Quantifying Historical Accommodation Formation, Sabine National Wildlife Refuge, Southwest Louisiana

Julie C. Bernier and Robert A. Morton

U.S. Geological Survey, St. Petersburg Coastal and Marine Science Center, St. Petersburg, FL email: jbernier@usgs.gov

Abstract

A prior U.S. Geological Survey study (Morton *et al*., 2010) documented large volumes of new accommodation that formed at 10 study areas within the Mississippi River delta plain since the mid 1950s in association with widespread, rapid land-surface subsidence and conversion of coastal wetlands to open water. This study extends that work, integrating data from sediment cores, remotely sensed imagery, and bathymetric surveys to assess historical accommodation formation at six additional wetland sites in Sabine National Wildlife Refuge (SNWR) in the western chenier plain.

The one-dimensional (vertical) processes responsible for accommodation formation were quantified by comparing surface elevations, water depths, and vertical displacements of stratigraphic contacts that were correlated between short sediment cores. Results of these analyses indicate that erosion contributed more than subsidence to the formation of accommodation associated with historical wetland loss at SNWR. Integration of data from remotely sensed imagery and bathymetric surveys at the study areas provided a basis for estimating the total three-dimensional accommodation (volume) formed by land-surface subsidence and subsequent erosion. At the six study areas, almost 20 x 10^6 m^3 of accommodation formed across areas of formerly continuous interior marsh. In total, about 65 x 10^6 m^3 of new accommodation formed within SNWR between 1956 and 2004. These volumes provide estimates of the new sediment that would be needed to restore the SNWR wetlands to their pre-1956 areal extent and elevations and represent just a fraction of the total accommodation associated with western chenier-plain wetland loss since 1956.

Despite their different geological settings, the temporal and spatial trends of historical wetland loss are similar in both the western chenier and delta plains. Analysis of historical imagery identified expanses of wet marsh, indicating that land-surface subsidence was the process that initiated historical wetland loss and accommodation formation in both regions. Compared with the delta plain, however, magnitudes of subsidence and accommodation were generally less at the SNWR study areas.

Objectives

(1) Quantify historic accommodation created where wetland loss in SNWR was rapid and extensive,

(2) Quantify the primary surficial processes responsible for forming new accommodation in these areas,

(3) Compare the magnitudes of accommodation that formed in the western chenier and delta plains.

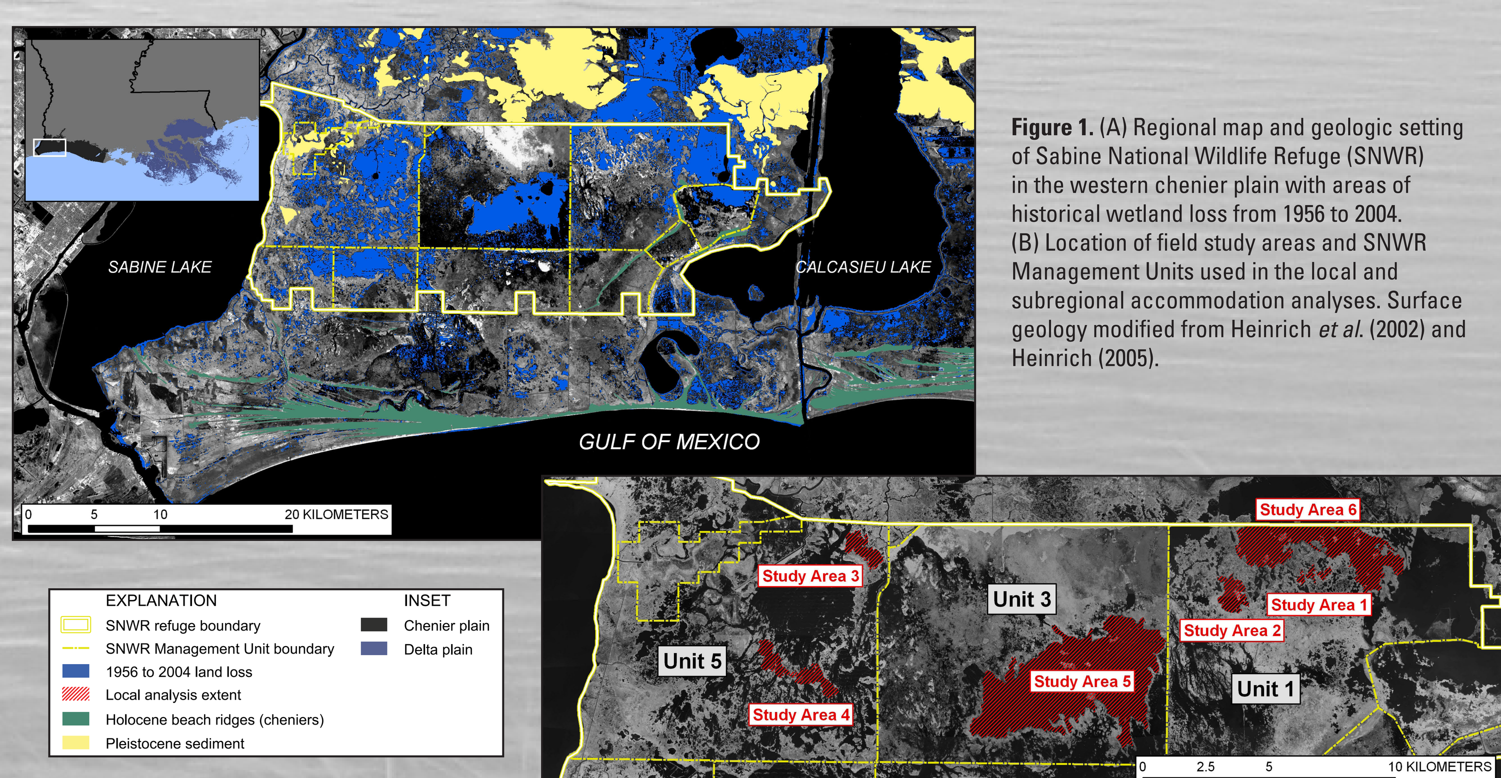


Figure 1. (A) Regional map and geologic setting of Sabine National Wildlife Refuge (SNWR) in the western chenier plain with areas of historical wetland loss from 1956 to 2004. (B) Location of field study areas and SNWR Management Units used in the local and subregional accommodation analyses. Surface geology modified from Heinrich *et al*. (2002) and Heinrich (2005).

Methods

Coring Operations: Sediment cores and water depths were collected along transects at five study areas where historical wetland loss had occurred to provide close stratigraphic correlation between the remaining emergent marshes and adjacent open-water sites that were formerly emergent wetlands.

Bathymetric Surveys: Bathymetric surveys were conducted at four study areas using a combination of stop-and-go (semi-kinematic) and fully kinematic differential GPS surveying techniques to measure the emergent-marsh and open-water sediment-surface elevations to provide more extensive spatial coverage and more accurate 1D estimates of local accommodation.

Areas of Accommodation: The 2D accommodation that formed at SNWR between 1956 and 2004 was estimated for (1) the local study areas where bathymetric elevations and (or) sediment cores were collected and (2) the surrounding SNWR Management Units in which those study areas are located. Morton *et al*. (2005) and Barras *et al*. (2008) described the land-water classification methods that were used to generate the 1956 to 2004 land-change dataset from which the historic 2D accommodation was calculated.

Wetland Subsidence and Erosion: The 1D accommodation that formed at the SNWR core sites was apportioned to either subsidence or erosion using the methods and formulas described by Morton *et al*. (2009) and modified by Bernier *et al*. (2011). The sum of subsidence and erosion at a core location equal the 1D accommodation space created by the land-to-water change, which is the difference between the reference marsh-surface elevation and the existing water depth at that core site.

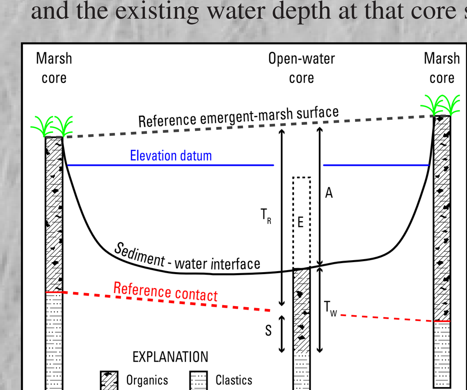


Figure 2. Conceptual diagram showing the stratigraphic relationships used to estimate subsidence and erosion at an open-water core site. A, 1D accommodation space; E, erosion; S, subsidence; T_r, reference stratigraphic thickness, T_w, stratigraphic thickness in the open-water core.

Geologic and Physiographic Setting

Delta Plain: The Mississippi River delta plain was constructed by sediment deposited in overlapping delta lobes that began prograding about 7,000 years ago. Thick aggradational peats that accumulated in interdistributary areas underlie much of the emergent delta plain wetlands (Kolb and Van Lopik, 1958; Frazier, 1967).

Chenier Plain: Compared with the delta plain, the chenier plain consists of a thin wedge of Holocene sediments that unconformably overlie stiff over-compacted Pleistocene sediments and range in thickness from less than a meter to about 6 m. Beginning about 3,000 years ago, the chenier plain was constructed by primarily alongshore processes resulting in the progradation of broad mudflats capped by wetland vegetation with intervening narrow, sandy beach ridges (cheniers) (Gould and McFarlan, 1959; Penland and Suter, 1989; McBride *et al*., 2007).

Sabine National Wildlife Refuge: SNWR encompasses about 500 km^2 of coastal wetlands between Sabine and Calcasieu Lakes in the western chenier plain. The refuge wetlands occupy a broad, shore-parallel, topographically low area that formed between the topographically higher beach ridges along the gulf shoreline to the south and Pleistocene upland areas to the north. Most of the wetland losses around the SNWR study areas occurred between 1956 and 1978, although some areas of wet marsh (the marsh surface is submerged but still visible, representing nearly uniform drowning of large sections of marsh; Morton *et al*., 2005; Bernier *et al*., 2006) around Greens Lake in Management Unit 5 did not become permanently submerged until the mid to late 1980s (Britsch and Dunbar, 1996, Barras *et al*., 2008). Some of the wetland loss within Management Unit 3 was associated with the creation of a freshwater impoundment in 1951. Wetland losses since 1990 were associated primarily with storm impacts (for example, Hurricane Rita in 2005 and Hurricane Ike in 2008).

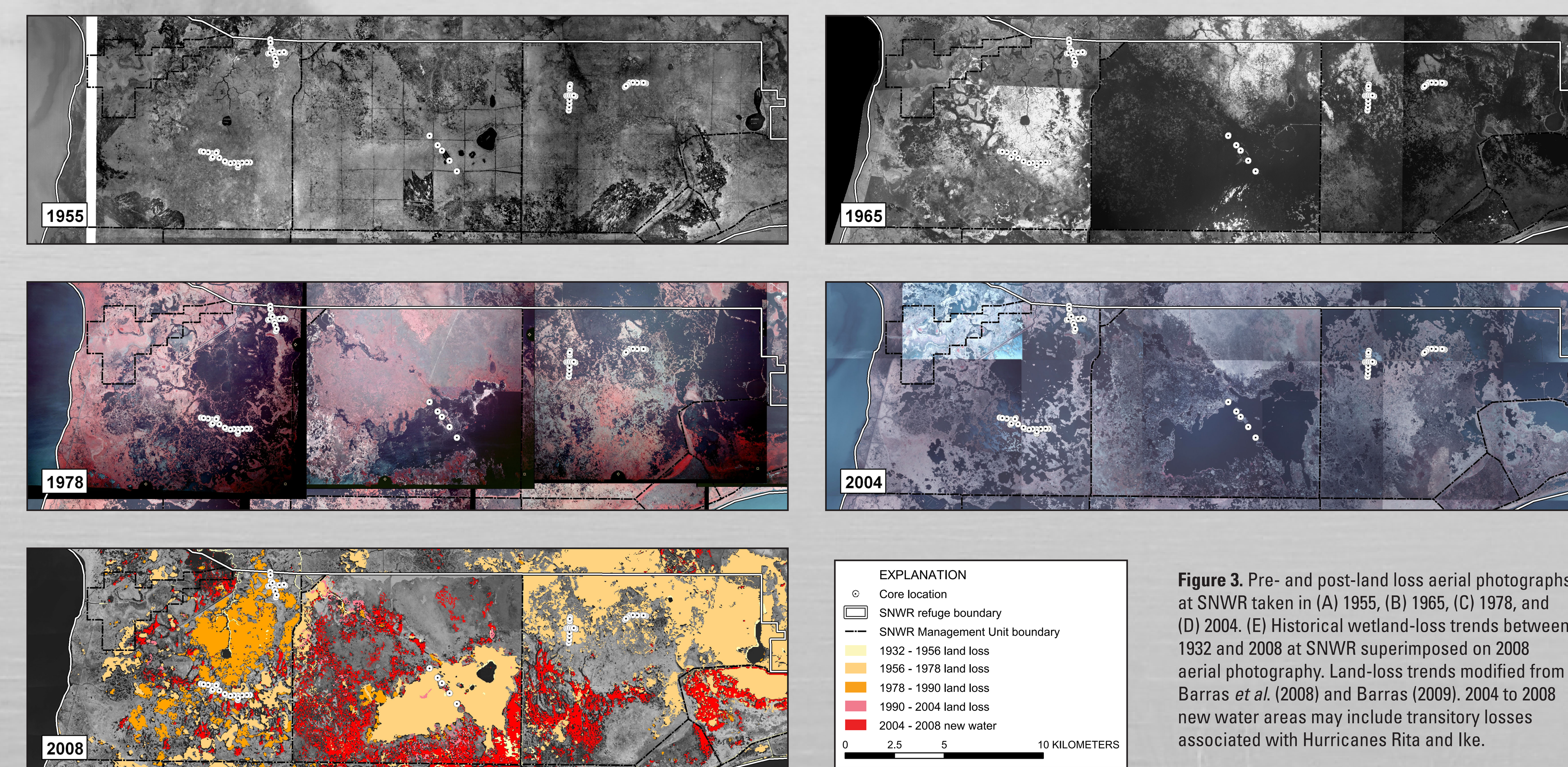


Figure 3. Pre- and post-land loss aerial photographs at SNWR taken in (A) 1955, (B) 1965, (C) 1978, and (D) 2004. (E) Historical wetland-loss trends between 1932 and 2008 at SNWR superimposed on 2008 aerial photography. Land-loss trends modified from Barras *et al*. (2008) and Barras (2009). 2004 to 2008 new water areas may include transitory losses associated with Hurricanes Rita and Ike.

Historical Accommodation Formation

Table 1. Accommodation dimensions for Sabine National Wildlife Refuge (SNWR) study areas.

[Elevation and water depths are reported relative to NAVD 88. Local 2D (area) and 3D (volume) values describe the accommodation formed between 1956 and 2004 by historical wetland loss closest to the core sites. The larger subregional 2D and 3D accommodation values include the landscape beyond bathymetric control, but where wetland loss occurred at the same time and in the same SNWR marsh-management unit.]

Location	Average Subsidence (cm)	Average Erosion (cm)	Average Marsh Elevation (cm)	Average Water Depth (cm)	Average 1D Accommodation (cm)	Local 2D Accommodation (km^2)	Local 3D Accommodation (m^3 x 10^6)	Subregional 2D Accommodation (km^2)	Subregional 3D Accommodation (m^3 x 10^6)
Study Area 1[1]	11	20	39	6	33	0.4	0.1		
Study Area 2	20	20	24	-10	34	1.1	0.4		
Study Area 3	9	41	41	-26	67	1.1	0.7		
Study Area 4[1]	5	52	44	-20	64	1.9	1.2		
Study Area 5	23	32	30	-35	65	19.8	12.8		
Study Area 6	—	—	32	-23	54	7.2	3.9		
Total						**31.6**	**19.2**		
Management Unit 1					40			29.8	12.1
Management Unit 5					65			37.6	24.5
Management Unit 3					65			26.0	16.8

[1]No GPS survey – 1D accommodation estimated from a limited number of water-depth measurements.

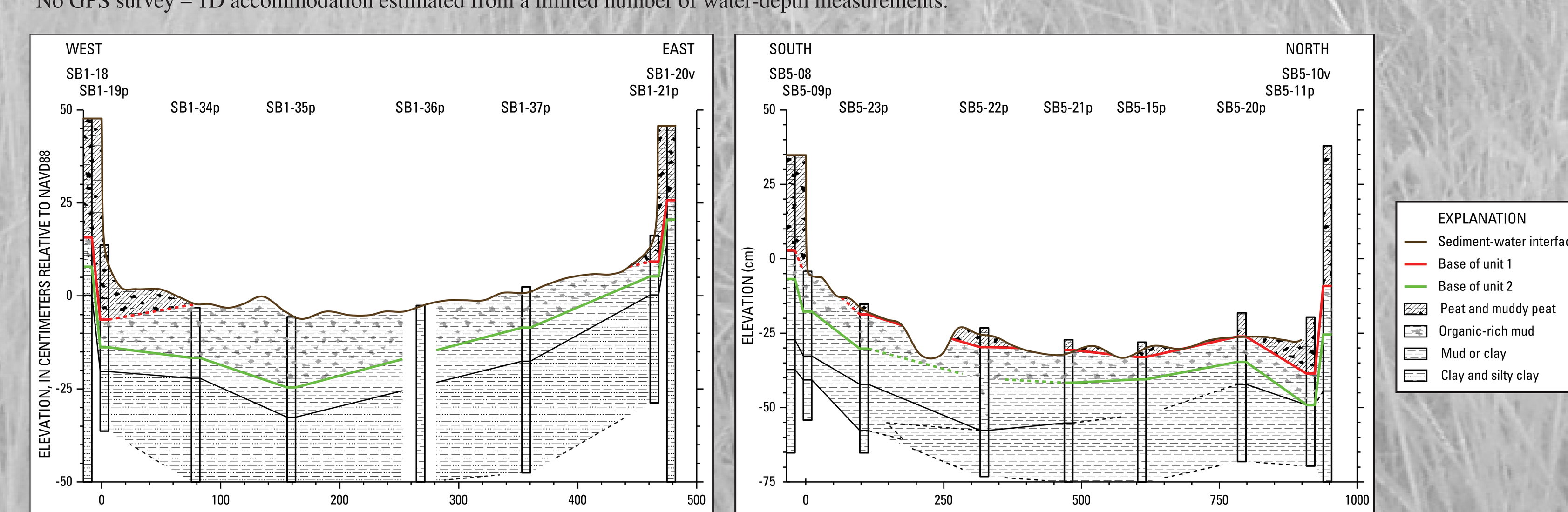
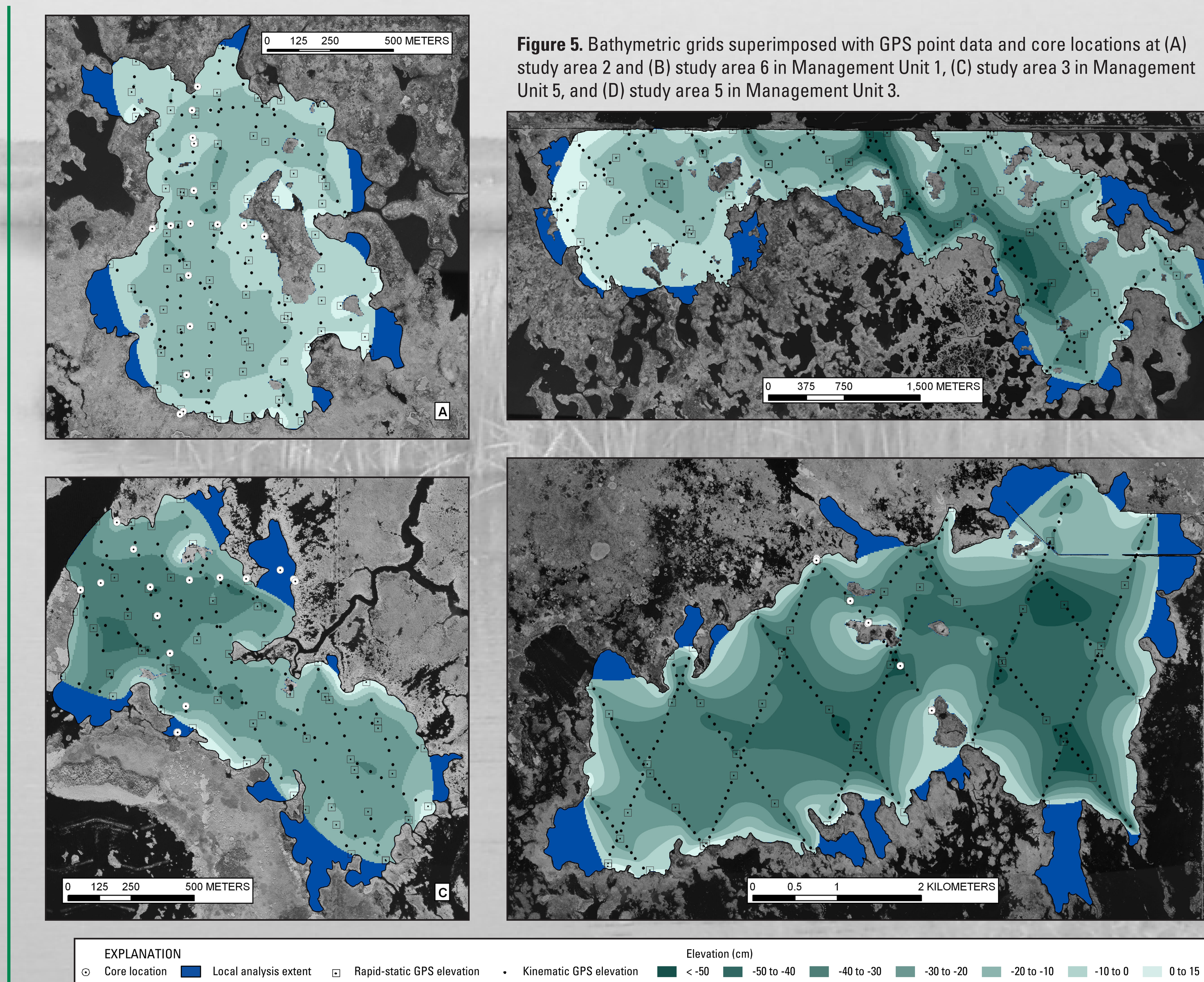


Figure 4. Combined bathymetric profile and stratigraphic cross section for marsh and open-water core sites (A) SB1-18 to SB1-20 at study area 2 in Management Unit 1 and (B) SB5-08 to SB5-10 at study area 3 in Management Unit 5 illustrating the magnitude of subsidence and wetland erosion (in centimeters). Vertical scale is greatly exaggerated.

Figure 5. Bathymetric grids superimposed with GPS point data and core locations at (A) study area 2 and (B) study area 6 in Management Unit 1, (C) study area 3 in Management Unit 5, and (D) study area 5 in Management Unit 3.



The wetland-loss parameters at SNWR provide a basis for comparing attributes of accommodation formation at SNWR in the western chenier plain with the same attributes in the delta plain:

- Erosion greatly exceeds subsidence and thin peat deposits are mostly eroded at most SNWR open-water core sites, whereas magnitudes of subsidence are greater than or equal to erosion at most delta plain open-water cores sites and thick peat deposits are preserved even where erosion exceeds subsidence.
- Compared with the delta plain study areas, the uppermost peat facies is substantially thinner, water depths are shallower, and magnitudes of subsidence and total accommodation are less at SNWR.
- Expanses of wet marsh, visible in historical imagery from both the western chenier and delta plains, indicate that subsidence was the process that initiated marsh fragmentation and widespread wetland loss in both regions; at SNWR, erosion eventually exceeded subsidence in forming the accommodation space and excavating the former emergent-marsh surface to extant water depths.

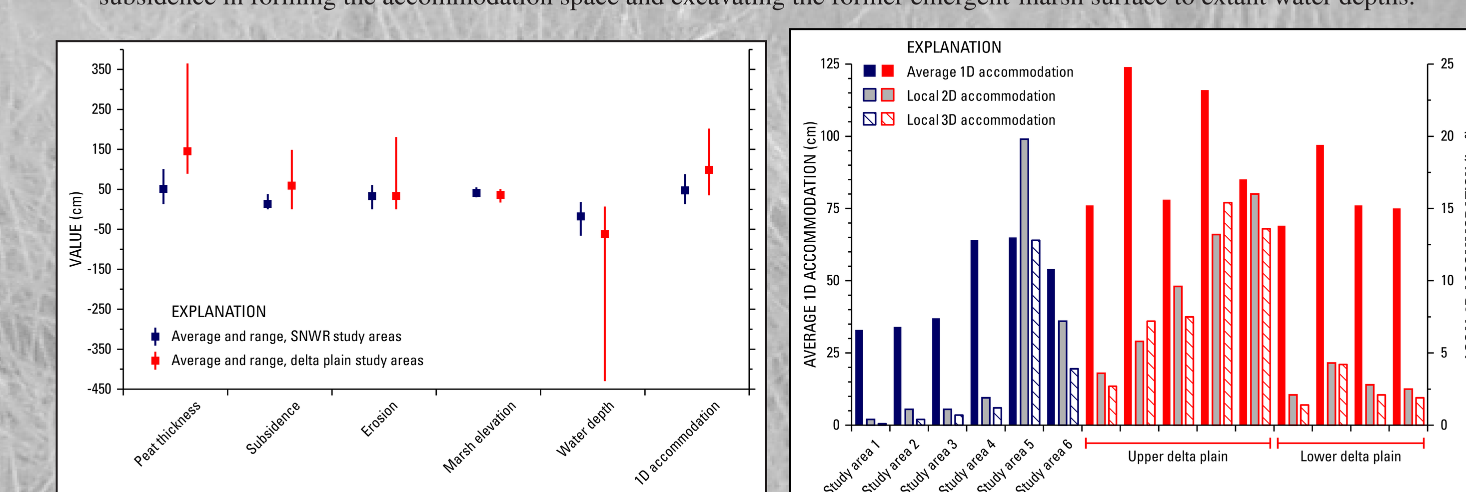


Figure 6. Comparison of accommodation paramenters and measurements at SNWR and delta plain study areas.

Conclusions and Implications

- Almost 20 x 10^6 m^3 of accommodation formed at the SNWR study areas between 1956 and 2004; this volume provides an estimate of the new sediment that would be needed just at the study areas to restore the SNWR wetlands to their pre-1956 aerial extent and elevations.
- Assuming that average marsh elevations and water depths are similar throughout the refuge, then the total accommodation that formed historically at SNWR is about 65 x 10^6 m^3.
- The temporal and spatial trends of historical wetland loss, including the development of persistent wet marsh, are similar in both the western chenier and delta plains, indicating that land-surface subsidence was the process that initiated historical wetland loss and accommodation formation in both regions. Compared with the delta plain, however, magnitudes of subsidence and accommodation were generally less at the SNWR study areas, and erosion contributed more than subsidence to the formation of accommodation associated with historical wetland loss at SNWR.
- Additional areas of new water formed within SNWR between 2004 and 2010 following the passage of Hurricanes Rita and Ike; however, not enough time has passed to assess which of these changes are transitory and (or) which changes will persist as areas of permanent land loss (Barras, 2009; Couvillion *et al*., 2011).
- Repeat bathymetric surveys, using the methods described in this study, provide a tool for monitoring short-term (event) and long-term accommodation formation in coastal wetlands.

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