COMPARATIVE UTILITY OF LANDSAT-1 AND SKYLAB DATA FOR COASTAL WETLAND MAPPING AND ECOLOGICAL STUDIES

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By Richard Anderson, Biology Department, The American University, Washington, D.C.
Linda Alsid, Biology Department, The American University, Washington, D.C.
Virginia Carter, U.S. Geological Survey, Reston, Virginia

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ABSTRACT

There are a variety of remotely sensed data and analysis methods currently available for application to wetland mapping and ecological studies. The most widely used techniques involve color and color infrared photography from low altitude (1830 M) aircraft. These techniques, while giving a high degree of accuracy, are time consuming, expensive, and have to be used on a piecemeal long term basis by some states. Less expensive methods which retain relative accuracy and detail would be an attractive near term alternative. Skylab 190-A photography and LANDSAT-1 analog data have been analyzed to determine coastal wetland mapping potential as a near term substitute for aircraft data and a long term monitoring tool. The level of detail and accuracy of each was compared. Skylab data provides more accurate classification of wetland types, better delineation of freshwater marshes and more detailed analysis of drainage patterns. LANDSAT-1 analog data are useful for general classification, boundary definition and monitoring of human impact in wetlands.

INTRODUCTION

Wetlands, especially salt marshes, play a primary role in estuarine productivity, providing food and shelter not only for organisms naturally inhabiting the wetlands, but also for the many organisms which spend all or part of their lives in the waters of the adjacent estuary or shallow ocean. Salt marshes are vitally necessary to the maintenance of virtually all major shallow salt water fish and shellfish populations.

During the last five years a clear need has been established for development of a rapid, relatively low cost method for mapping and monitoring coastal wetlands. This period has been one of unprecedented activity by state governments to preserve this sensitive and threatened part of the aquatic ecosystem. Laws regulating the types of activity in wetlands have been passed in almost all Atlantic coastal states. To implement this wetland legislation, practical methods are needed for mapping and evaluation of coastal wetlands.

With the launch of LANDSAT-1 and Skylab, relatively high resolution satellite data became routinely available for the investigation of earth resources. The research described in this paper was initiated to determine the feasibility of using LANDSAT-1 and Skylab data for investigations of coastal wetland ecology and to monitor and map coastal wetlands.

Test Areas for LANDSAT-1 and Skylab Studies

Due to the wide range of environmental conditions along the Atlantic Coast, two test areas were selected for study; one representing northern type coastal wetlands in the

Chesapeake Bay, Maryland, and Chincoteague Bay, Virginia, and one representing southern type coastal wetlands in South Carolina and Georgia. Lack of usable Skylab data over the southern test area prevented comparison with LANDSAT data; therefore, only the northern area will be discussed.

Two sites were selected for intensive study. Site 1 is a large, near-saline marsh at the mouth of the Nanticoke River in Dorchester County, Maryland. Site 2 is a salt marsh complex located at the mouth of the Chincoteague Bay in Virginia. The tidal range is about 1 meter.

The frequently inundated saline and near-saline marshes in the Chesapeake Bay area contain many of the same species found in the southern marshes (i.e., Spartina alterniflora, Spartina patens, Juncus roemerianus, etc.). However, these species seldom grow to heights comparable to those achieved in southern marshes and consequently, estimates of their primary productivity are lower (Keefe and Boynton, 1972). This is probably because of a shorter growing season and generally cooler air and water temperatures.

METHODS AND MATERIALS FOR DATA ANALYSIS

A variety of methods for satellite data analysis were tested and evaluated. These include both visual and automated interpretation techniques. The authors are particularly indebted to the NASA aircraft support programs operated from Ames Research Center, California, and Johnson Space Flight Center, Texas, and the Wallops Research Station, Virginia. Underflight data have been invaluable as aids in interpretation of the satellite data.

Prior to and during the time of receipt of satellite data, aircraft color infrared photographs of the test site were visually analyzed to identify boundaries, plant communities and disturbed areas. Preliminary interpretations were made using LANDSAT-1 analog and Skylab photographic data. Field trips were made to determine accuracy of laboratory interpretation.

To facilitate interpretation of grey levels and color tones on the satellite data, a considerable amount of data were gathered on the spectral reflectance characteristics of important wetland features; an ISCO field Spectroradiometer was used to obtain this information at 0.025 micrometer intervals between 0.4 and 0.75 micrometers and at 0.050 intervals between 0.75 and 1.350 micrometers. Figure 1 shows seasonal reflectance curves for some wetland features keyed to LANDSAT MSS band 7 (0.8 - 1.1 micrometers). These data were also used in the development of techniques for analysis of LANDSAT digital data.

RESULTS

A. LANDSAT-1

1. Plant species identification and wetland classification.- MSS bands 6 and 7 were found to be the most useful for wetlands interpretation.

Coastal saline and brackish marshes generally appear as a dark grey tone near the dense end of the scale on LANDSAT MSS band 6 and 7 images, and as a dark red-grey in a color infrared simulation (color composite) during the growing season. This is largely because the spectral reflectance of the dominant species, or species association, is generally low in MSS bands 6 and 7. These species include Spartina alterniflora (salt marsh cordgrass), Salicornia spp. (glasswort), and Juncus roemerianus (needlerush). In MSS bands 4 and 5, all marsh species have a low overall average reflectance, usually appearing less dark in tone than dryland vegetation and darker than spoil or agricultural fields with or without crops. Where the coastal marshes become fresher, the spectral reflectance of the species compositions is higher in the infrared region of the spectrum and the plant cover is generally denser. During the peak of the growing season, it is difficult to determine the landward boundaries of these fresh marshes.

The general vegetative composition of the test sites is typical of near-saline to slightly brackish tidal marshes of the Central Atlantic coast. The areal extent of plant communities range from small to very large.

A vegetation map (Figure 2) was produced from the 7 July 1973 MSS 7 (# 1349-15134) and the 30 August 1973 MSS 7 (# 1403-15124) images. Two different dates were used in order to evaluate the tidal differences. The imagery was placed in a Bessler enlarger and tonal patterns traced by hand. The general categories identified are listed in order of decreasing reflectivity: tree island, high marsh, low marsh, low marsh/water and water. The high marsh includes those plant species and communities which are generally found above mean high water. The vegetation is usually dense with little background reflectance and soil moisture. The high marsh category is more reflective and images lighter on MSS band 7 than other marsh categories. This category is made up of varying amounts of Spartina cynosuroides, Spartina patens/Distichlis spicata association, Iva frutescens, Baccharis halimifolia, and Phragmites communis.

Low marsh covers the greatest area within the test site, and is composed mostly of large stands of Juncus roemerianus. Other species of the low marsh category, Scirpus spp., may be found in homogeneous stands but are predominantly seen in large mixed plant communities. Juncus stands were indistinguishable from Scirpus stands or mixed Juncus and Scirpus communities.

Low marsh/water contains shorter Juncus and Scirpus stands, or areas with sparse plant cover which exhibit a very low reflectance in MSS band 7 due to the water background. In many instances it is impossible to determine the interior low marsh/water interface using satellite data.

High and low marsh patterns on the LANDSAT imagery are more distinct in summer than winter, due to the greater differences in reflectance of growing vegetation. Seasonal development or change within the high marsh category can be distinguished by comparing the spring and summer imagery. Increases in reflectance are especially noticeable in the areas bordering streams and water bodies of the marsh interior in MSS 7.

An attempt was made to determine the applicability of LANDSAT data for coastal wetland typing or classification. A wetland classification system based on satellite data would be useful for making and updating coastal inventories. Shaw & Fredine, 1956, suggested classification of coastal marshes into the following types on the basis of vegetation and inundation:

Type 12 - coastal shallow fresh marshes
Type 13 - coastal deep fresh marshes
Type 14 - coastal open fresh water
Type 15 - coastal salt flats
Type 16 - coastal salt meadows
Type 17 - irregularly flooded salt marshes
Type 18 - regularly flooded salt marshes
Type 19 - sounds and bays

Some of these categories can be differentiated using LANDSAT imagery. The differentiation is based largely on the reflectance differences of indicator species [e.g., Spartina alterniflora (Type 18), Juncus roemerianus (Type 17) or Spartina patens (Type 16)]. Although LANDSAT cannot be used to ascertain water depth, Type 14 and Type 19 which are based on water depth could be classified by using available bathymetric data in conjunction with areas of water detected with LANDSAT data. We have not successfully differentiated Type 12, 13, or 15 with LANDSAT images.

2. Monitoring of wetlands for natural or man-made reductions in productivity.- Natural reductions in productivity due to successional trends (e.g., wetland to dryland) must be ascertained over longer periods of time than this study permitted. Repetitive LANDSAT data will be particularly useful for this purpose.

The most useful short term use will be in monitoring dredge, fill and drainage activities in wetlands.

B. Skylab

Color infrared photography was found to be the best data form for wetland studies. Tonal contrast, expressed as variations of color, was found to be the most important recognition element in interpreting the color IR photographs. Texture, the frequency of color change, was also an important interpretive factor in certain areas. The September photography was superior to that taken in June for delineating the upper marsh boundary. The marsh-water interface, especially in small drainage channels, is also more easily identified in September because of reduced vegetation cover.

Tonal contrast and image sharpness within the marshes were of sufficient detail to allow delineation of five wetland classes. This was especially true of the June photography where certain individual species were easily identified by their characteristic colors.

To differentiate the wetland classes found in the test area, a wetlands classification system was developed. It is basically a synthesis of systems previously used by Nicholson and Van Deusen and Stewart modified by observations of marsh structure and composition in the field and the discrimination capability of the Skylab photography. The five major vegetation categories are:

Type I, Fresh estuarine river marsh.- Dominated by fresh water vegetation located along the upper reaches of tidal rivers and streams where water salinity ranges from fresh to slightly brackish, large areas of open water may be covered with Nymphaea odorata (white water lily). Broad leaf emergents, Pontederia cordata (pickerel weed), Peltandra virginica (arrow arum), and Nuphar advena (spatterdock), occupy the water edge. Shallower interior areas are characterized by a wide diversity of herbaceous vegetation which varies with area and season.

Because of the complex mixing of many diverse species within Type I wetlands, the appearance on the photography is one of homogeneity, with little internal tone contrast and a uniform texture. However, large, nearly pure stands of Phragmites communis (reed) and Typha spp. (cattail) occur and have been identified using the June photography. Phragmites is characterized by a bright pink color and rosette pattern; Typha spp. appear in the deepest shade of red. Nymphaea odorata, which exhibits a white tone and obscures the water surface, can also be discerned.

Type II, Brackish estuarine river marsh.- As salinity increases downstream, the Type I wetlands are gradually replaced by plant communities more tolerant of brackish water. Tidal fluctuation is regular and usually greater toward the river mouth. The marsh area may be large and heavily dissected by drainage creeks. This is perhaps the most complex category and most difficult to define. Many of the fresh water species listed as Type I vegetation extend into the brackish areas, and there is no distinct boundary between the two types. Typically, broad leaf emergents at the water edge are replaced by Spartina cynosuroides (big cordgrass), which also occurs in large stands in the interior marsh. Other brackish dominants include Scirpus olneyi (Olney three-square), Typha angustifolia (narrow-leaf cattail), Spartina patens (salt meadow cordgrass), and Distichlis spicata (saltgrass).

Type III, Fresh estuarine bay marsh.- Estuarine systems such as the upper Blackwater River may flow through a broad, shallow, permanently submerged flats. Salinity ranges from slightly to moderately brackish and tidal fluctuation is usually slight and irregular.

Scirpus olneyi, occurring in large pure stands, dominates this class in the test area. A mixture of Scirpus olneyi and Typha angustifolia is found in fresher water areas, and a zone of Panicum virgatum or Spartina patens occupies higher elevations at the upper marsh boundary.

Because of the complete dominance of Scirpus olneyi, this category appears as a rather homogeneous area on both the June and September photography. Large, shallow, irregular ponds and sparsely-vegetated mudflats in combination with the low reflectance of Scirpus olneyi make this the most difficult area in which to delineate accurately the marsh-water interface.

Type IV, Brackish estuarine bay marsh.- This class differs vegetationally from Type III because of higher water salinity. Scirpus olneyi, Juncus roemerianus (needlerush), and Spartina patens provide the dominant vegetative cover. Scirpus olneyi is found in low, poorly drained areas; Juncus roemerianus becomes established in low areas with sandy soils; and Spartina patens occupies higher elevations. Spartina alterniflora is common where tidal fluctuation is the most regular, and homogeneous stands of Typha spp. are often found along the upper marsh boundary. This marsh class exhibited the greatest variations of color of all classes, and had a distinctive texture.

Type V, Near saline marsh.- This class occurs near the open water of Chesapeake Bay. The water is moderately brackish to near-saline and species diversity is reduced. The marsh pattern is formed by extensive, pure stands of Juncus roemerianus and large meadows composed of Spartina patens and Distichlis spicata. At the highest elevations, patches of Iva frutescens and Baccharis halimifolia are found, and Spartina alterniflora occupies the narrow intertidal zone along creeks and streams.

Wetland maps were prepared at a 1:125,000 scale by making a direct overlay on the S190A enlarged color IR transparencies (June and September). The wetland maps depict the five categories as well as the boundary between marsh and upland or marsh and wooded swamp (upper marsh boundary) and the marsh-water interface (Figs. 2 and 3).

2. Monitoring natural and man-made reductions in primary productivity: Skylab is basically not a monitoring tool due to the short term duration of the missions. Due to the higher resolution of Skylab photography, dredge and fill projects of less than one acre may be observed. Also mosquito ditches are resolved and vegetational changes which accompany them.

DISCUSSION AND CONCLUSIONS

Wetland mapping and monitoring presents both a near and a long term problem. Maps showing boundaries and classes of wetlands are urgently needed by many states as baseline

information to begin management and preservation programs. Longer term, repetitive data are also necessary for monitoring of reductions in wetland acreage due to human activities or natural successional processes. High resolution, photographic data from Skylab provides the best information for detailed wetland mapping. LANDSAT analog data have been shown to be an excellent tool for mapping large area coastal wetland communities and monitoring changes in wetland habitat, particularly those associated with human activities.

Wetland maps produced from LANDSAT analog and Skylab 190-A photographic data of the Nanticoke test site were compared (see Fig. 2). The following generalizations apply:

1. **With regard to classification, a more detailed system may be used with Skylab data (5 classes as opposed to 3 for LANDSAT).**

2. **Freshwater marshes may be delineated with Skylab but not LANDSAT.**

3. **Drainage patterns may be mapped in more detail with Skylab.**

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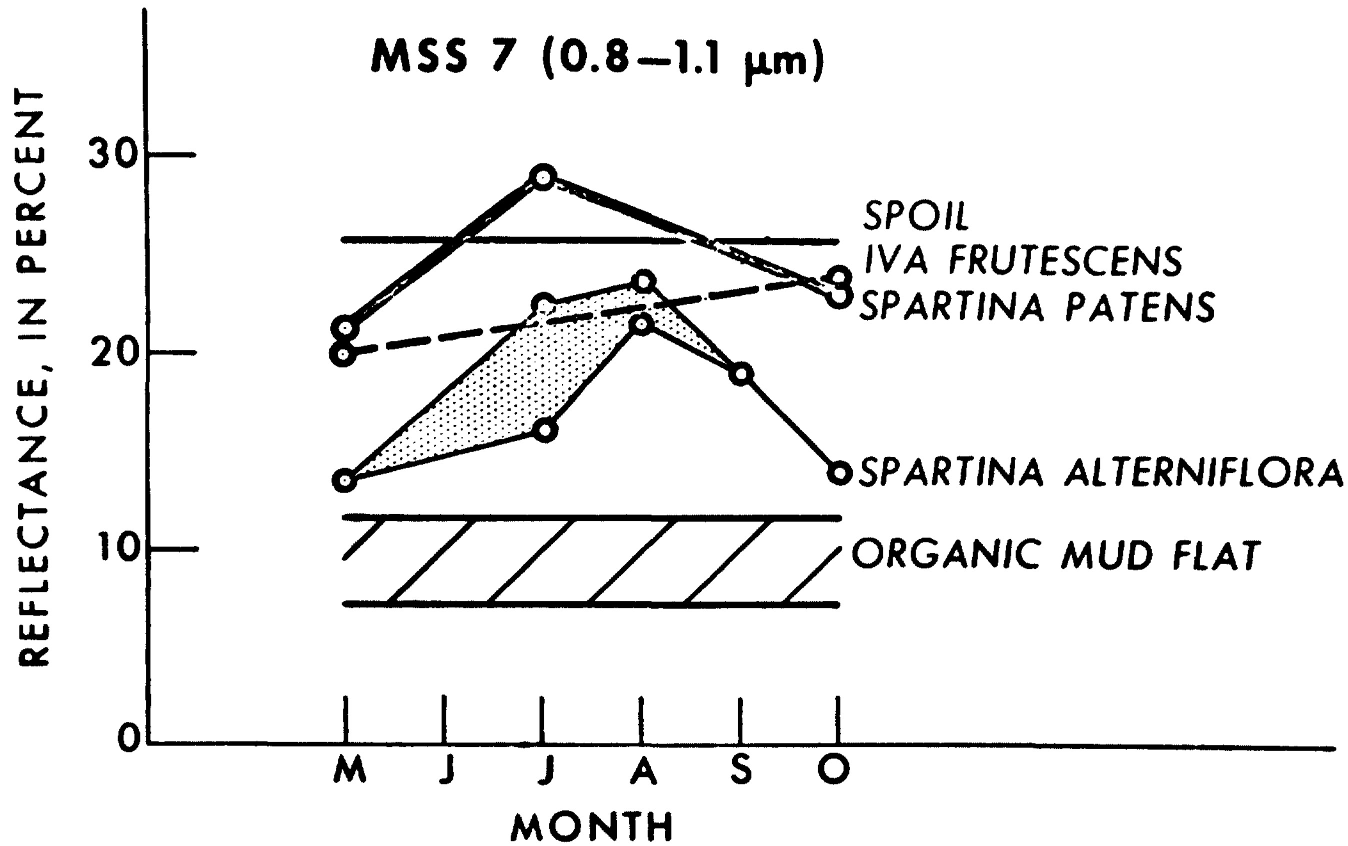
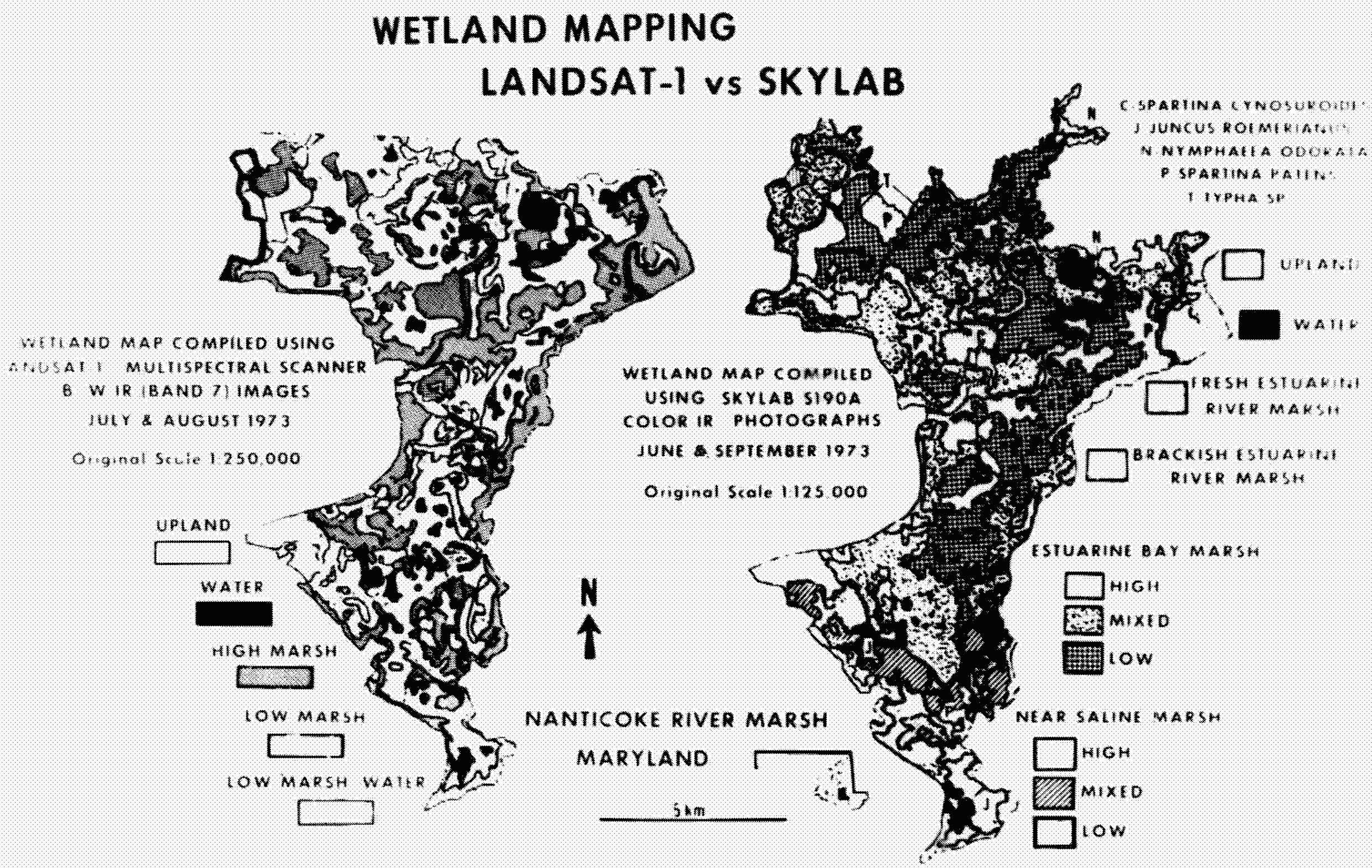


REFLECTANCE OF WETLAND CLASSES—MSS 7

Figure 1



WETLAND MAPPING
LANDSAT-1 vs SKYLAB
C SPARTINA CYNOSUROIDES
J JUNCUS ROEMERIANUS
N NYMPHAEA ODORATA
P SPARTINA PATENS
T TYPHA SP
UPLAND
WATER
FRESH ESTUARINE RIVER MARSH
BRACKISH ESTUARINE RIVER MARSH
ESTUARINE BAY MARSH
HIGH
MIXED
LOW
NEAR SALINE MARSH
HIGH
MIXED
LOW
WETLAND MAP COMPILED USING LANDSAT-1 MULTISPECTRAL SCANNER B W IR (BAND 7) IMAGES
JULY & AUGUST 1973
Original Scale 1:250,000
UPLAND
WATER
HIGH MARSH
LOW MARSH
LOW MARSH WATER
WETLAND MAP COMPILED USING SKYLAB S190A COLOR IR PHOTOGRAPHS
JUNE & SEPTEMBER 1973
Original Scale 1:125,000
N
NANTICOKE RIVER MARSH
MARYLAND
5km

Figure 2

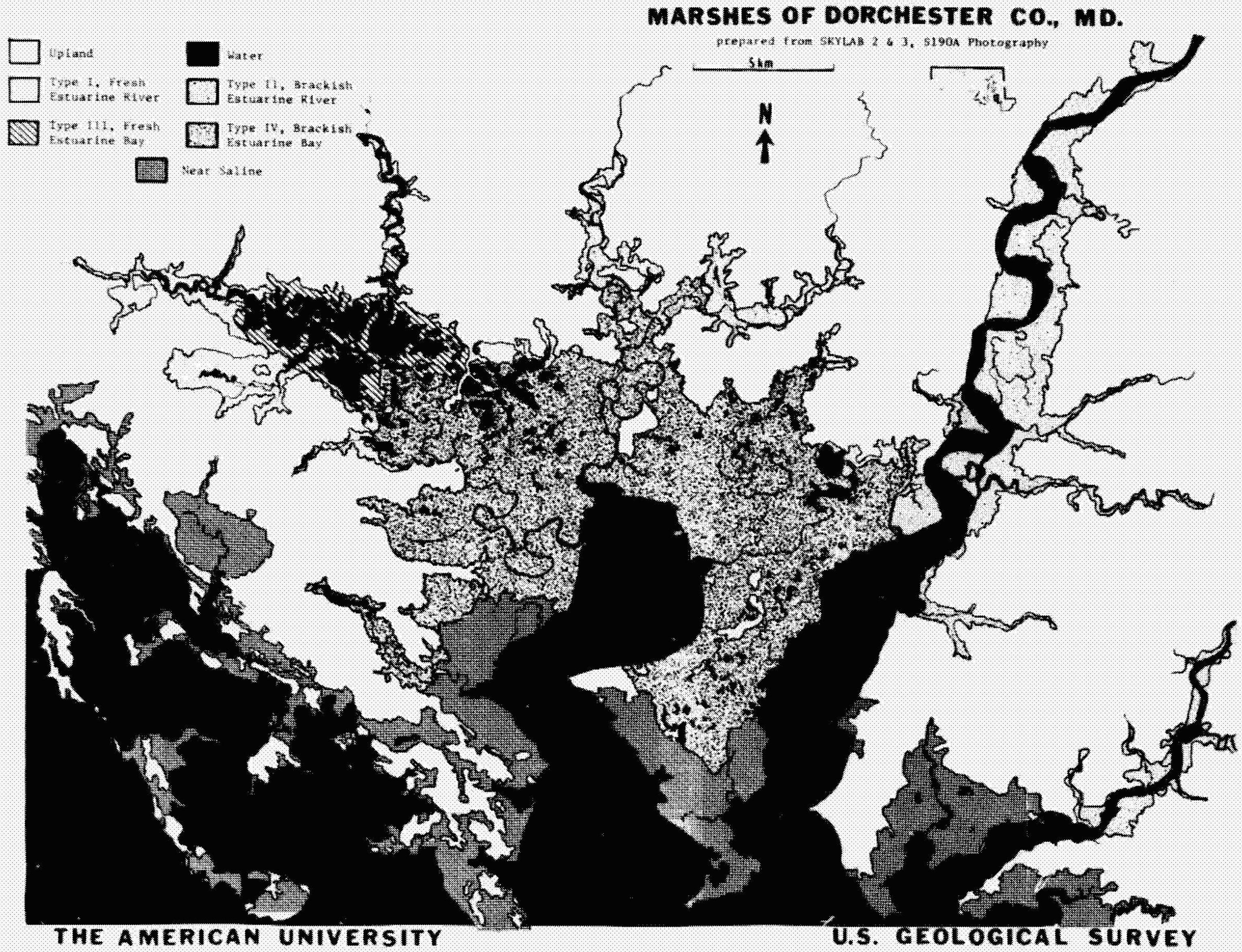

MARSHES OF DORCHESTER CO., MD.
prepared from SKYLAB 2 & 3, S190A Photography
5km
N
Upland
Water
Type I, Fresh Estuarine River
Type II, Brackish Estuarine River
Type III, Fresh Estuarine Bay
Type IV, Brackish Estuarine Bay
Near Saline
THE AMERICAN UNIVERSITY
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Figure 3