in the opposite direction. Consequently, cadmium concentrations in the north one-quarter of the marsh are high, ranging from 1,600 ppm down to 370 ppm. In the central and south portions of the marsh they are significantly lower, ranging from near background up to 100 ppm. In Tivoli Marsh, levels were at or near background, ranging from 0.28 to 3.6 ppm.

Cadmium levels in vegetation were also closely correlated with site, being near background in Tivoli Marsh and south Constitution Marsh and significantly elevated in north Constitution Marsh and Foundry Cove. Hazen and Kneip (1980) demonstrated that leaf concentrations of cadmium in emergent plants generally reflected the cadmium concentrations in the soil where the plants were growing. Cattails are a preferred muskrat food.

CADMIUM

Cadmium is a relatively rare soft, silvery metal found primarily in zinc ores. It was first commercially produced in 1907. Cadmium is used for electroplating, in pigments in plastics, paints and inks, and in the manufacture of batteries, among other uses. As a natural element, cadmium does not break down over time and therefore remains available for absorption from air, soil and water by plants and animals exposed to it. According to the EPA Toxics Information Series, cadmium creates both acute and chronic health effects in humans and other animals. Inhalation can cause pulmonary enema, anemia and central nervous system disorders. Approximately 70% of cadmium absorbed by the human body is accumulated in the kidney and liver. Functional liver damage and serious structural kidney damage have been observed. Cadmium may be a carcinogen and has induced mutations in bacteria and mammalian cells. Laboratory animals developed cancer at the site of injection and significant increases in prostate cancer have been reported in workers who were occupationally exposed. One study of mothers working in the cadmium industry recorded lower birth weights, signs of rickets and delayed development of teeth in newborn children. Laboratory tests in which pregnant rats, mice, hamster and frogs were fed cadmium produced birth defects in the offspring.

Nickel, also present in the study area, is toxic and may be contributing to the muskrat decline. The effects of nickel were not studied. Remediation will remove both metals from the site.

PURPOSE OF THE RESEARCH

The major purpose of the study was to gather baseline information regarding the ecology of the muskrat in Constitution Marsh and to determine the role of cadmium in the observed decline of the muskrat population.

Several goals and objectives were established at the outset of the project:

PRIMARY GOALS

1. To obtain accurate seasonal indices of muskrat activity in Constitution Marsh through lodge counts.

2. To assess the possible chronic effects of cadmium bioaccumulation on the reproductive success of adult female muskrats from contaminated and control areas.

SECONDARY GOALS

1. To determine if there is a significant correlation between cadmium bioaccumulation and Hepaticola infestation in the livers of adult female muskrats.

2. To determine the incidence of Hepaticola infestation in livers of all other muskrats and in Norway rats from contaminated and control areas.

3. To determine age and sex ratios, whole body weights and standard measurements for all muskrats from contaminated and control areas.

4. To determine the extent of use by muskrats of lodges and burrows in Constitution Marsh.

LONG-TERM OBJECTIVES

1. To determine the extent of increase, if any, of reproductive success of Constitution Marsh muskrats following the removal of cadmium-contaminated sediments.

2. To formulate muskrat management recommendations for Hudson River tidal marshes.

STUDY AREAS

Constitution Marsh Sanctuary is a 270-acre tidal marsh on the east shore of the Hudson River, opposite West Point Military Academy and about fifty miles north of New York City. It is managed by the National Audubon Society as a public wildlife sanctuary. Primary vegetation in the marsh is narrow-leaf cattail, pickerelweed, arrow arum and arrowhead. Approximately four miles of channels were dredged in the marsh during the 1830's in an attempt to farm wild rice.

Foundry Cove is adjacent to Constitution Marsh on the north and contains about 44 acres of open water and cattail marsh. Near Foundry Cove, and connected to it by an outfall pipe, is a former nickel-cadmium battery manufacturing plant. It operated from 1952 until 1979, and discharged several hundred tons of toxic cadmium wastes into both Foundry Cove and the adjacent Hudson River. In 1983, Foundry Cove, Constitution Marsh and the adjacent Hudson River became an EPA Superfund Site. Numerous studies have sampled biota, water, and sediments. Cadmium concentrations in Foundry Cove range up to 171,000 ppm. Because of tidal flow patterns, only the north one-quarter of Constitution Marsh is heavily contaminated, with cadmium levels ranging down to 370 ppm. Thus, Foundry Cove and the north end of Constitution Marsh are together called the Foundry Cove **(FC)** area for purposes of the muskrat research.

The remainder of Constitution Marsh is comparatively clean, with cadmium levels ranging up to about 100 ppm, but generally lower. This is called the Constitution Marsh **(CM)** area.

The two areas above; FC and CM, are the contaminated areas.

Tivoli Marsh is a large, freshwater tidal marsh, also located on the east shore of the Hudson about 100 miles north of New York City. It has been used as the control area in EPA Superfund studies, since cadmium levels there are at background, ranging from < 1.0 to 3.6ppm, and was used as the control marsh for the muskrat research. It is referred to as the **TM** area.

See the maps (Figs. 1,2,3) for locations of the study areas.

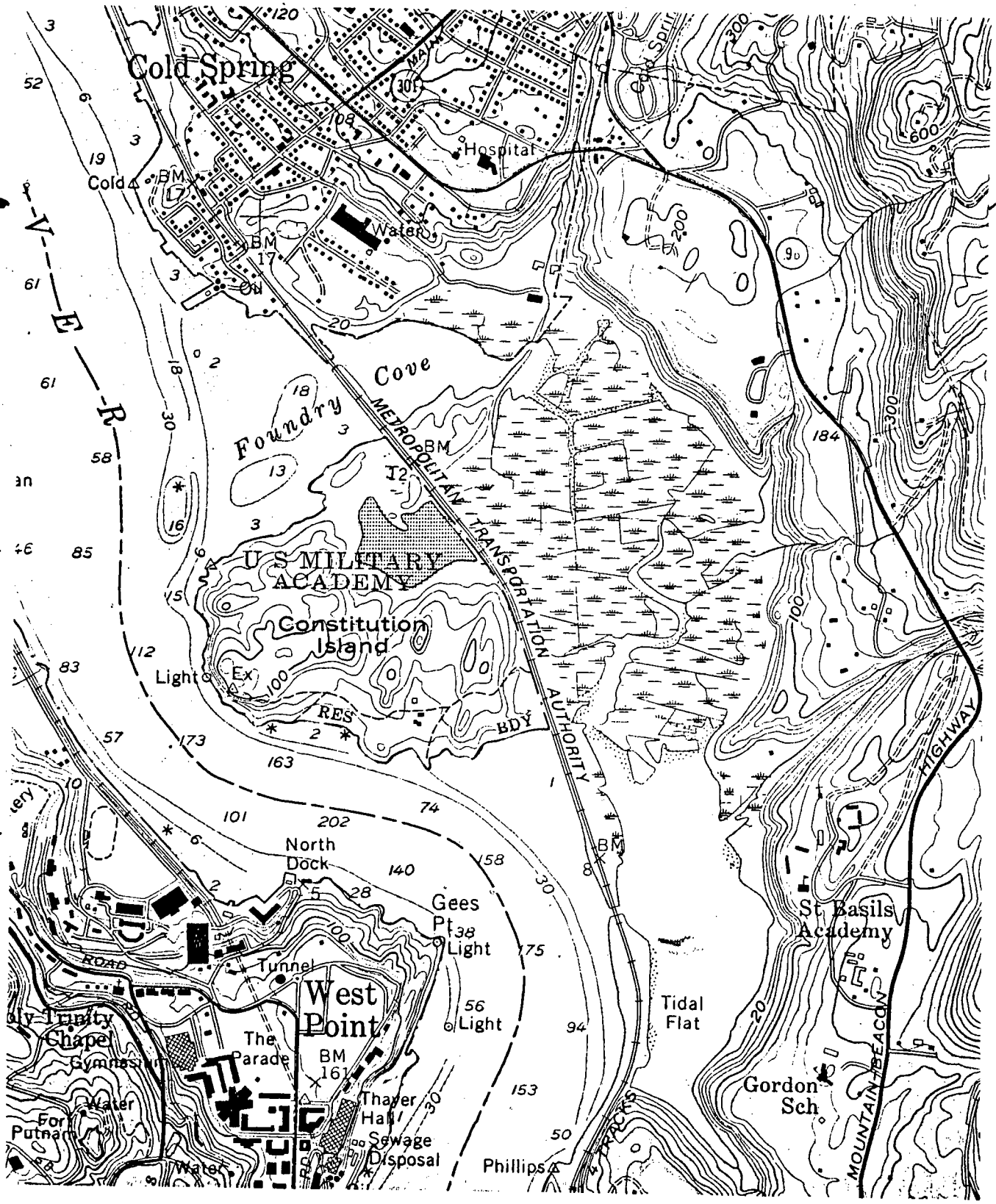


FIGURE 1. Location of Constitution Marsh

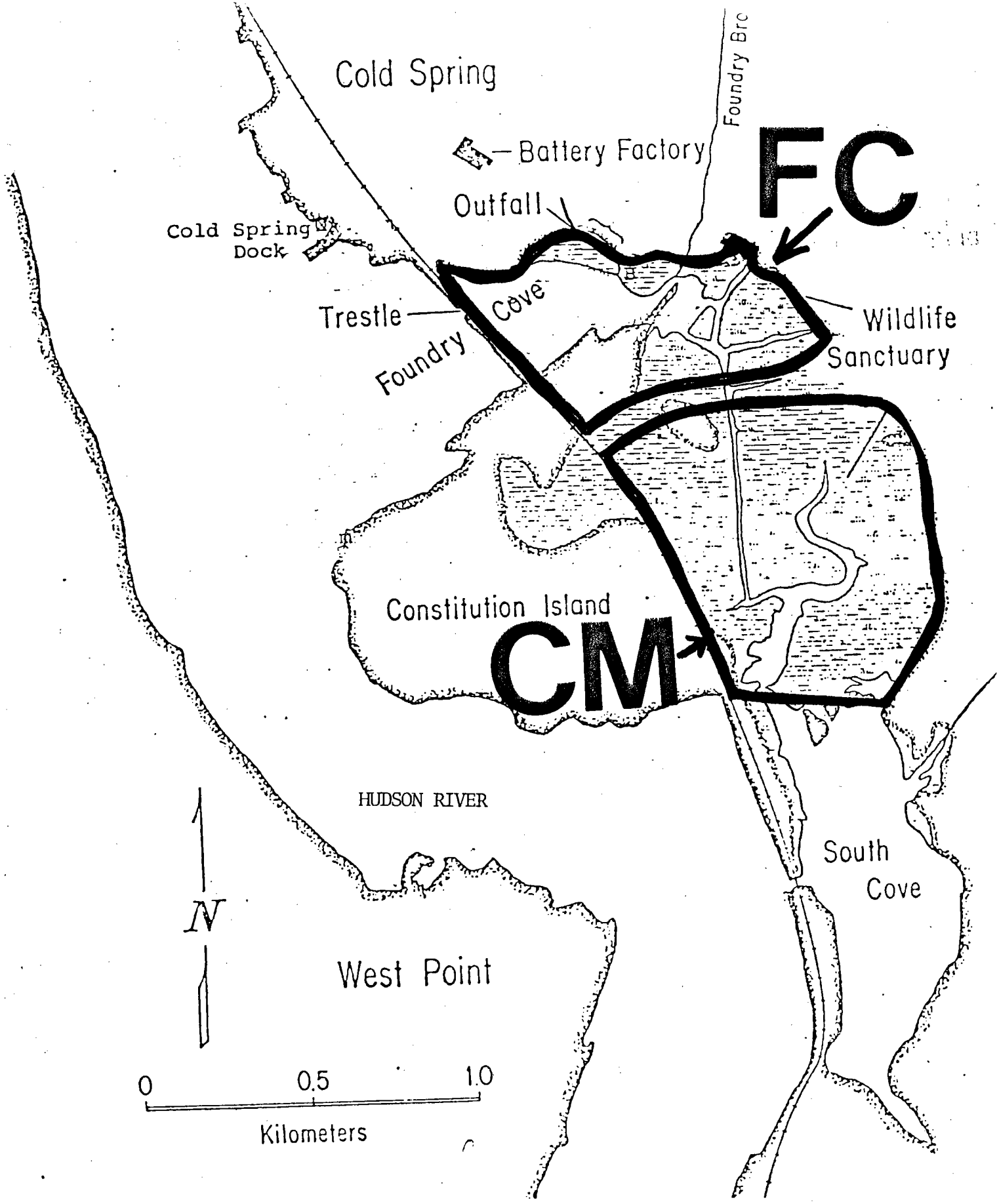


FIGURE 2. Constitution Marsh and Foundry Cove study areas

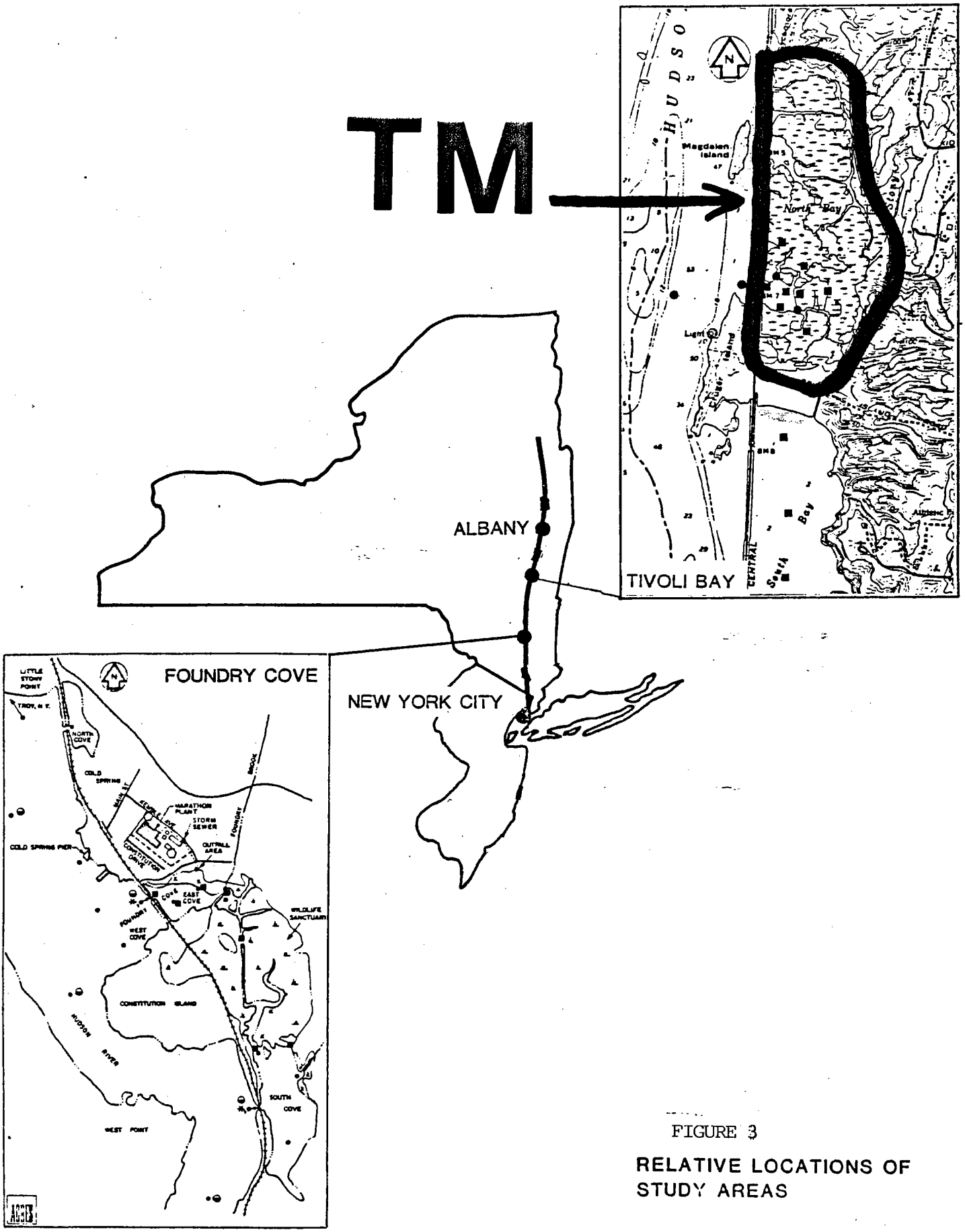
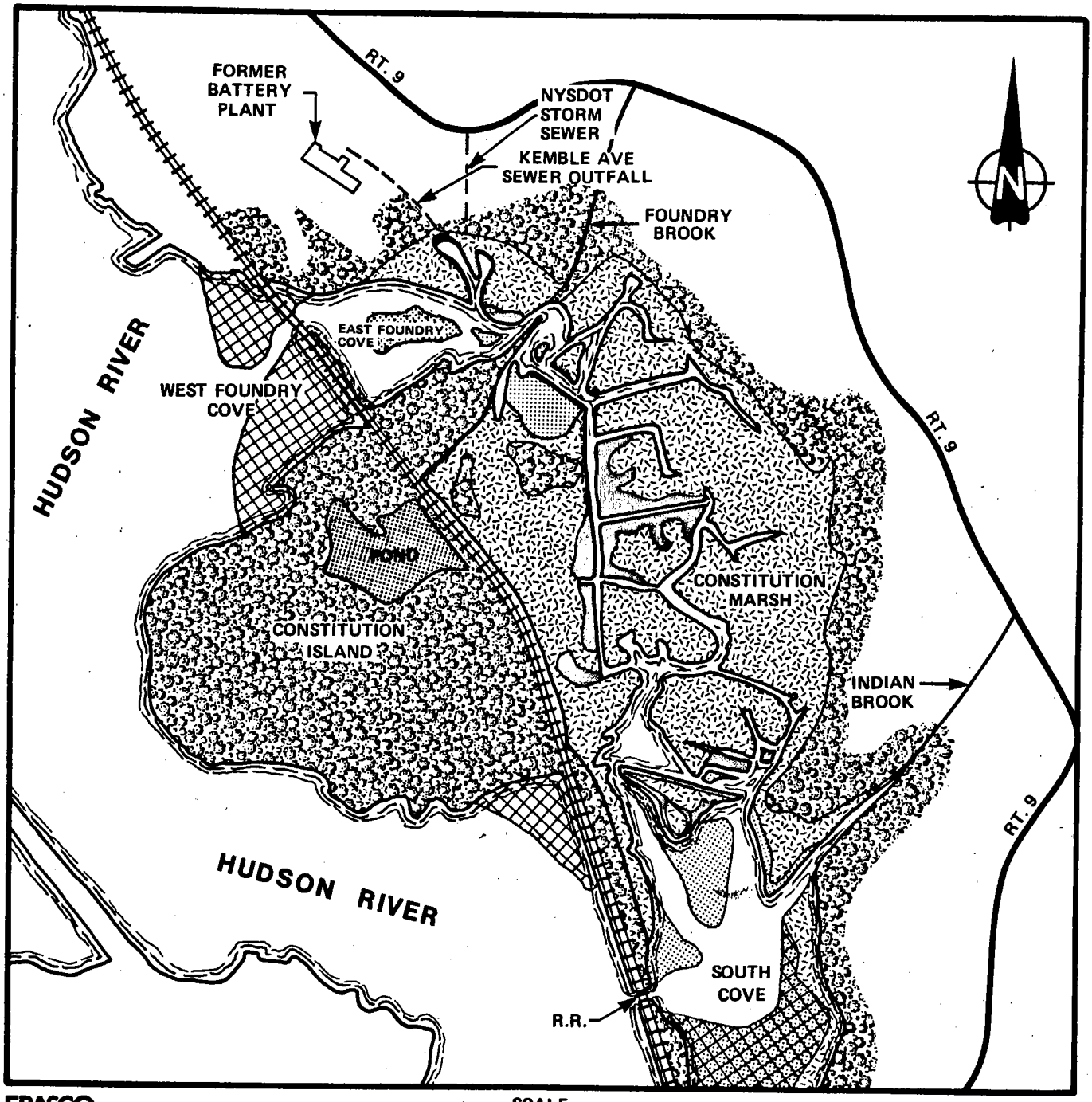


FIGURE 3

RELATIVE LOCATIONS OF STUDY AREAS

FIGURE 4

MAJOR VEGETATION PATTERNS



NOTE: ARROW ARUM OCCURRED ALONG THE BANKS OF THE CONSTITUTION MARSH CHANNEL & THE EAST COVE OUTFALL CHANNEL.