Use of Aerial Photographs to Measure the Historical Areal Extent of Lake Erie Coastal Wetlands

John Grimson Lyon
Department of Civil Engineering, The Ohio State University, Columbus, OH 43210-1275
Richard G. Greene
Department of Civil Engineering, Louisiana State University, Baton Rouge, LA 70803

ABSTRACT: Aerial photographs were used to measure historical areas of wetlands at Pointe Mouillee in Monroe County, Michigan, and these results were compared with Lake Erie water levels. Measurements indicated a decrease of 836.4 hectares in total wetlands between 1935 and 1980. This was a reduction of 80 percent in the total area of wetlands that existed previous to the 1940 period. The majority of wetland losses occurred between 1940 and 1950, and may be partially attributed to the construction of dams across the Huron River prior to 1950. The dams presumably trapped sediment that may have created and maintained the deltaic wetlands and beach barrier of the Pointe Mouillee area. After losses of 1940 to 1950, wetlands area varied inversely with water levels. Regression of total wetlands and water levels between 1950 and 1980 demonstrated an inverse relationship, with a coefficient of determination (R^2) of 0.8722. This result is similar to conditions found in other Great Lakes areas.

INTRODUCTION

GREAT LAKES WETLANDS HAVE CHANGED IN area over recent time. The change results from a variety of conditions that include fluctuating water levels, storms, filling, and other causes. Parties interested in this resource have raised questions concerning the natural variation of coastal wetlands and resultant losses. While there are many questions, only a few studies (Harris *et al.*, 1981; Lyon *et al.*, 1986; Bukata *et al.*, 1987) have sought to answer some of these concerns. Previous work has been localized, as compared to the size of the lakes, and conditions in other Great Lakes need to be addressed.

To better understand and measure natural variation of Lake Erie wetlands, we evaluated their historical area and distribution from aerial photos and maps. The Pointe Mouillee area provided a good opportunity for study due to the large number of wetlands. The objectives were to (1) quantify change over time and evaluate probable causes of change in wetlands, and (2) use the measurements to develop a model of wetland area versus water levels.

METHODOLOGY

This study investigated the Huron River delta (Figures 1 and 2a), which includes Pointe Mouillee wetlands, and is located along the western shore of Lake Erie. The effort involved measurements of wetlands from eleven dates of aerial photos and comparisons of results with Lake Erie water level records.

Black-and-white aerial photographs were acquired at various scales and times of the year from the National Archives and Record Service, Agricultural Stabilization and Conservation Service, U. S. Army Corps of Engineers, and the U. S. Geological Survey (Table 1).

Wetland boundaries were interpreted from aerial photographs using photo interpretation. Boundaries of polygons were traced onto mylar using a 0.3-mm drafting pencil (Pentel, Japan). Interpretations were completed with the assistance of an MS-1 mirror stereoscope (Q-0-S Corp., N.Y.), an ODSS III Old Delft Scanning stereoscope (Old Delft, The Netherlands), a PS-2a pocket stereo viewer (Air Photo Supply, N.Y.), and a light table. Area determinations were made using a polar planimeter

TABLE 1. AERIAL PHOTO SCALE, AND TOTAL WETLANDS AND CHANGE IN WETLANDS IN RELATION TO AVERAGE DAILY WATER LEVEL

Date	Actual Photo Scale	Average Daily Water Level (Metres)	Wetland Area (Hectares)	Change in Water Level from Previous Date (Metres)	Change in Wetlands Area from Previous Date (Hectares)
05 to 08-35*	1/30,162	173.38	1,043.2	–	–
07-37-37	1/20,824	174.00	1,011.2	+0.62	−32.0
09-28-40	1/20,244	173.83	1,079.6	−0.17	+68.4
10-16-50	1/20,064	173.92	448.5	+0.09	−631.1
11-05-55	1/20,721	173.87	495.6	−0.05	+47.1
05-16-57	1/16,465	174.11	335.7	+0.24	−159.9
05-27-64	1/20,556	173.68	596.3	−0.43	+240.6
07-01-72	1/31,600	174.53	238.2	+0.85	−338.1
08-11-73	1/41,605	174.68	266.6	+0.15	+28.4
07-17-78	1/24,130	174.38	212.7	−0.30	−53.9
06-11-80	1/24,771	174.55	206.8	+0.17	−5.9

* It was impossible to determine exact day or month of the 1935 photograph. Hence, the summer season average of monthly water levels was used for comparison (annual average water level was 173.22m)

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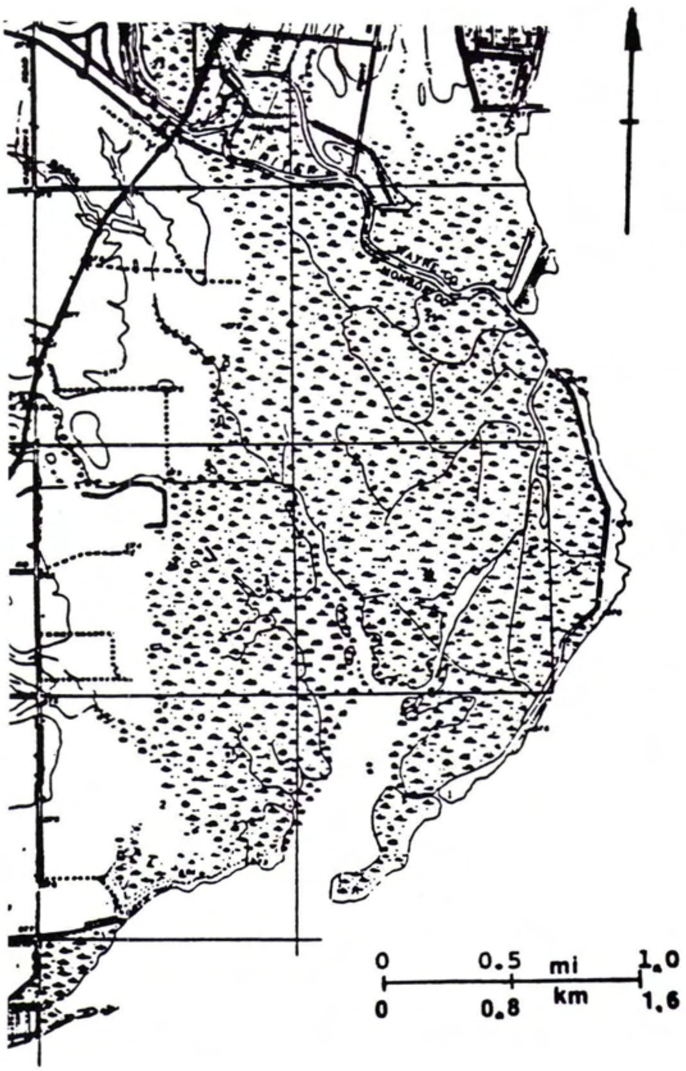


FIG. 1. U.S. Geological Survey map of the Pointe Mouillee area from 1942. The area is in the western basin of Lake Erie. Original map scale was 1:62,500.

(Keuffel and Esser Co., N.Y.). Areas of wetlands were compared to water levels using standard statistical techniques.

The planimeter was calibrated by evaluating the perimeter of a carefully selected square of 161.29 sq cm in area (12.7 cm on the side, with diagonals of 18.0 cm). From the number of units obtained for that square area, the exact value, in sq cm, of one unit was determined for the particular setting of the planimeter. The value of one unit was multiplied by the number of units obtained for the total wetlands for each date of photographs. The results were converted into area units (ha) based on the actual scale of photographs.

Care was taken to minimize errors associated with the planimeter. Some of the precautions included (1) use of the same type of paper and surface for calibration and measurement, (2) use of a large sheet of paper so that the planimeter drum did not roll off the paper, (3) checking the planimeter calibration at regular intervals, and (4) measurement of the wetland areas at least three times using different initial settings for the planimeter. For example, the result of three measurements for a given wetland area had a mean of 22.33 wetland units and a standard deviation of 0.58, indicating good precision of measurement.

Historic water level data were obtained from the U. S. Department of Commerce (1978) or from records at the Detroit District of the U. S. Army Corps of Engineers. The gauges at Gibralter, Michigan, and Toledo, Ohio, were used for analyses as their records spanned the entire duration of the study. All water level data were referenced to the International Great Lakes Datum of 1955 (Table 1), and daily levels were employed for analysis.

Wetland boundaries were interpreted from aerial photographs using photo interpretation techniques (Lyon and Drobney, 1984; Schloesser *et al.*, 1988). Wetland boundaries were interpreted from the photos (Table 1) and annotated on transparent overlays. The area of wetlands was measured from the overlays using a planimeter.

The actual scales were determined by comparison of the photo distance with the corresponding map distance and scale. This comparison can be expressed by the following relationship. Photo Scale = (Photo distance/Map distance) * Map Scale. The actual photo scale used was a mean of three separate photo scale measurements for each photograph.

As presented in Table 1, the actual scale of photographs used in this study ranged from 1:16,465 to 1:41,605. By using several sets of photographs, any variability due to difference in scale was minimized. In addition, the comparison of photographs at approximately similar water level and/or approximately similar scale had little or no effect on the interpretation of wetlands. For instance, a comparison of 1972 and 1980 photographs, which were taken at approximately similar water levels, showed that there was little difference in the amount of wetlands measured. This occurred in spite of a large difference in scale. Similarly, a comparison of 1950 and 1955 photographs, which were taken at approximately similar scales and water levels, indicated only a small difference in total wetlands.

Wetland classes were defined according to Cowardin et al. (1979), and they included emergent wetlands (EM), aquatic beds (AB), unconsolidated shore (US), and shrub/scrub (SS) types. These types were identified and their sum areas were totaled and reported as wetlands. The emergent wetlands were the most abundant and were typical of the Detroit River and Lake Erie vegetation plant communities. Plant species included cattail, bulrush, pondweed, reed grass, and shrub/scrub plant communities.

Uplands (U) and wetlands outside the study area were all excluded from the analysis. In addition, the diked marsh that is the Pointe Mouillee Game Management area was not included in the totals because the hydrology had been managed for waterfowl habitat since the mid-1960s and we sought to address only undiked wetlands influenced by Lake Erie and Huron River hydrology.

Cowardin *et al.* (1979) defined the wetland-upland boundary as a division between lands that are flooded and are not flooded, respectively, during years of normal precipitation or water level. To a certain extent, upland boundary locations are unaffected by changes in water level in the Great Lakes. This boundary stability results from human activities including drainage and filling. Interpretation of aerial photos showed little change in these upland boundaries in the Pointe Mouillee area over 45 years. Hence, for this study, the upland boundaries were fixed to (a) follow the Cowardin *et al.* definition and (b) facilitate year-to-year comparisons of change in wetland area by completing wetland area measurements within the same boundaries.

RESULTS

This investigation determined that there was an overall decrease of 836.4 ha in total wetlands between 1935 and 1980

(Table 1). This was an 80 percent reduction in total wetlands area over the historical 1.17-m range in water level. Most of this loss (631.1 ha) occurred between 1940 and 1950 (Figures 2 and 3).

Previous studies of wetlands and beaches along the Great Lakes (Lyon, 1981; Lyon and Drobney, 1984; Whillans, 1985; Lyon *et al.*, 1986) showed that the effect of the fluctuation of water levels on wetlands can be represented by a linear regression model. This approach was a focus of this experiment, and a regression of all 11 dates of photographs resulted in a coefficient of determination (R^2) of 0.5777 and a significance of $p<0.0118$ (Greene, 1987). The equation was $Y = -366.43 \times + 690{,}021.03$, where x was water level in metres and Y was area in ha.

The low, but significant, R^2 value indicated that several factors were probably involved in the change in total area of wetlands between 1935 and 1980. The water levels found for 1935, 1937, and 1940 were similar to the water levels found for 1950, 1955, and 1964. However, the areas of wetlands in 1935, 1937, and 1940 were more than twice that present in later years (Table 1). This information was evidence that additional factors may be involved. This result argued for a different approach to analysis which may separate the influence of causative factors.

The data were stratified to exclude wetland measurements for 1935, 1937, and 1940, and additional regression analyses were performed. The basis for the stratifications was the hypothesis that there was a one-time, permanent loss of wetlands. Presumably, such a loss was due to the over-topping and destruction of the lakeward, sand, or beach barrier called Pointe Mouillee.

The regression of the remaining eight dates of aerial photographs (1950 through 1980) resulted in a coefficient of determination or $R^2 = 0.8722$, which was significant at the level of $p<0.0008$ ($Y = -203.15 \times + 383{,}123.33$). Clearly, there was a strong, inverse relationship between total wetlands and water levels between 1950 and 1980. This result is similar to those results found in several other studies addressing wetlands in the Great Lakes system (Lyon *et al.*, 1986; Williams and Lyon, 1991).

To further establish that a pre-1950 historical loss had indeed occurred, we examined historical descriptions of the area (Larson, 1981) and USGS topographic maps. Measurements from historical USGS maps indicated that there were approximately 764.2 ha of wetlands in 1906 and about 779.3 ha in 1942. Results obtained from the 1935, 1937, and 1940 aerial photographs were comparable but less in area than those measured from 1906 and 1942 USGS topographic map sheets (Figure 1). The area of wetlands shown on the 1906 and 1942 USGS maps was significantly greater than that obtained from aerial photographs for the period 1950 to 1980. The map results provide a separate or verification evaluation of the results reported here, that larger areas of wetlands existed in the past, and that a permanent loss had really occurred.

DISCUSSION

The area studied was once bordered by the Pointe Mouillee beach barrier (US) on the lakeward side of the emergent (EM) wetlands (USACE, 1974). The sandy beach barrier had historically protected the Huron River delta wetlands from wave action and over-topping during storms (Larson, 1981). The construction of eleven dams on the Huron River (1912-1927) preceded the loss of wetlands (Table 2). Presumably, the dams have trapped and reduced sediment loads carried by the river (Greene, 1987), and, therefore, reduced its ability to create or replenish the delta wetlands and Pointe Mouillee beach barrier (USACE, 1974; GLBC, 1975; USACE, 1984). These and other factors have made the former beach barrier and wetlands at Pointe Mouillee more susceptible to erosional affects of wave action. Loss of the beach barrier circa 1940 to 1950 resulted in a general decrease in the relatively lower elevation wetlands behind the barrier.

TABLE 2. CHARACTERISTICS OF HURON RIVER DAMS*

Name	Approximate Date of Construction	Surface Area (Hectares)
Flat Rock	1920–1923	small
French Landing (Belleville Lake)	1925	577
Ford Lake	1932	425
Superior	1914–1919	44
Geddes	1913–1919	118
Argo	1913	43
Barton	1913–1915	126
Peninsula Paper	1914–1918	29
John Flook (Portage Lake)	1965–1967	210
Kent Lake	1946–1950	486
Milford	1939	small

* Information from the U.S. Fish and Wildlife Service, Michigan NDR (Engineering and Water Divison), and Huron River Water Council files; construction dates vary by sources. Dams are listed in order from the mouth (Flat Rock is approximately 20 km from the mouth; Milford is approximately 167 km from the mouth). After Greene, 1987.

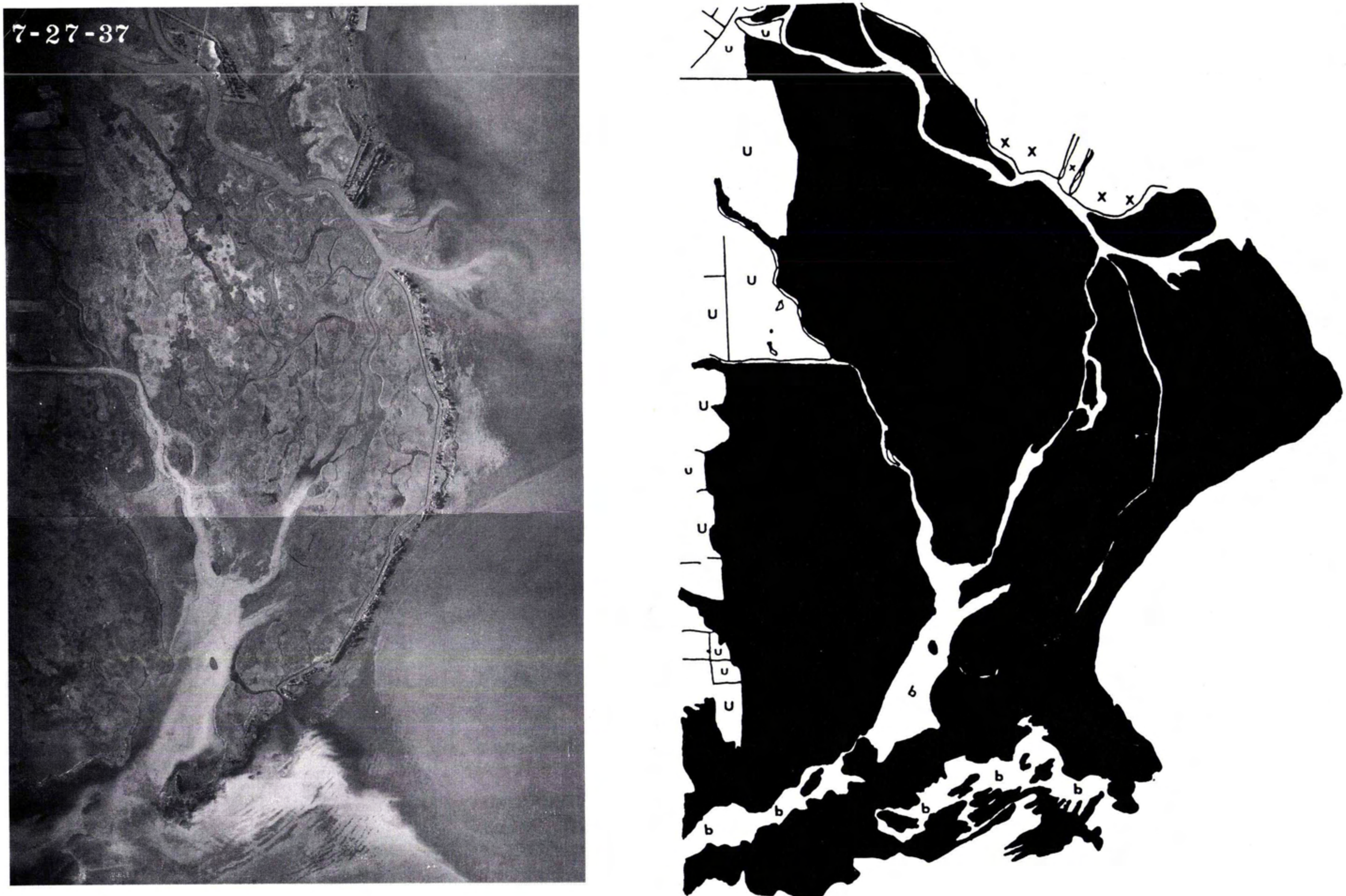
This mechanism of loss of wetlands due to destruction of the beach sand barrier is a well-known phenomenon of coastal processes. Indeed, a similar loss of wetlands behind the Woodtick Peninsula, 30 km south on the Lake Erie shore, was recorded. This change was postulated to have occurred due to capture and loss of beach "nourishing" sands deposited by littoral drift (Jaworski *et al.*, 1979; USACE, 1985). The same phenomenon caused the destruction of beach barrier and back-barrier wetlands at Sheldon's Marsh (Robb, 1989), near Cedar Point, Ohio, on Lake Erie. These results are also consistent with observations of other investigators (McDonald, 1955; Jaworski *et al.*, 1979).

Since the loss of 1940-1950, the remaining area of wetlands has fluctuated in an inverse relationship with water level. This condition has been demonstrated to be characteristic of large wetland areas in a number of Great Lake areas (Jaworski *et al.*, 1979; Harris *et al.*, 1981; Lyon, 1981; Lyon *et al.*, 1986; Bukata *et al.*, 1987).

This methodology and results are important for a number of reasons. Currently, little information is available on the area of wetlands and its variability over time. This is a good approach to supply detail necessary to answer vital questions. Studies that have been done often used a few photos; such an approach would have missed the timing of the loss of wetlands at Pointe Mouillee.

The result of this project is significant for understanding Great Lakes wetlands. The Lakes experience this fluctuation in areas, and many folks have theories for cause and effect. The analysis of multiple dates of aerial photos allows for quantitative analysis, and brings hard facts to the discussion.

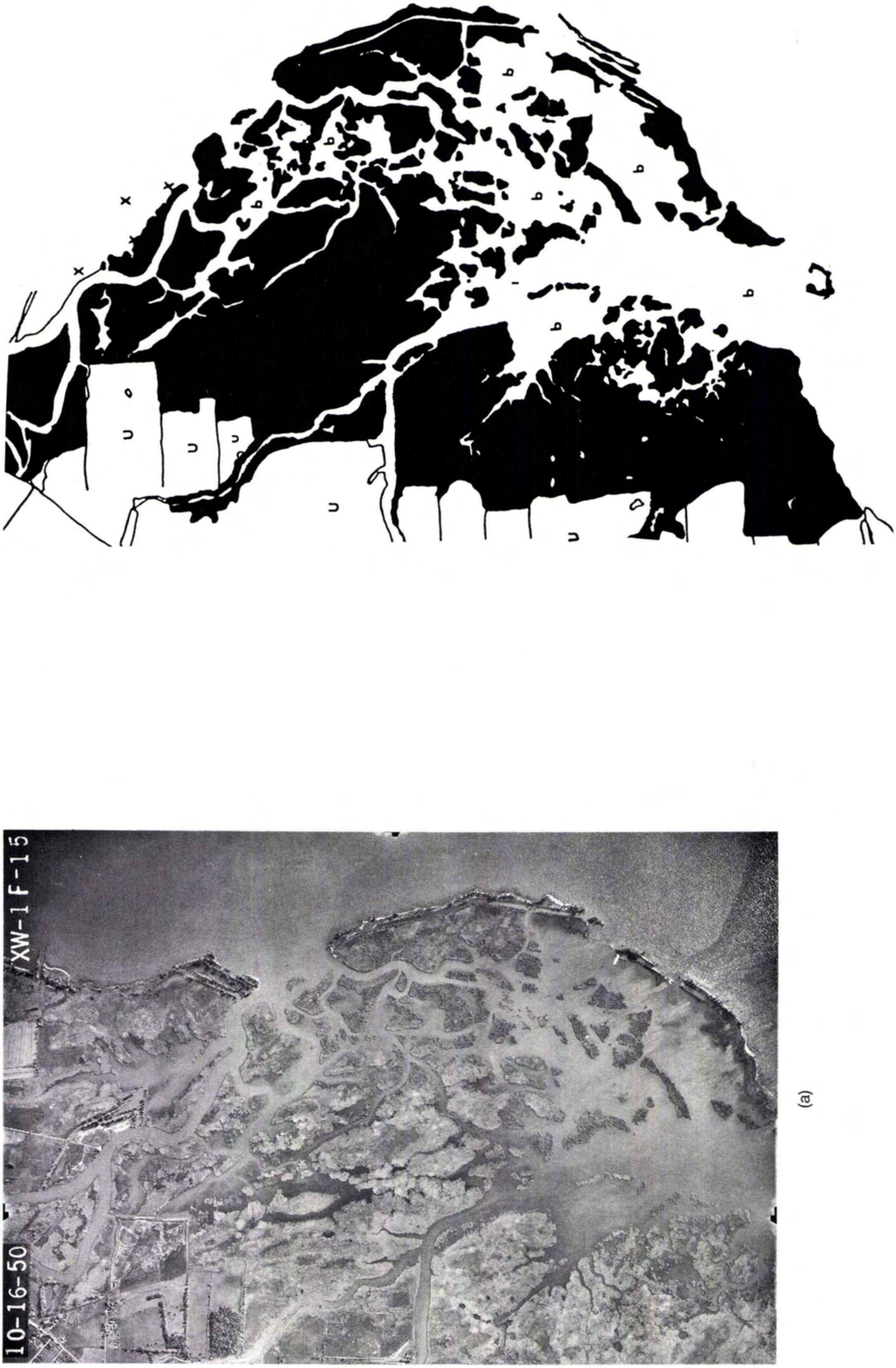
Historical analysis of Pointe Mouillee wetlands indicated a substantial loss in total wetlands during the period 1940 to 1950. This reduction was most likely the result of the damming of the Huron River, and decreasing contributions of sediment to the sand beach barrier known as Pointe Mouillee that protected the Huron River delta wetlands from wave action. Variations in total wetland during the 1950-1980 period were inversely related to lake levels, and the phenomenon was modeled. This study demonstrated the value of historical aerial photos to measure total wetlands. These quantities along with water level data may



(a)

(b)

FIG. 2. (a) Aerial photos from 1937. (b) Wetland map interpreted from the 1937 photos. See Table 1 for map scale and water level. Areas outside the study are indicated by an "x", wetland areas are denoted in black, open water areas are indicated by a "b", and upland areas by a "U".



(a)

(b)

FIG. 3. (a) Aerial photos from 1950. (b) Wetland map interpreted from the photos.

be useful for prediction of natural, wetland variability in large lake systems.

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