LANDSCAPES THROUGH THE LENS

AERIAL PHOTOGRAPHS AND HISTORIC ENVIRONMENT

edited by
David C. Cowley, Robin A. Standring and Matthew J. Abicht

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Front cover: Étang de Montady, Languedoc-Roussillon in southern France. A remarkable pattern of field boundaries created in the 13th century on a reclaimed lake photographed on 6 August 1944. Drains converge on the circle which lies at the centre of the former lake, with water then transported out of the shallow basin through a tunnel 1.3km long under the Hill of Malpas. TARA_MAPRW_106G_1960_4175, © Crown Copyright, RCAHMS

Back cover: Erbil, the capital of Iraqi Kurdistan, is a claimant to the title of oldest continuously inhabited settlement in the world. The modern city is still dominated by the ancient tell, recorded here on 22 October 1948 when still a relatively small town. RAF_13A/131_3144, © Crown Copyright, RCAHMS

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16. The use of historical charts and photographs in ecosystem restoration: examples from the Everglades Historical Air Photo Project

Thomas J. Smith III, Ginger Tiling-Range, John Jones, Paul Nelson, Ann Foster and Karen Balentine

Introduction

Ecosystem restoration projects, both large and small, are proceeding at numerous locations around the world (Benayas *et al.* 2009). In Puget Sound, in the northwestern United States, the effort is aimed at removing pollutants from storm-water runoff and improving water quality for a variety of coastal ecosystems (Gelfenbaum *et al.* 2006). In the 1970s, phosphorus levels were drastically reduced in Tampa Bay, Florida leading to increased water clarity and a return of seagrasses to the bay's shallow bottom (Greening and Elfring 2003). In the central Great Plains of the United States, the Platte River provides crucial habitat to the Whooping Crane, Interior Least Tern, Pallid Sturgeon and Piping Plover, all endangered or threatened. Over time, the river's channel has been dredged and straightened to accommodate commercial cargo ships and dammed for hydro-electric power and water supply, all with severe, negative impacts on these species. The river is the subject of a multi-agency restoration effort aimed at reinstituting historical levels and patterns of water flow (1). However, one of the most ambitious large-scale ecosystem restorations is aimed at the Everglades in Florida: the Comprehensive Everglades Restoration Plan (CERP, 2).

Lake Okeechobee, the largest lake in the United States south of the Great Lakes, is the hydrologic lynchpin of CERP. However, early accounts of this lake are inaccurate or nonexistent in historic documents such as the 1834 and 1861 Florida maps (3). The first European explorers to cross the Everglades did so in the mid- to late 19th century. Lt Col. William Harney entered "The River Grass" in 1840 near Fort Dallas (present day Miami) and exited on the southwest side via a tidal channel that still bears his name, the Harney River. Hugh Willoughby's expedition sailed up the Harney River and pushed their way across the southern Everglades to an area south of Miami in 1893. In 1882–3 the New Orleans Times-Democrat sponsored two expeditions that explored the Caloosahatchee River, Lake Okeechobee, and the sawgrass plains south of the Lake (Peoples and Davis 1950, 1951; Wintringham 1963, 1964). These expeditions described the sawgrass plains of the Everglades as vast, almost impenetrable and unfit for development. But development did come.

By 1930, four large canals had been constructed from Lake Okeechobee running southeastward and connecting with the Atlantic Ocean to provide drainage for agriculture. An additional canal had been cut from the west to connect with the Caloosahatchee River (Light and Dineen 1994). A major highway had been built from Naples on the southwest coast to Miami on the southeast and ran across the southern Everglades (Tebeau 1968). The resultant removal of water from this vast freshwater ecosystem had consequences for wetland plant communities and the animals that inhabited them (Gunderson 1994; Ogden 1994).

Calls for restoration of the Everglades date to the 1920s. J. K. Small (1929), for example, chronicled environmental degradation throughout south Florida, including the Kissimmee River – Lake Okeechobee – Everglades ecosystem, in his book entitled "From Eden to Sahara: A Story of Florida's Tragedy." In 1948, the U.S. Congress authorized the Central and Southern Florida Project to manage water resources in southern Florida for a variety of reasons including flood control, water supply and for the natural environment (4). CERP was authorized in 2000 as part of the Water Resources Development Act (5) in recognition that the natural system required restoration above and beyond earlier projects.

But to what state or condition do you restore an ecosystem? It is here that archival materials such as maps, charts and aerial photographs can prove invaluable, if they are indeed, saved, preserved and archived.

In August 1992 Hurricane Andrew, a Category 5 storm, crossed south Florida, impacting three United States National Parks: Everglades (ENP), Biscayne Bay and Big Cypress. Not only were natural ecosystems subjected to severe disturbance (Loope *et al.* 1994; Smith *et al.* 1994), but the Park's man-made infrastructures were also essentially destroyed. The visitors' centers for both Biscayne and Everglades National Parks needed to be bulldozed and totally rebuilt. In the aftermath of Hurricane Andrew, some of the present authors were studying the ecological consequences of the hurricane. While visiting ENP, and consulting with Park staff, we discovered that archives of aerial photographs and charts, both recent and historical, were not being maintained due to damage to the archive rooms and museum curatorial areas from the hurricane. In November 1995, we salvaged >25,000 individual aerial photographs, maps, charts and film canisters from Everglades NP and transported them to a U.S. Geological Survey laboratory in Gainesville, Florida where they could be safely stored while the Park was rebuilt.

Subsequent funding allowed us to begin scanning the materials into a permanent electronic format and the Everglades Historical Air Photo (EHAP) project was initiated (6). Additional funding has expanded the work and allowed us to begin using the digital information to address questions of ecosystem restoration, forecast potential impacts of climate change (*e.g.* sea level rise), inform management of endangered species and provide resource managers with crucial information to assist them with their responsibilities. In this chapter, we discuss the types of archival materials that we used, where they were found and how they were processed so they could be used. The primary purpose of our use of archival materials is to address questions of change: has change occurred, where change has occurred, how much change has occurred, what type of change has occurred, and what were (are) the drivers of the change? This last question is of prime importance for resource managers.

Methods

Sources of materials: aerial photographs

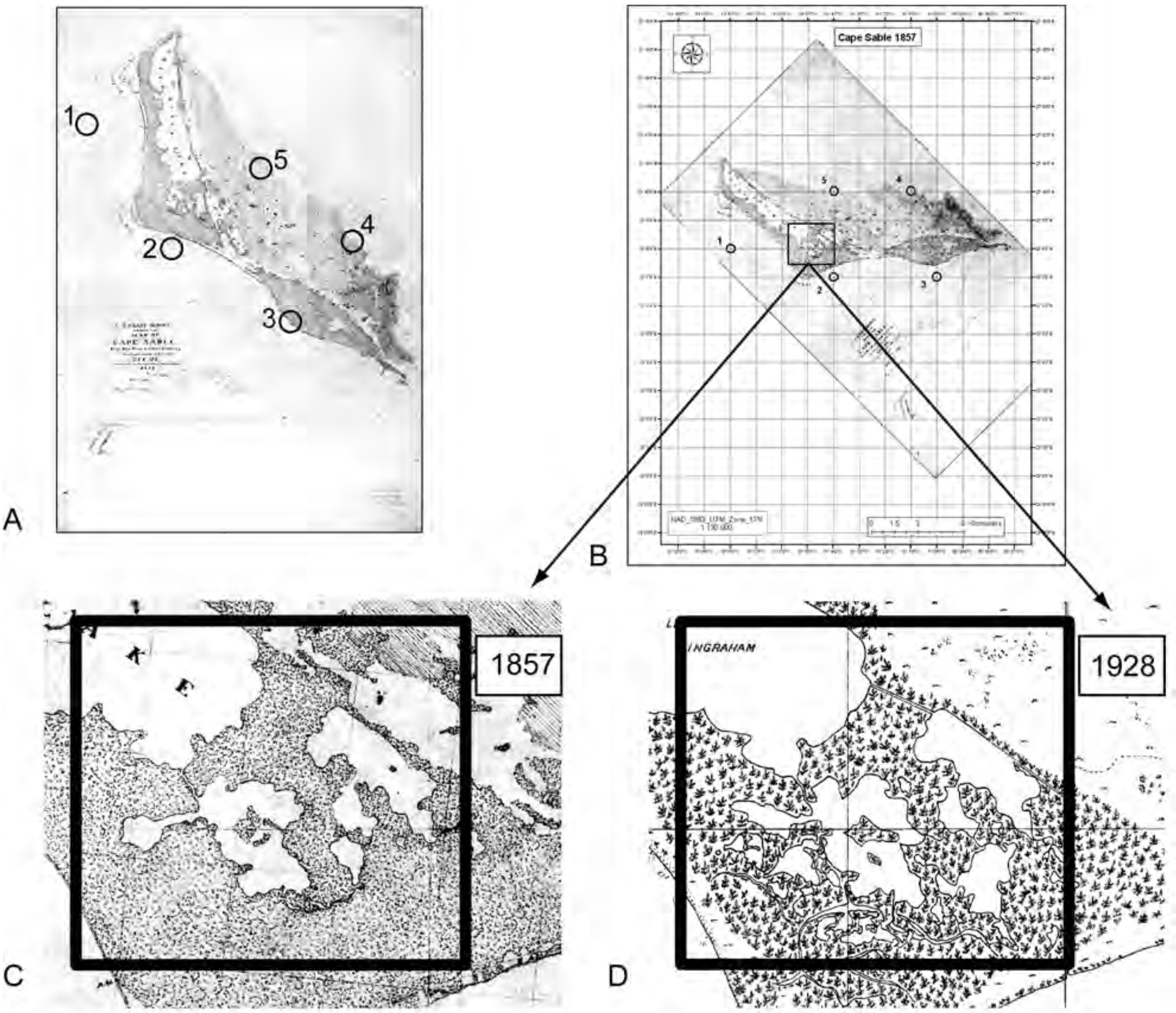
As mentioned above, the initial source of material came from archives at Everglades National Park. As the project expanded beyond ENP to the Greater Everglades we began the task of contacting numerous governmental agencies, both federal and State of Florida, that we felt may contain useful materials. The former U.S. Soil Conservation Service (now the Natural Resources Conservation Service [NRCS]) had conducted soil surveys throughout Florida in the 1940–50s and used 1:40,000 scale aerial photographs for their base maps. The numerous offices of the NRCS throughout the state were contacted and many still retained hard copies of the original images in their files. Offices were visited and photographs scanned using portable computer equipment. We subsequently discovered that a state agency, the South Florida Water Management District, had an almost complete set of the 1940s photographs for areas south of Lake Okeechobee. These were in emulsion, rather than print, format. We borrowed these in sets and scanned them at our laboratory in Gainesville, Florida. The USGS maintains extensive collections of aerial photographs and satellite imagery at its Earth Resources and Observations Data Center (7). These archives were searched and photographs that were missing from the ENP archives were obtained. At present, relatively complete coverage is available for four time periods: 1928, 1940, 1952 and 1964. Recent aerial photography (1970s on) has been routinely collected by Florida's Water Management Districts and Department of Environmental Protection and is accessible via numerous web-sites (*e.g.* the Land Boundary Information System of FDEP [8]). These photos, called Digital Orthographic Quarter Quadrangles (DOQQs) are available in several map projections. We use the North American Datum of 1983 (NAD83) and the Universal Transverse Mercator (UTM) Zone 17 North projection.

Sources of materials: historical charts and maps

Cartographers have been producing maps and charts for centuries, but accurate mapping is much more recent. Comprehensive surveys of ports and harbors were being made in colonial times in the United States (1700s). Soon after independence, the Survey of the Coast (now the National Geodetic Survey, NGS) was established and given the mission of surveying the entirety of the country's harbors, ports and all coastlines. During the second and third Seminole Wars (1835–1842 and 1855–1858 respectively), surveying of Florida's coastlines became a priority. Many expeditions were mounted (*e.g.* Bache 1857) and numerous maps and charts, of varying scales and detail, were produced. They are archived by the CGS and scanned copies are provided to other U.S. government agencies upon request.

Data georeferencing

Once scanned into digital format, brightness numbers, as well as row and column positions are assigned to the lines, shades, and text on historic maps and photos. Column and row positions of each digital number implicitly provide information on relative spatial location of boundaries and other features. Before these scanned images can be effectively combined with other digital spatial data and used in computer aided analyses (geographic information system or GIS), the implicit "X" and "Y" values for each point must be transformed to well-described geographic ones (Figure 16.1). This process of georeferencing can be simple or complex, approximate or very accurate, depending on the information available and the technique used to assign the geographic coordinates. The georeference coordinates can be longitude and latitude values or other units such as meters or feet from a designated reference. These coordinates are assigned through a system (a "map projection") that mathematically transforms 3-dimensional earth surface features to 2-dimensional ones (Robinson *et al*. 1995). When a map is made, its projection is often documented. If the map's projection is known and identifiable points are labeled with known



Pt	X	Y	Lon	Lat
1	331	1684	-81.134	25.134
2	1355	3464	-81.067	25.117
3	3466	5558	-81.000	25.117
4	4236	4779	-81.017	25.167
5	3241	2269	-81.067	25.167

Figure 16.1: An example of georeferencing using the "rubber sheet" approach is shown here. Map (A) is the scanned ungeoreferenced historic T-Sheet # 649 from 1857. Known points (e.g. #1–5) of latitude (Lat) and longitude (Lon) are visible on this map. Using the points of latitude and longitude (Table), this map is georeferenced resulting in a new rectified map (B). Areas of the rectified map B can now be compared with other rectified and georeferenced images. The box in (B) has been enlarged and compared with the same area from a 1928 chart (C vs D). Areas of change, or no change, can then be identified.

coordinates, georeferencing is a simple process of selecting points with known coordinates in the scanned image and defining the map projection for the computer. However, for many historic maps the projection is poorly described or unknown. Moreover, for historic aerial photographs, information that can be used to systematically project the imagery, such as aerial camera characteristics (*e.g.* pitch and roll), is often unavailable. In such cases, it is common to use a "rectification" or "rubber sheet" approach (Jensen 2004). With this method, numerous points for which coordinates can be found on another map or photomap with a well-described projection are selected in the scanned map. Through statistical regression, an equation that minimizes differences between known coordinates for those points and those predicted by the equation is created. The equation can then be used to transform all points within the scanned photograph or map to projected coordinate values in the output image. A hypothetical example using a portion of an Everglades historical topographic map ("T-Sheet") is provided (Figure 16.1). For our T-sheets, a mixed case exists in which lines of latitude and longitude are shown on maps but the map projection is poorly described. These maps were georeferenced by using four steps:

1) converting a minimum of 4 shown longitude and latitude pairs to a commonly used coordinate system named the Universal Transverse Mercator (UTM) system (Snyder 1987);
2) determining the scanned image column/row coordinates for those points;
3) calculating a regression equation to transform the column/row designations for those points to UTM values; and,
4) applying that equation to every column/row pair in the image to transform them to UTM coordinates (Smith *et al*. 2002).

Data accuracy

The best way to estimate accuracy is to compare the mapped and scanned information with independently collected data of higher accuracy. Two types of accuracy are important: thematic and spatial. Thematic accuracy refers to feature identification and labeling during the mapping or digital encoding process. In the case of historical map data, independent sources of highly accurate thematic information can be difficult to acquire or non-existent. This is the case with the T-sheets. And since the T-sheets are simply being encoded as images for subsequent visual interpretation (i.e., no additional attribution is being assigned to boundaries or shades in the scanned images) no additional thematic error is introduced through the digitizing process. Therefore, an assessment of their thematic accuracy will not be described here.

Spatial accuracy refers to the amount of error associated with location positioning. Sources of spatial error include the following:

1) boundary line placement during aerial photographic visual interpretation;
2) photogrammetric processing of source airborne imagery;
3) expansion/contraction of paper map products;
4) scanner induced distortions;
5) imprecise determination of row / column locations for map identifiable points on the T-Sheets during rubber sheeting;
6) imprecise determination of corresponding map or orthorectified image points during rubber sheeting.

In the case of the T-sheets, error produced by any of items 1–4 above cannot be specifically identified. In practice, utmost care must be taken in the selection and correction of control points (items 5 and 6) to minimize the introduction of additional error. Assessment of T-sheet control-point selection is made during the rubber-sheeting process. An evaluation of overall spatial accuracy (that is, items (1–6) is possible when some features that are known not to have significantly changed can be located in the scanned historic maps and other current geospatial data such as high-resolution digital orthophotographs (USGS 2002). In later figures in this chapter, examples of lines from a T-Sheet superimposed on a high-resolution digital orthophotograph are given.

Example applications

In the following, we present six examples of how the archival materials have been used to address both scientific and resource management questions.

Lake Okeechobee: 1928 and 2004

Lake Okeechobee has been called the hydrologic lynchpin of the Everglades (Light and Dineen 1994). Historically, it received water from the Kissimmee River to the north and released water via sheetflow to the Everglades to the south (Figure 16.2). By the early 1900s, farming had begun in the peat-lands south of the lake (Snyder and Davidson 1994). In September 1928, a category four hurricane passed just to the northeast. The resulting winds drove the lake's water southward, overtopping its banks, and drowning over 2,000 people in the small farm towns along the south shore (Mitchell 1928). Subsequently, an extensive dike system was built which totally surrounded Lake Okeechobee. Included in the engineering were four large pump stations at the outlets of the major drainage canals to the south. Water management was implemented that lowered Lake Okeechobee's water levels by 2m to prevent future flooding. Wetland vegetation colonized the exposed lake bottom and today extensive marshlands are located along the western and southwestern shorelines (Figure 16.3).

Captiva and Sanibel Islands: 1859 and 2004

These barrier islands form a reverse J-shape arc on the southwest coast of Florida (Stapor *et al.* 1991, see fig. 2), and are relatively low-lying with distinctive, linear, beach-ridge systems. The coast is characterized as low wave energy with low sediment supply (Haung and Goodell 1967). The oldest portions of the islands date to ≈3,000 YBP (Stapor *et al.* 1991). Stapor *et al.* (1991) discuss the islands' stability over the past 3,000 years, including that of the passes that separate them. However, they make no comment concerning Redfish Pass. In examining the

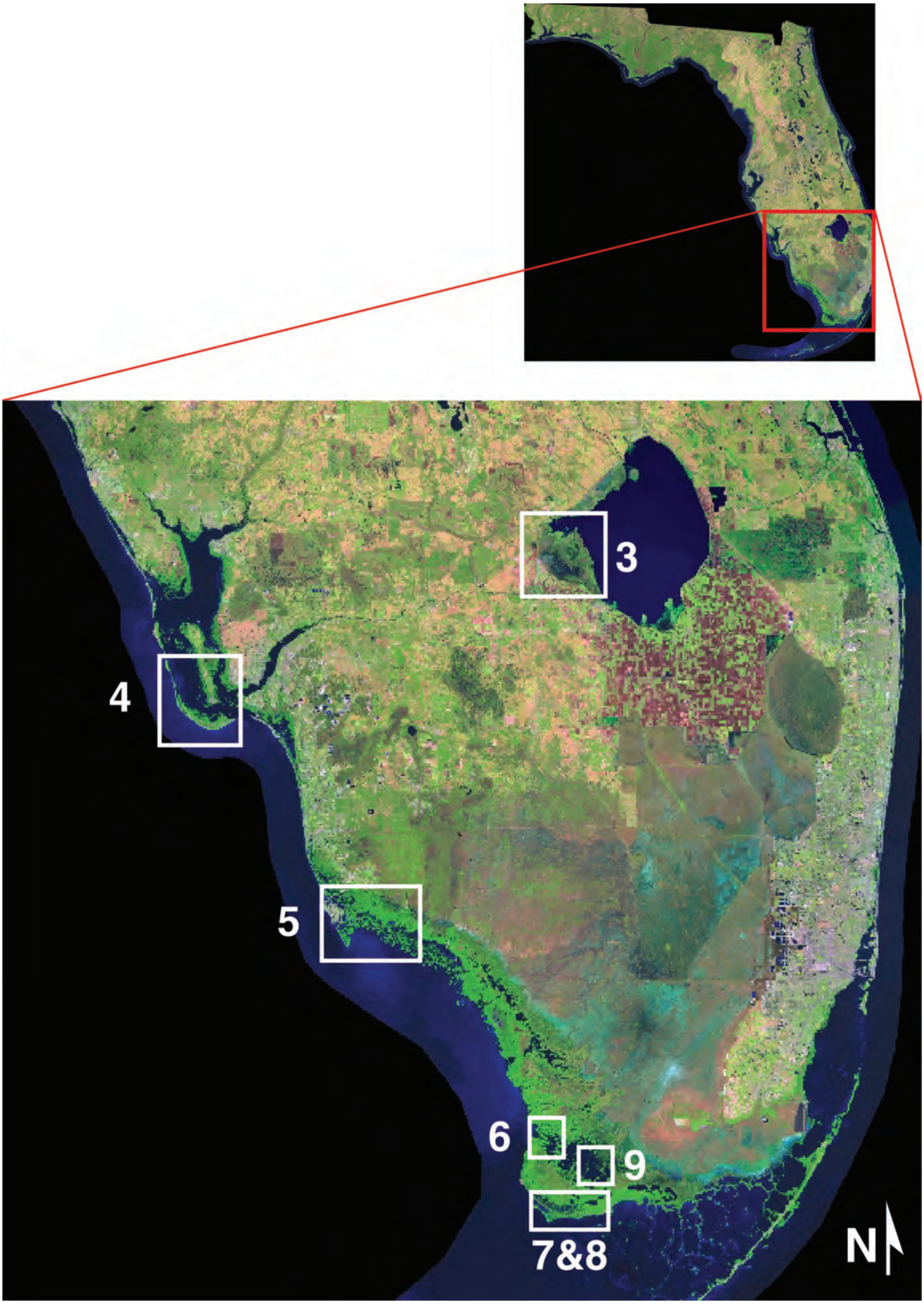


Figure 16.2: The State of Florida is shown above and the greater Everglades ecosystem in south Florida is enlarged below. Inset boxes give the approximate positions, and figure numbers, for the remaining figures in this chapter.

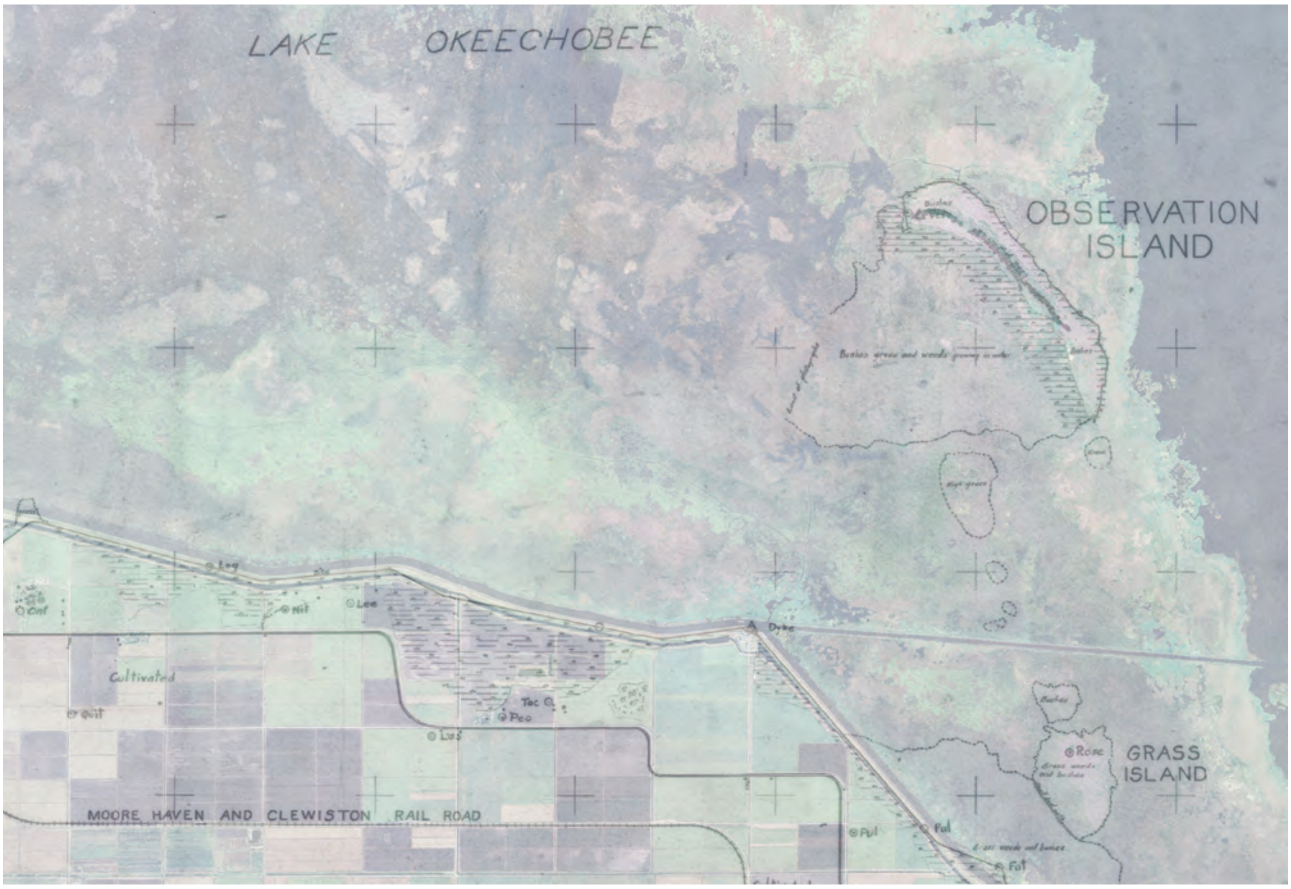


Figure 16.3: Shown is an region on the southwestern shore of Lake Okeechobee. The geo-referenced 1928 T-sheet (#4128) is draped over the 2004 DOQQs. In 1928, Observation Island, was in fact, an island. Today it is surrounded by extensive marshes that are clearly visible in the 2004 aerial photography. (Scale 1:50,000)

historical charts, it became clear that Redfish Pass was closed in 1859 (Figure 16.4a) and that Captiva was a single island, not the North and South Captiva Islands of today. A nearby inlet was opened during the passage of Hurricane Charley in August 2004 (Sallenger *et al.* 2006). Major hurricanes crossed Charlotte Harbor area in 1873, 1894, 1910, 1926, and 1944 (Anonymous 1873; Dunn and Miller 1964) and may have been responsible for opening Redfish Pass, since they are known to play an important role in inlet dynamics (Leatherman 1988). While this area of Captiva Island has undergone major changes, shorelines of nearby Sanibel Island have remained relatively unchanged (Figure 16.4b). This is true for both the Gulf of Mexico shoreline and the estuarine shorelines on the backside of the island. The hurricanes which impacted Captiva also struck Sanibel. The one obvious difference between the two islands is their orientation, with Captiva's being 170° (approximately north-to-south), and Sanibel's is much more east-to-west at 100°. These differing orientations would mean differing exposures to waves, and subsequent erosion, during the passage of a hurricane.

Historic and modern shorelines in the southwest Everglades: 1888/9 and 2004

The Gulf of Mexico shoreline of the southwest Everglades coast, from Cape Romano to northwest Cape Sable, was published in a series of five charts in 1888–89 (Figures 16.5 and 16.6; not all charts are shown). Comparison with modern shorelines has revealed interesting patterns. In the northern portion of the study area, little change has occurred (Figure 16.5). Shoals that were demarcated on the 1888 chart are clearly visible on the 2004 aerial photographs in very nearly the same locations. In the southern portion of the area, particularly at the mouth of the Shark River, major differences are apparent (Figure 16.6). The shoreline has retreated landward by over 500m in some cases. Why would these two areas differ in their history since 1888? Although sea level has been rising along this coastline since the 1840s (Maul and Martin 1995) it has not varied along the coast. Both portions of the coast have been impacted by approximately the same number and strength of land-falling hurricanes. The northern area may receive some protection from the Cape Romano shoals which are a few kilometers offshore (Holmes and Evans 1963). A more likely explanation is differences in surficial geology between these areas. The northern and southern 10,000

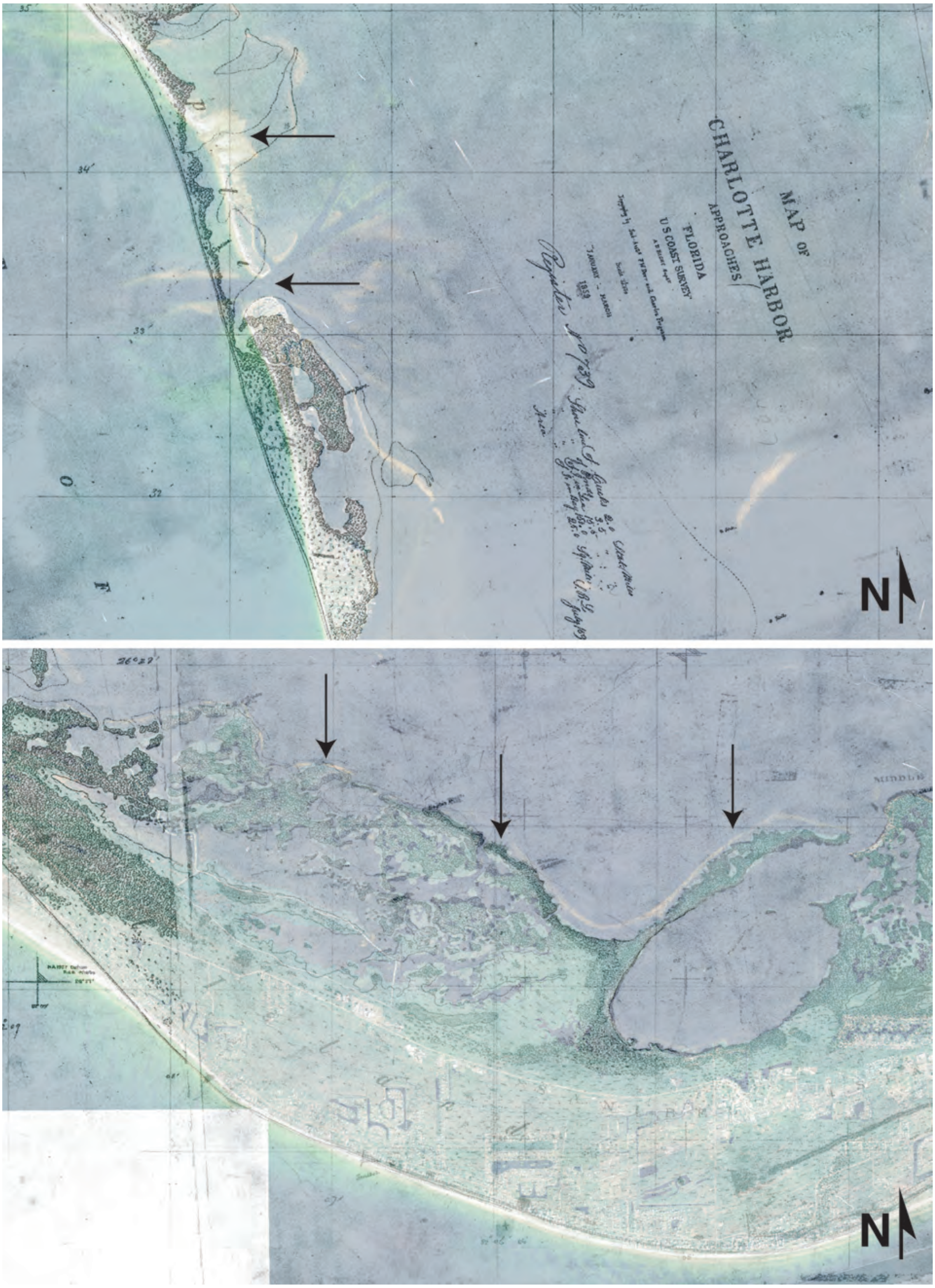


Figure 16.4: This figure shows two nearby regions of Sanibel and North Captiva Islands on Florida's west coast. Geo-referenced charts from 1859 are superimposed on the 2004 baseline aerial images. Major changes are clearly visible between times in the upper panel depicting North Captiva Island. Redfish Pass (lower arrow) was clearly closed in 1859. The upper black arrow points to a breech in the island that was caused by storm overwash and erosion during the passage of Hurricane Charley in August 2004. The estuarine shorelines (black arrows in lower panel) of Sanibel Island, 15km to the southeast, have undergone little change. (Scale 1:50,000)

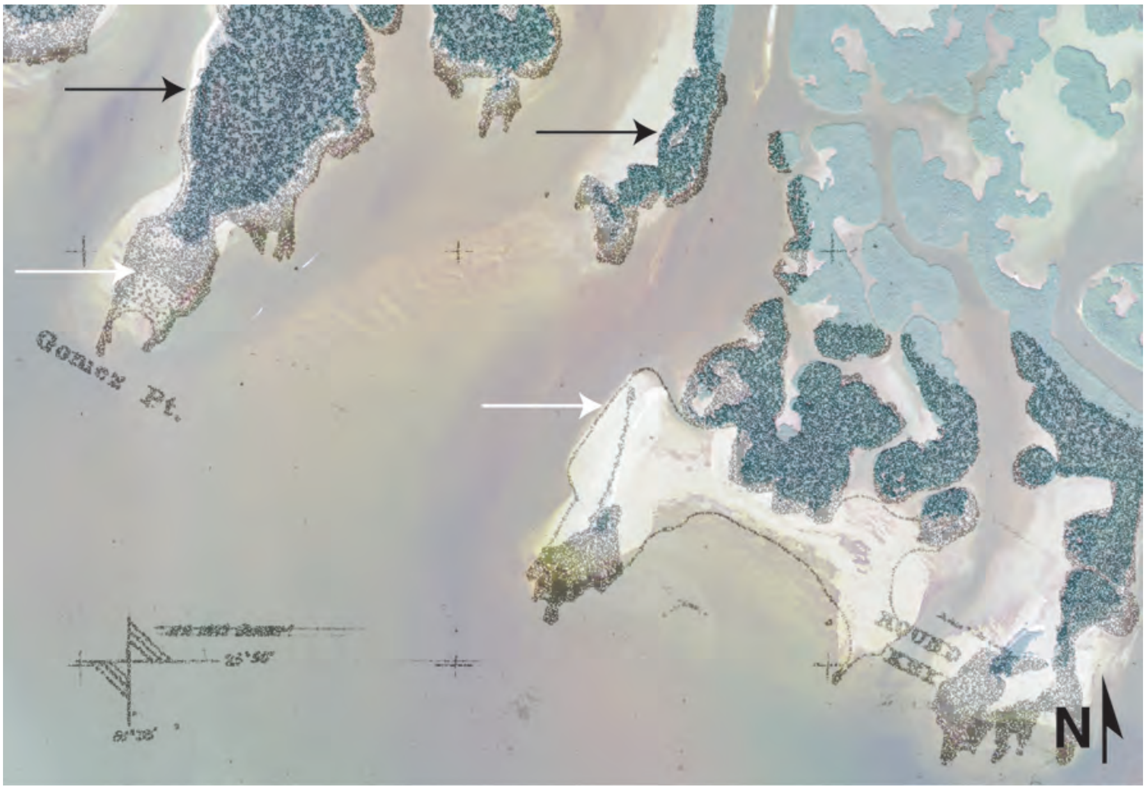


Figure 16.5: This figure shows an area in the northern 10,000 Islands. Chart T-1836 from 1888 is overlain onto 2004 aerial photographs. Positions of shoals and reefs (white arrows) and mangrove forest shorelines (black arrows) have changed little in the 116 year interval. (Scale 1:24,000)

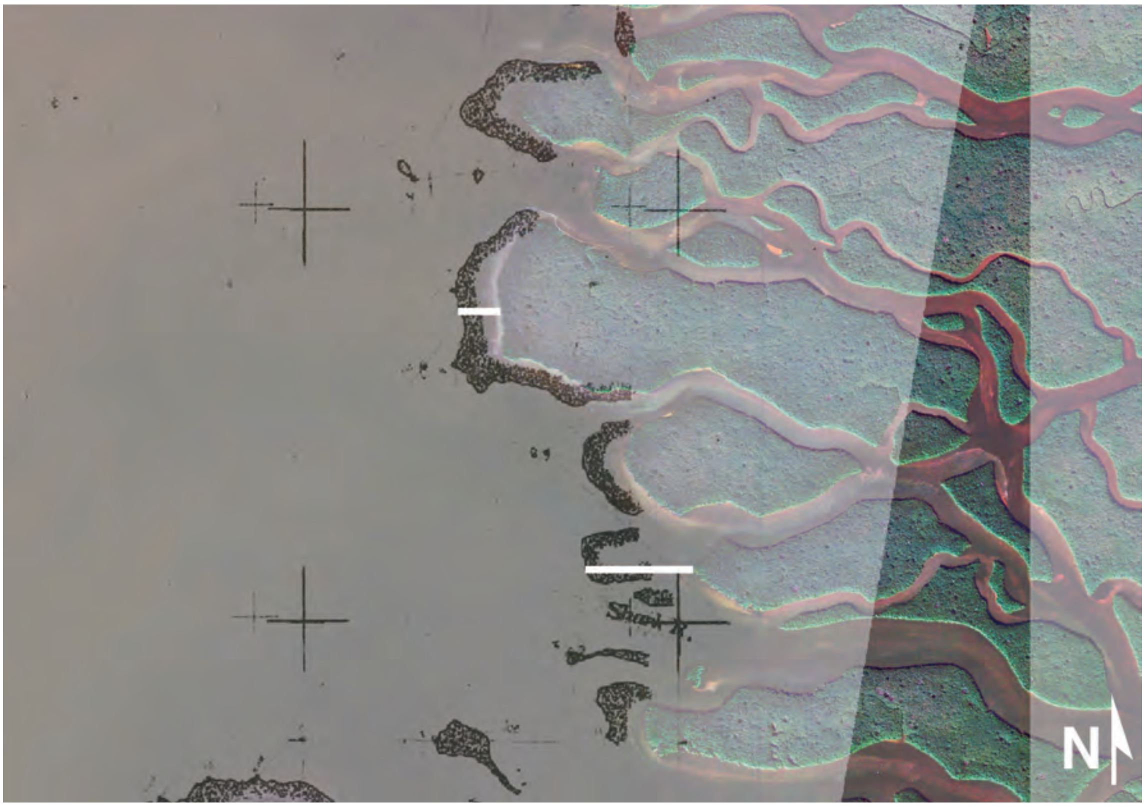


Figure 16.6: This figure shows an area in the southern 10,000 Islands at the mouth of the Shark River. Chart T-1903 from 1889 is overlain onto 2004 aerial photographs. Major erosion and coastal set-back of the mangrove islands is clearly evident. Upper line is 250m and the lower white line 500m. (Scale 1:24,000)

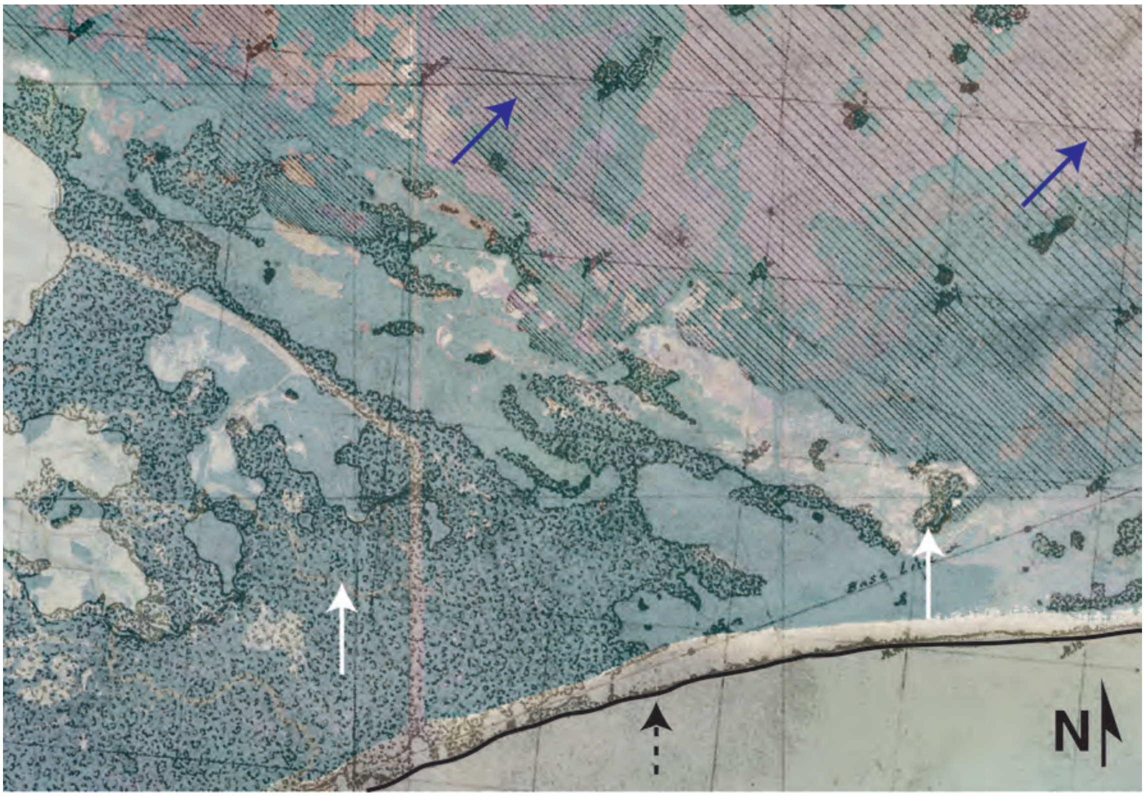


Figure 16.7: This figure shows a region of south central Cape Sable. The 1857 T-sheet (#649) is overlain on 2004 aerial photographs. The 1857 shoreline has been digitised and appears as a bold black line (dashed arrow). The symbols on the chart clearly delineated mangrove forest (solid white arrows) from marsh (blue arrows). (Scale 1:24,000)

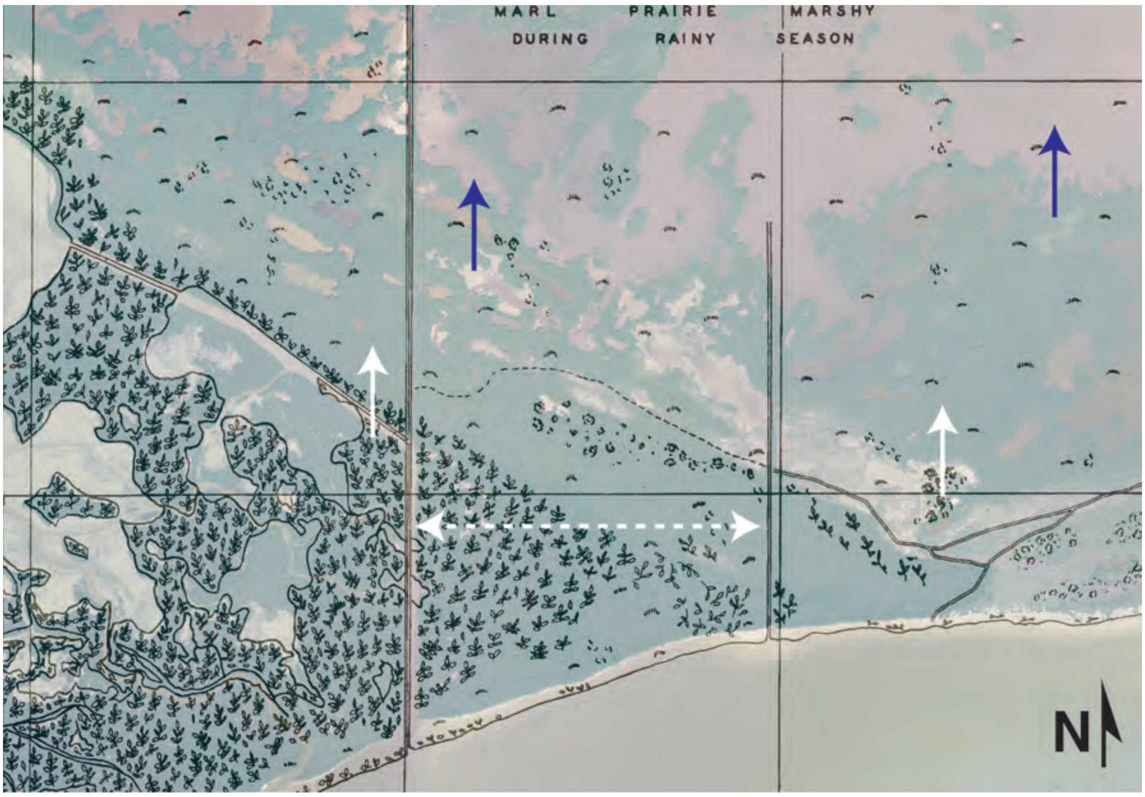


Figure 16.8: This figure shows the same area as in Figure 16.7. Here however chart T-4460, based on 1928 air photos, is overlain on the 2004 aerials. Major changes are readily apparent with marsh habitats in 1928 becoming open water (blue arrows) or mangrove forest (white arrows). The dashed white arrow points to two canals constructed in the early 1920s. (Scale 1:24,000)

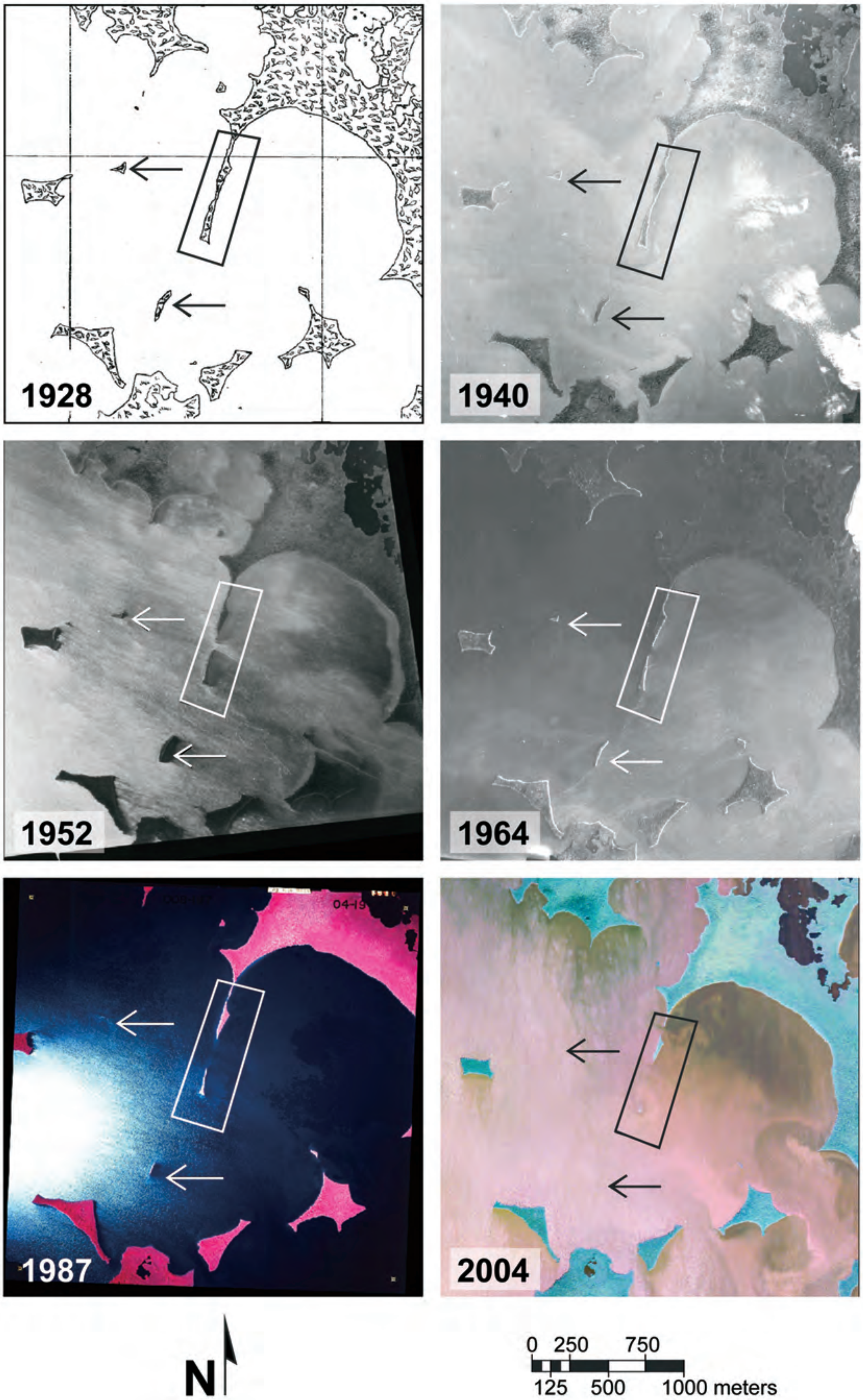


Figure 16.9: A small area of southeastern Whitewater Bay is shown here at six points in time. Two small mangrove islands and a narrow mangrove forest peninsula are indicated in 1928. The two islands can be found through 1987, however between 1987 and 2004 they have disappeared. The mangrove peninsula shows a steady erosion and decrease in size over the entire time period.

Islands are very distinct physiographic regions (Parkinson 1989). The small islands of the northern 10,000 Islands often are fringed by hard oyster and vermetid worm reefs (Scholl 1964) resistant to erosion, whereas the mangrove islands in the mouth of the Shark River consist of deep organic peats (Spackman *et al.* 1977), a substrate that may be more easily eroded.

Habitat change on southern Cape Sable: 1857, 1928 and 2004

Cape Sable is the southwestern extremity of the Florida peninsula and Everglades National Park (Roberts *et al.* 1977). The interior marshes of the Cape are where the critically endangered Cape Sable Seaside Sparrow was first described (Howell 1919). Because of the Cape's importance during the Seminole Wars it was surveyed and mapped (Bache 1857). We superimposed two historic charts over the 2004 aerial photographs. In 1857, marsh habitats were clearly delineated by the surveyors in the northern portions of the area (Figure 16.7). The area is reported as "Marl Prairie Marshy During Rainy Season" on chart T-4460, which was based on 1928 aerial photographs (Figure 16.8). By 2004, the marshes were gone, having been replaced either by open water habitat or by mangrove forest. Reasons for these habitat conversions are subject to debate. In the mid-1920s, canals, clearly delineated on T-4460, were dug through the Cape and connected the interior marshes with Florida Bay (Will 1984). Some resource managers and researchers believe the canals allowed saltwater into the marshes and this resulted in their conversion to other habitats (Wanless and Vlaswinkel 2005). However, the area is of very low relief and is regularly flooded by salt water from hurricane storm surges (Houston and Powell 2003; Smith *et al.* 2009). Also, early botanical and ornithological explorers reported that the region's marshes were brackish and salty long before the canals were dug (Bent 1904; Small 1916). From 1929 to 1960, Cape Sable was struck by six major hurricanes (Category 3 or larger) which had profound impacts on the vegetation. Additionally, during the winter dry seasons fires were common, as Small (1916) reported, "*In March the region was very dry and fires were often seen. It is quite possible that the whole area might be devastated by a single blaze.*" As in many situations, there are probably multiple causes for the habitat changes seen on Cape Sable, with canals, hurricanes and fires all playing a role.

Vanishing islands in Whitewater Bay, six snapshots in time: 1928, 1940, 1952, 1964, 1987 and 2004

Whitewater Bay lies between the Florida mainland and Cape Sable. It is an important habitat for a variety of endangered (*e.g.* Florida Manatee, Smalltooth Sawfish) and recreationally important fish species (*e.g.* Mangrove Snapper, Redfish). The Bay is also dotted with low elevation, mangrove-forested islands of various sizes. Some islands are >1,000ha in area and many are <1ha in size. In conducting over 20 years of research in south Florida and having made numerous trips in and through Whitewater Bay we noticed that smaller mangroves islands in the Bay were disappearing (T. J. Smith, pers. obs.). We have just begun to use the resources within the EHAP project to address this phenomenon. Our interest is to determine where in the bay islands are being lost, how many have disappeared, determine when they disappeared, and if possible to develop hypotheses as to why they have vanished. As an example, we mapped a small area in the southeast portion of Whitewater Bay for six time periods. We initially hypothesized that the period of island loss would correspond to the period of high hurricane activity mentioned above. This was not the case. Most islands appear to have disappeared between 1987 and 2004 (Figure 16.9). Although Hurricane Andrew struck in 1992, it passed well north of Whitewater Bay and few environmental impacts were noted in the Bay (Smith *et al.* 1994). At present, we are revising the initial hypothesis for this portion of our work, and are confident that continued analysis of historic charts and aerial photographs will aid in this endeavor.

Conclusions

Analyses of historic maps and charts is aiding in the restoration of the Florida Everglades. Resource managers from a variety of agencies are using information the EHAP project has developed. Understanding where, and what type, of habitat changes have occurred is important to the restoration process. This information can be used to help set restoration targets and goals, and to determine if certain goals are feasible. As an example, restoring the marshes on Cape Sable, which have converted to open water or mangrove forests, is most likely impractical. However, preventing further loss of marsh may be an attainable goal. Additionally, change analyses aid in the development and testing of hypothesis which will further aid Everglades restoration efforts.

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Contents

Contributors

Matthew J Abicht
Alexandria,
VA 22315, USA

Cinzia Bacilieri
English Heritage,
37 Tanner Row,
York, YO1 6WP, UK

Karen Balentine
USGS, Everglades Field Station,
40001 SR 9336,
Homestead,
FL 33034, USA

Robert Bewley
The Manse,
Fore St,
Ashton Keynes,
Wilts, SN6 6NP, UK

Jean Bourgeois
Department of Archaeology,
Ghent University,
Sint-Pietersnieuwstraat 35,
9000 Ghent, Belgium

Jarrod Burks
Ohio Valley Archaeology Inc.
Columbus,
OH 43229, USA

Giuseppe Ceraudo
Dipartimento di Beni Culturali,
Laboratorio di "Topografia antica e Fotogrammetria LabTAF",
Università del Salento,
Lecce, Italy

Alison Cook
British Antarctic Survey,
Natural Environment Research Council,
High Cross, Madingley Road,
Cambridge, CB3 0ET, UK

David C Cowley
RCAHMS,
16 Bernard terrace,
Edinburgh, EH8 9NX, UK

Andreas Cziferszky
British Antarctic Survey,
Natural Environment Research Council,
High Cross,
Madingley Road,
Cambridge CB3 0ET, UK

Alison Deegan
Independent Consultant,
Yorkshire, UK

David R Easton
RCAHMS,
16 Bernard Terrace,
Edinburgh, EH8 9NX, UK

David N Edwards
School of Archaeology and Ancient History,
University Road,
Leicester, LE1 7RH, UK

Robert Evans
Anglia Ruskin University,
Mellish Clark Building,
East Road,
Cambridge, CB1 1PT, UK

Ann Foster
USGS, Southeast Ecological Science Center,
7920 NW 71st St.
Gainesville,
FL 32653, USA

Martin J F Fowler
Les Rocquettes,
Orchard Road,
South Wonston,
Winchester, SO21 3EX, UK

Adrian Fox
British Antarctic Survey,
Natural Environment Research Council,
High Cross,
Madingley Road,
Cambridge, CB3 0ET, UK

Wouter Gheyle
Department of Archaeology,
Ghent University,
Sint-Pietersnieuwstraat 35,
9000 Ghent, Belgium

Waclaw Godziemba-Maliszewski
94 Dodgingtontown Road, Bethel, CT 06801, USA

Jane Golding
English Heritage,
NMRC,
Swindon, SN2 2YP, UK

Vanessa M A Heyvaert
Geological Survey of Belgium,
Royal Belgian Institute for Natural Sciences,
Jennerstraat 13,
B-1000 Brussels, Belgium

Pete Horne
English Heritage,
37 Tanner Row,
York, YO1 6WP, UK

John Jones
USGS, Eastern Region Geography,
12201 Sunrise Valley Dr.,
Reston,
VA 20192m, USA

David Kennedy
The University of Western Australia,
Crawley,
Perth,
Western Australia 6009, Australia

Jolanta Kijowska
Institute of Physical Geography and Environmental Planning,
Adam Mickiewicz University,
Ul Dziegielowa 27,
610680 Poznan, Poland

Andrzej Kijowski
Institute of Physical Geography and Environmental Planning,
Adam Mickiewicz University,
Ul Dziegielowa 27,
610680 Poznan, Poland

Steffen Terp Laursen
Institute of Anthropology, Archaeology and Linguistics,
University of Aarhus & Department of Oriental Archaeology,
Moesgaard Museum,
8270 Højbjerg, Denmark

Chris Musson
Tanyffordd,
Pisgah,
Aberystwyth, SY23 4NE, UK

Paul Nelson
Jacobs Inc.
600 4th St., South,
St. Petersburg,
FL 33701, USA

Lis Helles Olesen
Holstebro Museum,
Museumsvej 2,
7500 Holstebro, Denmark

Rog Palmer
Air Photo Services,
21 Gunhild Way,
Cambridge, CD1 8QZ, UK

Włodzimierz Rączkowski
Institute of Prehistory,
Adam Mickiewicz University, ul. Sw.
Marcin 78,
P61-809 Poznan, Poland

Francesca F Radcliffe
Old Farm House,
Elworth,
Weymouth, Dorset, DT3 4HF, UK

Elizabeth J Shepherd
Ministero per i Beni e le Attività Culturali,
Aerofototeca Nazionale-ICCD,
Roma, Italy

Robin A Standring
Cambridge Archaeological Unit,
Department of Archaeology,
Downing Street,
Cambridge CB2 3DZ, UK

Birger Stichelbaut
Department of Archaeology,
Ghent University,
Sint-Pietersnieuwstraat 35,
9000 Ghent, Belgium

Tom J Smith III
USGS, Southeast Ecological Science Center,
600 4th St., South,
St. Petersburg,
FL 33701, USA

Cathy Stoetz
English Heritage,
NMRC,
Kemble Drive,
Swindon, SN2 2GZ, UK

Anke Stoker
Statemaan 124,
9301 RP,
Roden, The Netherlands

Roger J C Thomas
English Heritage,
37 Tanner Row,
York, YO1 6WP, UK

Ginger Tiling-Range
Jacobs Inc.
600 4th St., South,
St. Petersburg,
FL 33701, USA

Daniel Uziel
Yad Vashem,
POB 3477,
Jerusalem, 91034, Israel

Peter Verkinderen
Department of Languages and Cultures of the Near East and North Africa,
Ghent University,
Sint-Pietersplein 6,
B-9000 Ghent, Belgium

Jan Walstra
Department of Languages and Cultures of the Near East and North Africa,
Ghent University,
Sint-Pietersplein 6,
B-9000 Ghent, Belgium

Helen Winton
English Heritage,
NMRC,
Kemble Drive,
Swindon, SN2 2GZ, UK

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