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Wetlands Mapping in New Jersey

A pilot study showed that biological discrimination techniques using color and color-infrared photos could be applied.

INTRODUCTION

THE New Jersey Department of Environmental Protection (NJDEP) is currently mapping and inventorying wetlands along the marine coastal zone and tide-influenced estuaries of the State to fulfill the requirements of the New Jersey Wetlands Act of 1970.

To fulfill the requirements of the Act, the Wetlands Mapping Pilot Project was undertaken to develop, test and apply a methodology for aerially mapping and inventorying state wetlands preliminary to the production of a state-wide wetlands map series. Earth Satellite Corporation, Washington, D. C., was contracted by NJDEP to conduct the study. Mark Hurd Aerial Surveys provided color and color-IR photography flown at 2,000 m. An objective of the pilot project was to test procedural details and solve problems while simultaneously preparing legally viable products to implement the Act.

In addition to the legal basis for protecting the state's wetlands as provided by the Act, state riparian rights can provide a basis for protecting tidal lands. Delineation of riparian lands requires determination of a line of mean high-water, lands seaward of which are owned by the state.

Mapping a mean high-water line within densely vegetated wetlands is a difficult problem. Ground survey methods are too costly and time consuming; aerial survey methods used along open shorelines require complex ground-to-air logistics. Furthermore, the mean high-water boundary is difficult to discriminate where it occurs in dense wetlands vegetation.

The methods tested in the project were premised on scientific investigations by Anderson[1] that tidal wetlands are distinguishable by characteristic botanical associations. These associations, if identified on aerial photographs and further substantiated by selected field observations, can be used to determine the upper wetland boundary and a line of biological mean high water. Analysis of aerial photographs also permits the inventory of plant species (delineation of major species associations) present in wet-

ABSTRACT: *The New Jersey Wetlands Act of 1970 required that mapping and inventory of wetlands along the marine coastal zone and tide-influenced estuaries of the State be undertaken in order that this important natural resource be properly managed. A prime requirement was that map products have validity which could withstand the challenge of litigation. Natural-color and color-infrared aerial photographs at a scale of 1:12,000 were obtained over two sites designated by the State. Final map products were prepared containing (a) the upper wetlands boundary; (b) the line of biological mean high water to establish state riparian lands; and (c) delineation of major plant species associations of five acres or larger in size. The state-wide wetlands mapping effort will be one of the largest* operational *remote sensing projects ever conducted. The authors believe that the methods developed, ecological data collected, and products prepared will have far reaching effects on future coastal zone programs.*

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land areas as a measure of the aesthetic, nutrient and recreational value of specific wetlands areas.

Sites within which aerial mapping and biological discrimination procedures were to be tested were selected in Salem County (Mannington Meadows) and Ocean County (Tuckerton), New Jersey. The two pilot areas that were mapped at 1:2400 and 1:6000 scale are, respectively, a fresh-brackish marshland and a saline marshland.

The saline wetlands in the Tuckerton area contains middle-class shore housing and some light (e.g., fish processing) industry. A high incidence of mosquito ditching has already changed the natural ecosystem of the area. Ditching has caused the wetlands to become partially dried in some places and the natural succession or the orderly process of change in plant species is being upset. Tidal plant communities are locally being replaced by those characteristic of upland (dryer) areas.

The Mannington Meadows site is a fresh to brackish wetland. Diking occurs throughout; furthermore, diking (which has since been destroyed) makes passage of surface craft through the area hazardous because of submerged obstacles, including concrete blocks and stumps.

Procedure

General

Vegetation types (species associations) are sensitive indicators of wetland conditions. For example, (1) vegetation integrates many environmental parameters, (2) vegetation responds sharply to slight changes in moisture or salinity, and (3) vegetation is stationary and easily observable. Although little or no significance can be assigned to the occurrence of an isolated individual species or small stands of a single species, large stands of characteristic species are reliable indicators of such variables as soil moisture, salinity, conditions of sedimentation, and topography.

For example, salt meadow grass (*Spartina patens*) and spike grass (*Distichlis spicata*) thrive in an environment which is normally flooded during spring tides. Saltmarsh grass (*Spartina alterniflora*) is an inter-tidal species which must be flooded daily to thrive and reproduce. Depauperate (low-vigor) *Spartina alterniflora* thrives in the zone which receives less frequency of flooding than high-vigor *Spartina alterniflora*. In addition to biological criteria, sedimentary criteria which have narrow vertical and lateral limits can also be used as supplementary indicators of tidal conditions, or location of the upper wetlands boundary. The basis for interpretative procedures will be discussed in depth later.

Preparation of Photo-Base Map

The base maps developed met National Map Accuracy Standards for that portion of each map sheet falling within the wetlands area. These standards require that 90 percent of well-defined map features be positioned on the map within 1/30 inch of their correct location with respect to the basic ground control. Basic control refers to government surveys previously established by such agencies as the U. S. Coast & Geodetic Survey, U. S. Geological Survey, New Jersey Geodetic Survey, State of New Jersey, Bureau of Geology and Topography, and the U. S. Army Corps of Engineers. These standards do not necessarily apply outside of wetlands areas (such as uplands which may be shown on the map sheet for convenience and reference), nor to the biological high-water line, upper (inland) wetlands boundary line, and lines enclosing major species associations.

To meet National Map Accuracy Standards, a network of ground control points at Tuckerton and Mannington Meadows sites was established.

Image Interpretation Techniques

Many of the procedures by which photo interpreters analyze aerial photographs are difficult to document in a step-by-step detail. Experience, knowledge of complex biological interrelationships and, at times a necessity for subjective interpretational decision, are factors which provide the photo analyst with keys by which wetlands-phenomena are defined. Interpretive experience developed during this project with both color and infrared-color aerial photographs to date indicates that manual procedures will probably not, in the near future, be completely supplanted by automated techniques.

The manual techniques used for wetland mapping (and which relate both to color and color-IR photographs) are discussed below:

- *Preliminary scan of imagery.* This is accomplished to determine tonal structure and range of tones; for example, variations in sun angle from one flight line to the next will result in changes in tonal quality.
- *Relate tonal structure to species composition.* Intensity of tones may vary within a

frame or from photograph to photograph although the range of tonal signatures relative to species composition will remain constant under near-constant conditions of illumination. This procedure must therefore be repeated (and checked) from photograph to photograph.

- *Confirm tone codes.* Tonal indications for various wetland plant species and communities which are indicators of tidal influence and the mean high-tide line are determined—careful attention is given to the environment in which the tone occurs, i.e., between mosquito ditches or along open shorelines, as a key to proper species identification.
- *Delineate tide-influenced wetlands.* Based on indicator plant species tide-influenced wetlands including mean high-tide lines, and upper wetlands boundaries (landward extent of marsh) are delineated.
- *Spot field checks.* Field checking is conducted in selected wetland areas to verify interpretation of plant species composition from tone on the film. Biological environments are also checked. This is done with persons not intimately associated with the delineation as a quality control measure.
- *Up-date maps.* Corrections are made to base maps and the final map then prepared.

A variety of enhancement techniques are currently available for facilitating rapid and accurate image interpretation. These vary from viewing the transparencies through different filters to density slicing where false colors displayed on a screen relate to differences in density on the film. The latter more sophisticated techniques were not used in the New Jersey program. These are still in the experimental-developmental stage and cannot at the present time be relied on for accurate delineation of wetlands biology.

Biological Techniques Description

High Tide Boundary Determination: Saline Wetlands

Results of several research investigations in wetlands (including leveling experiments) have shown that certain species are accurate indicators of environmental parameters. The presence of *Spartina alterniflora* zones, for example, have been used as an indicator of areas inundated by each lunar high tide. Recent work has cited the occurrence of three growth forms of *Spartina alterniflora* based on the height of the plant; tall, medium and short. Leveling experiments and EarthSat field observations have indicated that the mean high water line fell somewhat below the upper boundary of medium height *Spartina alterniflora.*

Infrared-color photographs obtained during the New Jersey mapping pilot project showed many areas as having a *Spartina alterniflora* community which was low in vigor. Subsequent field studies at selected points during periods of mean high water in-

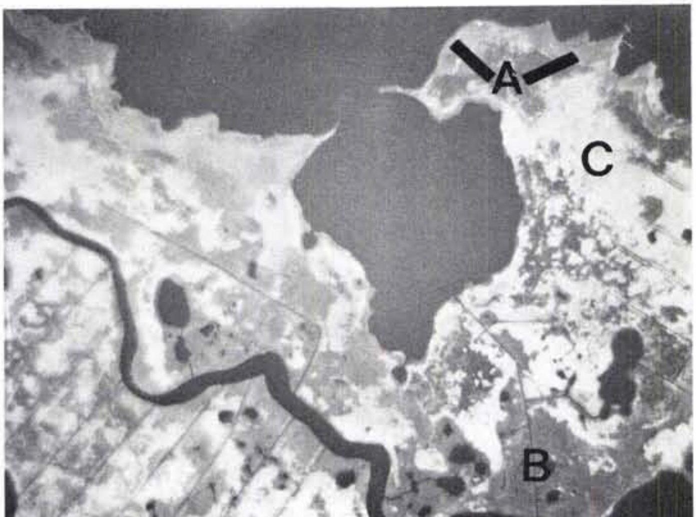

FIG. 1. Black-and-white photographic print from color-IR transparency shows tonal differences among high-vigor (A) and low-vigor (*B*) *Spartina alterniflora* and *Spartina patens* (*C*).

dicated that tidal inundation did not occur in these areas at all times. It was concluded that the low vigor *Spartina alterniflora* represented portions of the population which did not receive sufficient tidal flooding (i.e. were above mean high water) to provide all the nutrients required for vigorous growth. The high vigor and low vigor forms of *Spartina alterniflora* were, in most cases, easily distinguished on color IR film. The line of demarcation between the two forms was used to establish a mean high water line (Figure 1).

A more easily interpretable key for drawing the mean high-water (MHW) line was differentiating between *Spartina alterniflora* (high vigor) and *Spartina patens*. The latter species is known to grow almost exclusively above areas where frequent (daily) tidal inundation occurs. Tonal contrast between these two species was particularly sharp using infrared-color photographs. In this instance, the mean high-water line was interpreted as the boundary between *Spartina alterniflora* and *Spartina patens* (Figure 1).

HIGH TIDE BOUNDARY DETERMINATION: FRESHWATER-BRACKISH WETLANDS

Wetlands which occur in the upper tidal reaches of rivers (i.e., Mannington test site) are characterized by a wide variety of plant species. Many of these species occur below mean high water and can be used as indicators of daily tidal inundation. Species such as *Typha, Peltandra, Spartina alterniflora* and *Zizania* are almost unique to tide-influenced fresh-brackish water wetlands. In some instances, however, these species (with the exception of *Spartina alterniflora*) may occur in non-tidal areas along rivers where soil moisture is high. The definition of a MHW line may therefore be subject to slight errors for this reason. Furthermore, *Phragmites* will grow both below and well above the mean high-water line, obscuring useful (mappable) vegetative indicators and making definition of a line of mean high-water especially difficult.

UPPER WETLANDS BOUNDARY DETERMINATION

The upper boundary of wetlands occurs characteristically under three separate, definable types: (a) abruptly changing topography where both stereoscopic techniques and image tone may be used; (b) gradual change in topography where subtle vegetational changes must be interpreted, and (c) along man-made disturbances such as ditches, dikes and roads.

All three types were presented in the Mannington and Tuckerton test sites, and are discussed in detail below.

Abruptly changing topography. This type of upper wetland boundary was very common at both test sites. The change in relief varied from 1.5 to 9.0 feet. In all instances, vegetational changes were striking and contrasted well with the wetland vege-

FIG. 2. Portion of a cronapaque map produced for the New Jersey wetlands project.

tation. Only in areas obscured by shadows was the line difficult to interpret. Common dryland species bordering the wetland were Arrowwood, Cedar, Pine, and various hardwood trees such as Oak, Tulip, Poplar and Hickory.

Wetland species which occurred at the upper boundary varied considerably within each test site. Examples are: (a) *Spartina patens* growing up to a sharp rise in local relief; (b) *Spartina patens* in association with *Iva frutescens;* (c) *Baccharis halimifolia* in association with *Panicum virgatum;* (d) *Typha* species along the upland border; (e) *Phragmites* on the upland border, occasionally growing across the border into well defined dry land and onto roads.

Gradual change in topography. In localities where the transition from wetland to dryland was gradual, delineation of the boundary on aerial photographs was particularly difficult. Extensive field checking was required to draw the boundary to NJDEP specifications in these areas. In many instances the line was drawn on five-time photo enlargements by walking portions of the boundary. These data were then transferred to office (Cronaflex) work sheets.

Aerial photographic interpretation of the upland boundary was often difficult due to the gradual change in vegetation and poor tonal contrast between important indicator species on both color and infrared-color photographs. A part of this poor contrast was caused by the low sun angle at which the photographs were taken (the sun angle required by NJDEP).

Some of the typical intermixed plant species encountered along a transition from a wetland to a dryland habitat were:

- ☆ *Spartina patens, Juncus gerardi, Iva frutescens, Baccharis halimifolia, Panicum virgatum*, cedar and hardwood trees;
- ☆ *Spartina patens, Scirpus olneyi, Typha* species, red maple, willow, alder and hardwood trees.

Shadows cast by surrounding tree species also obscured what otherwise might have been good tonal signatures for key species.

MAJOR ASSOCIATIONS

For operational wetlands mapping, major species associations were interpreted as those natural groups of species indicative of a given environmental condition and occurring in areas of sufficient size to give a unique tone on aerial photographic film. The minimum-sized mappable unit was approximately five acres. Areas of less than five acres were mapped where points of reference were required in otherwise large areas of the same species association, or where significant ecological benefit might be realized for NJDEP by mapping smaller units.

Species associations were differentiated according to unique tones or combinations of tones on the aerial photographs. An understanding of regional biological and sedimentary dynamic features was also essential. The infrared-color photographs proved to be the most useful for this aspect of the mapping program.

A considerable amount of ecological information is available from observation of species associations within the test areas. For instance, the low vigor *Spartina alterniflora – Spartina patens* association in the ditched areas indicates a successional trend from *Spartina alterniflora* to the less desirable *Spartina patens.* Ditching and disposition of spoil on wetlands accelerates this *drying out* process in wetlands; ecological significance of this can be ascertained through careful analysis of the completed maps.

FIELD CHECKING

Although interpretation of the color-infrared aerial photographs provided 85–90 percent of the required wetlands biological data, supplementary (and selective) field checking was also undertaken. The most efficient procedure required the use of 36 × 48 inch black-and-white photographic enlargements made from original color-infrared transparencies. All field annotations were added to this enlargement. Original color-infrared photographs and polaroid prints were used for field checking of vegetative detail. Once field work was completed, field data was transferred to the 36 × 48-inch Cronaflex office copy from which final (master) maps were prepared.

State-operated helicopters were the most efficient method of field checking. They increased both the speed and accuracy of field checking. Areas otherwise inaccessible on foot could also be checked.

FINAL MAP PRODUCTS

Using color-infrared aerial photographs supplemented by color photographs and the techniques described above, 1:2,400 and 1:6,000-scale wetlands maps were prepared. Tax-map overlays and tax records to facilitate management of the wetlands areas were added. The maps were found to meet national map accuracy standards by the National Ocean Survey.

Summary and Conclusion

Twenty-one maps at 1:2400 scale were produced for the Tuckerton and Mannington Meadows site in a 105 day period. These maps were prepared using color-infrared and color aerial photographs, supplemented by biological field checking. Field checking by an independent party confirmed the accuracy of the approach.

Based on information gained from the pilot study, state-wide wetlands mapping using biological discrimination techniques can proceed using aerial survey methods.

Literature Cited

1. Anderson, R. R. 1970. Spectral Reflectance Characteristics and Automated Data Reduction Techniques Which Identify Wetland and Water Quality Conditions in the Chesapeake Bay. NASA, *Third Annual Earth Resources Program Review*, Vol II 53–1 to 53–29.

New Sustaining Members

R. W. Borrowdale Company

The R. W. Borrowdale Company, located on the Greater Chicago south side, was founded in 1947 as a designer and manufacturer of photomechanical equipment and has since become recognized as the leader in custom design of large, precision camera equipment for cartography and engineering. In 1971, in response to an obvious need in photogrammetric and cartographic reproduction, the Densitrol Division, located a special designed environmentally controlled area of the parent company plant, was founded to produce large contact screens and tints.

Densitrol tints are incomparable with control of values and an overall smoothness and freedom from defects which must be seen to be appreciated. Tints are available in sizes up to 48 × 60 inches, and in 10-percent step values as well as in values to the government standard printing screen system adopted by the Department of Defense for its Mapping, Charting and Geodesy (DOD-MC&G) agencies.

Contact screens are being produced in sizes up to 48 by 60 inches and in nine different types. Screens are available in magenta and gray, positive and negative values, and conventional and elliptical types. A special screen is being produced and is recommended for photogrammetry to insure the maximum detail in halftones. The screen is of the gray type (which is highly resistant to stains and damage), the range is slightly greater than the usual positive screen (for greater detail), and in elliptical dot (to eliminate middletone shift). A 9×11-inch sample screen is available on request.

The Borrowdale Company manufactures camera equipment in both overhead and low-bed designs, copyboards in sizes from 30×40 inches to as large as 60×144 inches in either horizontal loading with vacuum or in the vertical loading transuction type, basic back-case sizes from 16×20 inches to 48×60 inches, plus extension cameras from 40×50 inches to 60×144 inches.

In addition, a wide variety of accessory equipment is available. For instance, a choice of drive and calibration systems are offered on any Borrowdale camera from a fast cable drive with percentage tapes—to V-block systems—to micrometer re-registration—to an optical readout device direct reading to 0.001 inch over the full camera range with a National Bureau of Standards lens focal length certification. A dual-speed electric screw drive is also available with direct-reading verniers to 0.001 inch or a new digital readout system.