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Manipulation of wetlands for agricultural purposes by the ancient Maya of southern Mexico and Central America has been a subject of much research and debate since the 1970s. Evidence for wetland cultivation systems, in the form of drained or channelized fields, and raised planting platforms, has been restricted primarily to the southern Maya Lowlands. New research in the Yalahau region of Quintana Roo, Mexico, has recorded evidence for wetland manipulation in the far northern lowlands, in the form of rock alignments that apparently functioned to control water movement and soil accumulation in seasonally inundated areas. Nearby ancient settlements date primarily to the Late Preclassic period (ca. 100 B.C. to A.C. 350), and this age is tentatively attributed to wetland management in the area.

Introduction

Prior to the 1970s, ancient Maya subsistence was assumed to have been based on swidden (slash-and-burn) cultivation of maize within a tropical forest environment that was rather hostile and agriculturally limited (Fedick 1996; Turner 1978). Expanding settlement pattern studies forced a reassessment of the "swidden thesis" as regional population estimates for the Classic period (ca. A.C. 250–900) soared beyond the accepted carrying capacity of slash-and-burn agriculture. A new era of Maya subsistence studies opened in 1968 with the discovery by geographer Alfred Siemens of patterned ground in the wetlands of Campeche, Mexico. Joint investigation of these and other features in the early 1970s by Siemens and archaeologist Dennis Puleston produced the first evidence that the ancient Maya had modified and managed wetlands for intensive agriculture (Pohl 1990; Siemens and Puleston 1972). Subsequent studies by several researchers produced tantalizing, though often controversial, evidence that labor-intensive systems of wetland cultivation had been widespread in the southern Maya Lowlands, particularly during the Late Classic period when regional population levels were generally at their peak (e.g., Adams, Brown, and Culbert 1981; see also Turner 1990). Others tempered these

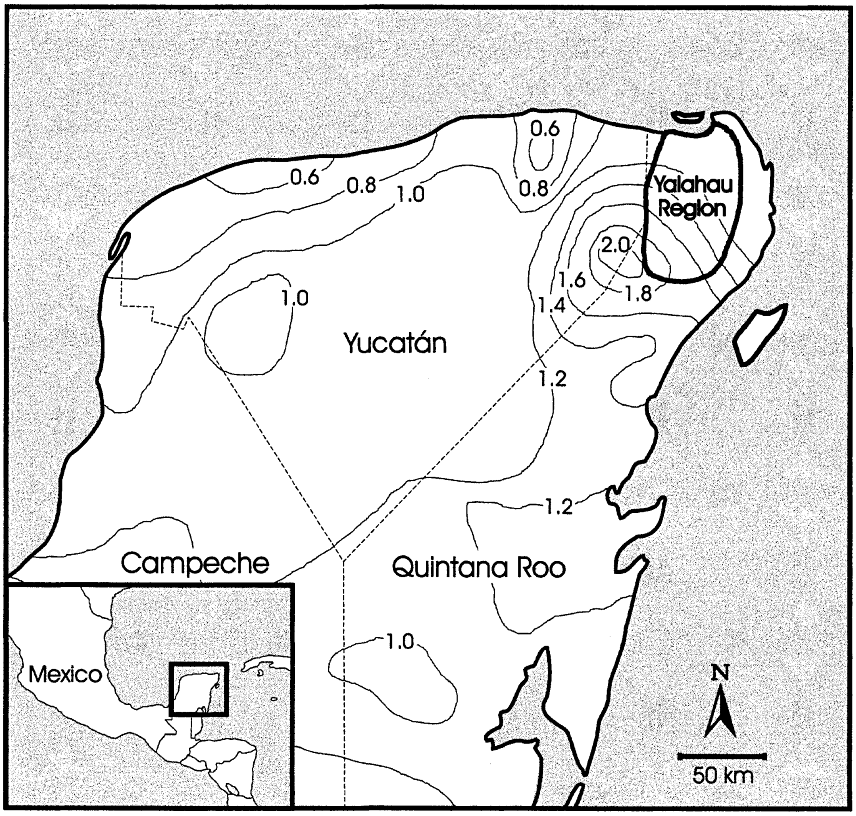

Figure 1. The Yucatán Peninsula of Mexico with mean annual rainfall (m) and the location of the Yalahau region.

claims, recognizing the importance of wetland cultivation, but suggesting that ancient use of wetlands was much more restricted in geographic extent, involved less labor-intensive cultivation techniques, and had been practiced primarily in karstic riverine floodplains during the Preclassic period when regional water-table levels were lower (Pohl et al. 1996; Pope and Dahlin 1989, 1993).

Current research and debates concerning wetland cultivation in the Maya Lowlands cover a number of interrelated issues: 1) the expanse of wetland cultivation at any given time; 2) the types of wetland ecosystems that were modified; 3) the time periods in which wetlands were put to use; 4) the labor required to initiate and maintain a particular wetland cultivation system; 5) the crops or other resources that were produced by a wetland cultivation system; 6) the economic, social, or political circumstances that fostered the development or decline of wetland cultivation; and 7) environmental changes, human induced or "natural," that may have affected wetland cultivation systems. The present contribution focuses on a previously uninvestigated wetland zone located in the Yalahau region of the northern Maya Lowlands (FIG. 1), and describes a system of constructed features that differs from other reported forms of wetland management. A discussion of these findings places them within the context of current research issues of wetland management by the ancient Maya.

Defining the Yalahau Region

The Yucatán Peninsula is part of a greater geographical unit known as the tropical lowlands of Middle America (West 1964: 370). Tracing the limestone platform of the peninsula from south to north, one finds a general decrease in elevation, topographic relief, forest canopy height, and annual rainfall. In the southern lowlands, south of approximately 19°N latitude, several major river systems drain to the eastern and western margins of the peninsula. Surface water is scarce in the interior of the southern lowlands, where the porous karstic geology allows rainwater to move quickly into caves and subsurface rivers, and the water table is generally far deeper than could be reached by hand-dug wells.

The limestone shelf of the northern lowlands is relatively flat; elevations rarely rise higher than 20 m above mean sea level, with the exception of the Puuc Hills in northern

Campeche and SE Yucatán. In the northern lowlands there are virtually no surface rivers, and the fresh-water aquifer floats on top of a regional saltwater intrusion (Back and Hanshaw 1970). The principal natural sources of fresh water in the northern lowlands are natural wells or *cenotes* (karstic sink holes) and occasional small lakes associated with fault systems. The lower elevation of the northern lowlands allows access to the water table in much of the area, where wells can be dug with relative ease through the soft limestone bedrock (Winzler and Fedick 1995). Soils are rich, yet very thin, with vast areas of exposed bedrock mantled with only a skeletal covering of earth. Vegetation of the northern lowlands is medium to low semi-deciduous forest, decreasing to nearly desert-like low scrub-forest in the extreme NW.

The NE corner of the Yucatán Peninsula stands in sharp contrast to the general environmental characteristics of the northern Maya Lowlands. Northern Quintana Roo receives significantly more rain than the rest of the northern lowlands, with an average annual precipitation of up to 1500–2000 mm, an amount comparable to much of the southern lowlands (FIG. 1; Isphording 1975: 244; Wilson 1980: 23–25). The abundant rainfall of northern Quintana Roo has contributed to the formation of a series of elongated karst depressions, or solution features, that apparently follow an underlying N–S oriented fault system (Tulaczyk 1993: 55–111). This lineament system of depressions and aligned swales is referred to geologically as the Holbox fracture zone, as first defined by geologist A. E. Weidie (1982; see also Tulaczyk 1993; Tulaczyk et al. 1993; Weidie 1985). The elongated depressions support a series of fresh-water wetlands that were apparently formed when the descending karst solution features met the water table (FIG. 2). Consequently, the depth of water and hydro period (duration of flooding) of the wetlands is related to shifts in groundwater levels as well as seasonal rainfall accumulation (Tulaczyk 1993: 112–131).

The Holbox fracture zone extends in well-developed form about 50 km from the north coast to the south, and is approximately 40 km wide. The total area of wetlands within this zone covers about 134 sq km (FIG. 2). Analysis of remote sensing data indicates that a less-pronounced section of the Holbox fracture zone extends an additional 50 km to the south, terminating just north of the ancient center of Cobá (Southworth 1985). We refer to the northern half of the Holbox fracture zone, where wetlands predominate, as the Yalahau region (Fedick and Taube 1995; see also Dunning et al. 1998).

The varied topography of the Yalahau region results in a complex mosaic of soil resources and vegetation zones. Elevated areas of good to excessive drainage are characterized by surface lithosols with patches of deeper, more productive, rendzina soils. Soils found within the inundated zones of the shallow wetlands are mainly peaty deposits overlying a thin mantle of silty clay, with limestone bedrock at depths rarely exceeding 40 cm. Environmental zones include seasonal to perennial wetlands, well-drained upland areas dominated by semi-deciduous tropical forest reaching a canopy height of about 15 m, and lower forests of secondary growth resulting as an aftermath of hurricanes and the consequential fires that are so frequent in northern Quintana Roo (Konrad 1985; Wilson 1980: 21–23).

Previous Archaeological Research

Investigations of ancient Maya use of wetlands for subsistence production have previously been restricted to the southern lowlands, where various forms of wetlands cover about 40 percent of the terrain (for a review of ancient water management in the Maya Lowlands, see Harrison 1993; Matheny 1978; Scarborough 1993, 1994). In contrast, since wetlands are rare in the northern lowlands, being primarily restricted to coastal brackish-water zones, and to the fresh-water wetlands of the Yalahau region, little work has been done here. There have been a few scattered reports of features within the northern coastal wetlands that have been described as isolated linear depressions or channels. These linear features are visible on aerial photographs and have generally been interpreted as abandoned transportation canals of either prehistoric or historical origin (López Ornat 1983; Matheny 1976, 1978; Millet Cámara 1984).

Estuarine lagoons and swamps along the northern and NW coast of the Yucatán Peninsula support salt-making activities that have been conducted since pre-Hispanic times (Andrews 1983). These salt works consist of constructed rectilinear enclosures, or pans, where salt water is trapped at the beginning of the dry season and evaporates to form thick deposits of salt which are then harvested (Andrews 1983: 22–25). Archaeological evidence of salt making along the coast of the peninsula may extend back as early as the early phase of the Late Preclassic period (ca. 300–50 B.C.), with evidence for ancient salt pans surviving since the Early Classic period (ca. A.C. 300–600; Andrews 1983: 30–31). Anthony Andrews (1983: 41–42) has identified salt pans on the southern coast of Holbox Island (FIG. 2), off the north coast of the Yalahau region, that apparently date to recent times.

Analysis and interpretation of satellite imagery by Charles Duller (1990) has identified patterned ground in coastal wetlands of the Cabo Catoche area (FIG. 2), just NE of the Yalahau region, and suggests these still uninvestigat-

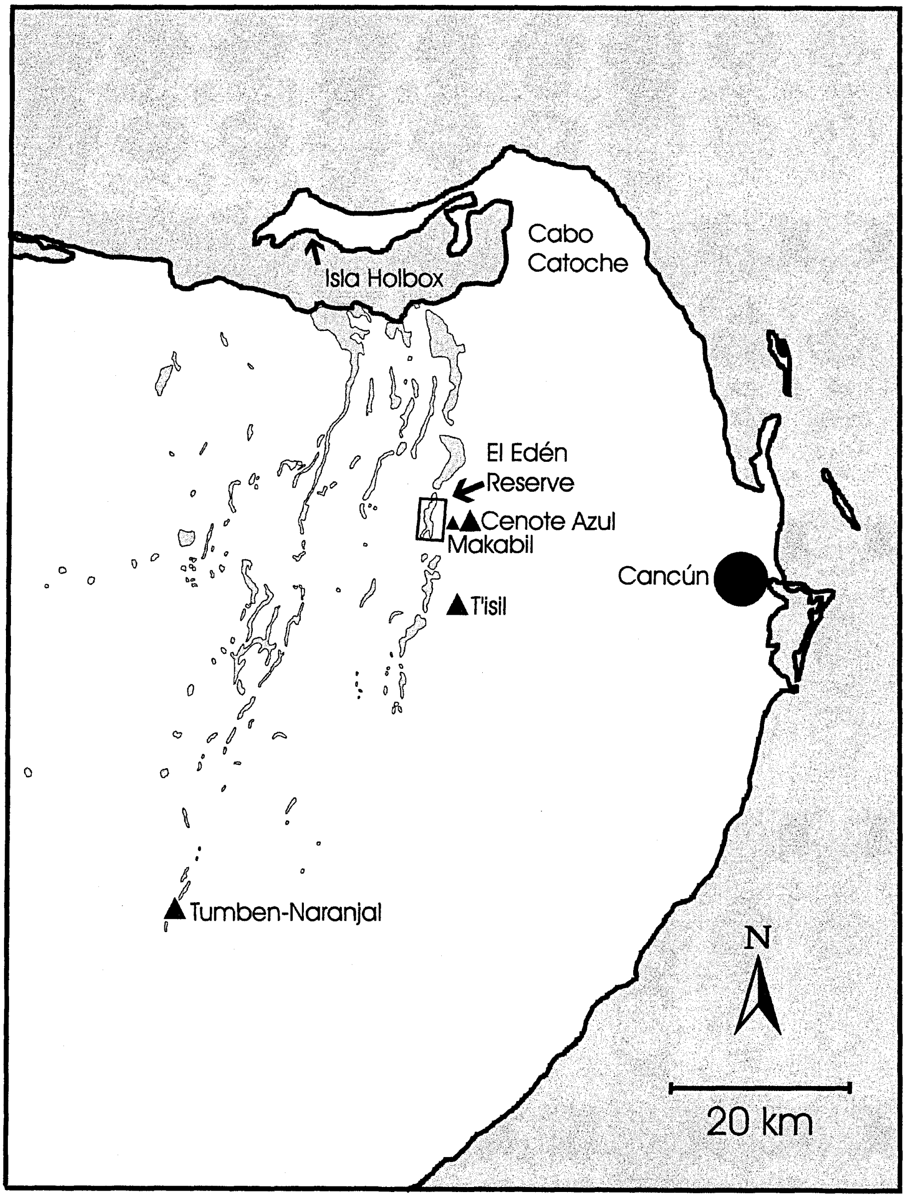

Figure 2. Wetlands of the Yalahau region and location of places mentioned in the text.

ed patterns may represent ancient canals and raised-field complexes.

Prior to the Yalahau Regional Human Ecology Project, little archaeological research had been conducted within the region (Escalona Ramos 1946; Sanders 1955, 1960; see Andrews 1985 for a recent summary of research in northern Quintana Roo). The Project was established in 1993 to investigate ancient Maya political organization, settlement patterns, and land use within the wetland environment of northern Quintana Roo, and to place culture change within this area into the context of Maya regional development (Fedick and Taube 1995, Fedick and Taube eds. 1995). The 1993 field investigations focused on the major center of Tumben-Naranjal (FIG. 2), mapping the large structures that form the core of the site, and documenting the megalithic-style architecture that characterizes the center (Fedick and Taube 1995; Mathews 1995, 1998; Taube 1995). The megalithic style was previously known from sites such as Aké and Izamal, and was generally thought to be restricted to the NW portion of the Yucatán Peninsula sometime during the Late Preclassic and Early Classic periods (ca. 300 B.C.–A.C. 550) (Andrews IV and Stuart 1975: 80; Roys and Shook 1966: 49–50; Sidrys 1978: 157; Velázquez Morlet et al. 1991: 61; Webster

1979: 156–157; chronology follows Robles Castellanos 1990: table 1). The 1993 season also produced evidence for the Postclassic reuse of earlier monumental structures at Tumben-Naranjal (Lorenzen 1995, 1999), recorded settlement patterns associated with the site and the adjacent wetland and other wetlands in the region (Fedick and Hovey 1995; see also Fedick 1998), investigated ancient use of wells in the area (Winzler and Fedick 1995), mapped numerous ancient roadways and other sites of the region (Fedick, Reid, and Mathews 1995; Mathews 1998; Reid 1995; Rissolo 1995; Taube 1995; see also Rissolo and Heidelberg 1998), and examined the effect of archaeological work on the modern community of Naranjal (Goldsmith-Jilote 1995).

Our 1993 investigations produced the first evidence that the extensive freshwater wetlands of the Yalahau region may have been utilized by the ancient Maya, as suggested by clustering of settlements around wetland margins, and a single rock-alignment feature constructed within the margin of the wetland adjacent to the site of Tumben-Naranjal (Fedick 1998: 115; Fedick and Hovey 1995: 92). In the spring of 1994, botanist Arturo Gómez Pompa reported to Fedick that he had found a rock-alignment feature well within the wetland at the El Edén Ecological Reserve (FIG. 2). A brief visit by Fedick in 1994, followed in 1995 by a season of environmental reconnaissance, revealed an extensive system of rock-alignment features within the El Edén wetland.

The El Edén Wetland and Ecological Reserve

The El Edén wetland consists of a large, shallow depression measuring approximately 5.5 km N–S by 0.8 km E–W. This wetland is included within the El Edén Ecological Reserve, established in 1990 on a privately owned tract of 1492 ha (Gómez Pompa and Dirzo 1995). The entire wetland is subject to inundation during the rainy season (approximately June through December), while only small areas contain standing water throughout the year. Flooding of the wetland is caused by a combination of local inflow from heavy rains and a regional rise of the water table during the rainy season. The terrain surrounding the wetland is of very low relief, rising only a few meters within several kilometers of the wetland margin. This low terrain surrounding the wetland is subject to occasional flooding during years of unusually high rainfall.

Water within the wetland is clear and fresh, and supports a variety of species of very small fish, as well as many species of gastropods including the edible apple snail (*Pomacea flagellata*). The wetland also supports extensive periphyton communities—thick mats of microbiota that are attached to vegetation or rock. The complex periphyton communities include algae, bacteria, fungi, and animals, along with organic and inorganic detritus (see Wetzel 1983). Periphyton represents a vital component of many freshwater wetland ecosystems, providing the main source of food for grazing herbivores, such as gastropods, and contributing significantly to the cycling of nutrients, particularly nitrogen and phosphorus (see Batzer and Resh 1991; Doyle and Fisher 1994; Grimshaw et al. 1993; Lamberti et al. 1989; Lane 1991; Marks and Lowe 1989; Mulholland et al. 1994; Vymazal and Richardson 1995).

Within the wetland, vegetation zones are structured by topographic relief and associated hydro period. The lower areas of the wetland contain standing water throughout the year, and are dominated by cattail (*Typha dominguensis*) and water lily (*Nyphaea* spp.). Slightly higher areas subject to flooding or saturation through most of the year are dominated by dense stands of sawgrass (*Cladium jamaicensis*). As elevation gently rises, the sawgrass becomes more scattered and includes increasing numbers of palmetto or tasiste palm (*Paurotis wrightii*) and calabash trees (*Crescentia cujete*). Continuing up the elevation gradient (and decreasing hydro period), the next vegetation community is a swamp forest that includes logwood or palo tinto (*Haematoxylon campechianum*), black chechem (*Metopium brownei*), ya'axnik (*Vitex gaumeri*), nance (*Byrsonima bucidaeifolia*), and a stunted variety of sapote (*Manilkara zapote*).

The margin of the wetland is marked by a band of exposed limestone bedrock that is virtually free of soil. Within the wetland, soil depth averages about 20 cm over bedrock, and consists of peaty deposits over silt and silty clay. In the lower areas of the wetland, dominated by sawgrass and cattail communities, soils reach a maximum depth of about 40–80 cm.

Wetland Survey Methods and Results

A full-coverage survey of the El Edén wetland was conducted under the direction of Fedick by a team of four to six archaeologists walking transects spaced at intervals of 10–20 m, depending on the density of vegetation cover. The limit of the survey extended beyond the exposed bedrock margin of the wetland, and approximately 25 m into the surrounding upland forest. Orientation within the wetland was facilitated by an enlarged aerial photograph with a superimposed one-kilometer grid aligned to the Universal Transverse Mercator system as derived from a 1:50,000-scale topographic map. Using the geo-referenced aerial photograph, the survey crew would occasionally verify their location by use of a satellite-based Global Positioning System (GPS) receiver. Each identified feature was mapped with a Brunton pocket-transit and tape mea-

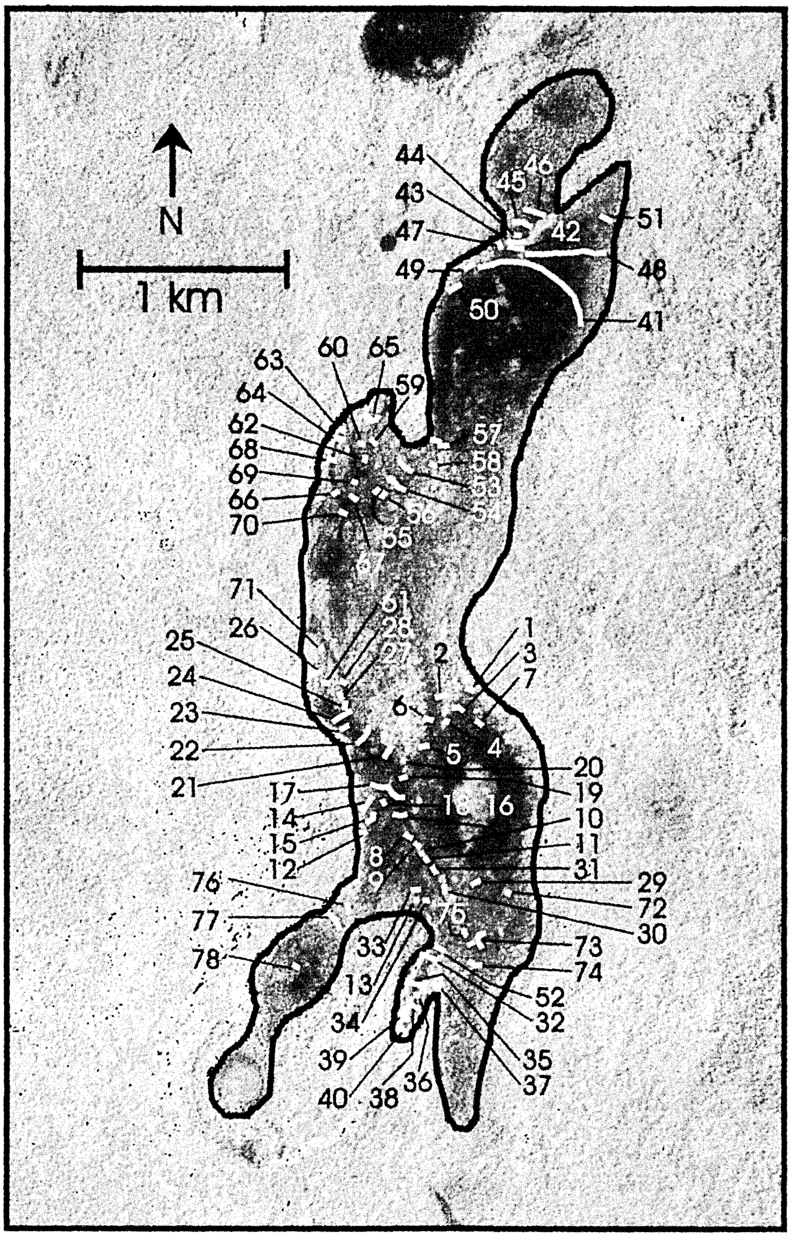

Figure 3. Aerial photograph of the El Edén wetland with numbered rock alignments superimposed. Black outline indicates the boundary of the survey.

sure, described by additional measurements, notes, and photographs, and labeled with a permanent aluminum tag. The location of each feature was determined with the use of the GPS receiver and marked on the aerial photograph.

A total of 78 features was recorded within the wetland (FIG. 3). These features consist of alignments of limestone boulders and slabs. The rock alignments range in length from a few meters to about 700 m. Analysis of the distribution, length, and form of the alignments suggests that these features can be divided into five types that are associated with different physiographic settings within the wetland.

Type 1: long alignments that close off major sections of the wetland. The most prominent features recorded during the survey are two alignments of limestone slabs and boulders in the northern end of the wetland, stretching between the west and east margins (FIG. 3, Alignments 41 and 48).

Alignment 41, the longest feature recorded, is about

Figure 4. Western end of Alignment 41, facing west.

700 m long and traverses seasonally inundated land dominated by sawgrass and tasiste palm, crossing some areas containing calabash trees (FIG. 4). The eastern and western ends of Alignment 41 terminate at the exposed bedrock margin of the wetland. Boulders range from approximately 40–70 cm in diameter, and slabs average about 15 cm in thickness with maximum diameters up to 115 cm. The rocks are arranged in single to double rows, with several segments of slabs remaining in upright positions, supported on one or both sides by smaller boulders. It is estimated that Alignment 41 consists of over 2000 large boulders and slabs, representing a substantial investment of labor.

Type 2: alignments that are situated to block the lowest margin of shallow natural depressions in the bedrock. In the northern and southern ends of the wetland are a series of smaller alignments associated with the margins of natural depressions (10–25 m in diameter) that are in turn situated within the courses of shallow channels (e.g., FIG. 3, Alignments 36, 38–40, 42–47, and 51). The alignments are situated so as to block the lowest terrain along the depression margin. These alignments are constructed of limestone boulders averaging about 30–40 cm in diameter, in single to double rows, occasionally reaching two or three courses in height.

Type 3: alignments that run perpendicular to slight slope gradients within higher areas of the wetland (e.g., FIG. 3, Alignments 35, 53, 54, 57, and 77), in fairly open transitional vegetation zones containing a scattering of swamp-forest species and sawgrass. Construction techniques and sizes of rocks are quite variable. Several of these alignments display a distinctive zigzag shape (Alignments 35, 57, and 77).

Type 4: alignments that run perpendicular to the slope leading into the larger depressions within the wetland, generally along the transition zone between lower areas with sawgrass and cattail, and higher areas with swamp forest (e.g., FIG. 3, Alignments 1–11). These alignments are generally constructed from single rows of boulders averaging about 60 cm in diameter.

Type 5: alignments that run perpendicular to and across narrow, relatively deep channels that are dominated by cattail (e.g., FIG. 3, Alignments 32, 52, and 63 through 68). These cross-channel alignments vary in length from 10 m to 66 m, and are constructed of limestone boulders or slabs, ranging from about 40 cm to 70 cm in diameter.

Test Excavations

Test excavations at rock-alignment features were conducted under the direction of Andersen and Fedick. A representative feature was selected for test excavation from four of the five types of alignments defined above. Test excavation of a cross-channel alignment (Type 5) could not be conducted due to water levels within the channels. The features selected for excavation were: Alignments 41 (Type 1), 42 (Type 2), 57 (Type 3), and 11 (Type 4).

All excavation units measured 2 × 2 m and were excavated as natural stratigraphic layers with further division into 10 cm levels as necessary. Two levels of recovery were used during the excavations. Intensive recovery methods were applied to the matrix from one excavation unit at each feature. The matrix from that unit was water screened using stacked 1/8-inch and 1/4-inch mesh screens. Water screening was facilitated in the field by the use of a portable gasoline-powered water pump. Any cultural material retained in the screens was collected. A 4 liter sample of the materials retained in the 1/8-inch mesh screen was also collected in order that very small artifacts or faunal materials could be recovered. Soil samples for pollen analysis were collected from the surface of the excavation unit, from within the excavated matrix, and from the near-bottom of the unit. After completing the first excavation unit using the intensive methods described above, subsequent units were excavated using 1/4-inch mesh screen and without collecting any additional soil samples.

Alignment 41

Alignment 41 (Type 1) was the longest rock-alignment feature recorded during the survey (FIG. 4). Four units were excavated at Alignment 41, at approximately 260 m along the alignment from the eastern terminus (FIG. 5). The intensive recovery methods described above were used during the excavation of Unit A, while Units B, C, and D were excavated by the less intensive method.

Depth from surface to bedrock averaged about 20 cm. The soil was silty clay loam and dark yellowish brown in color (Munsell color 10YR 4/4). The bedrock exposed at the bottom of each unit was consolidated, gently undulating, with a few small depressions and fissures.

By exposing the rocks that form the alignment, some details of construction technique could be discerned (FIG. 6). This segment of the alignment is constructed of limestone slabs that average about 60 cm across and 10 cm in thickness. The slabs were stood on edge and retained in an upright position by wedging them between limestone boulders that range in diameter from approximately 10–30 cm.

Quantification of gravel retained after 1/4-inch screening revealed that substantially more water-worn limestone gravel was present in the excavation unit centered over the alignment than was recovered from the adjacent excavation units located away from, and on either side of, the alignment. This water-worn gravel does not seem to have originated from the bedrock, which forms a relatively hard and smooth cap, and is unlikely to be fully explained by deterioration of the slabs and boulders that make up the alignment. It is possible that the concentration of water-worn gravel along the length of the alignment represents inclusions that have eroded out of an earthen berm that may have originally been constructed over the rock alignment. The slabs and boulders that make up Alignment 41 may be the remnants of a structural foundation for a much more substantial earthen construction that has eroded away.

Recovery of artifacts in association with the feature proved to be problematic. Ten small, highly eroded frag-

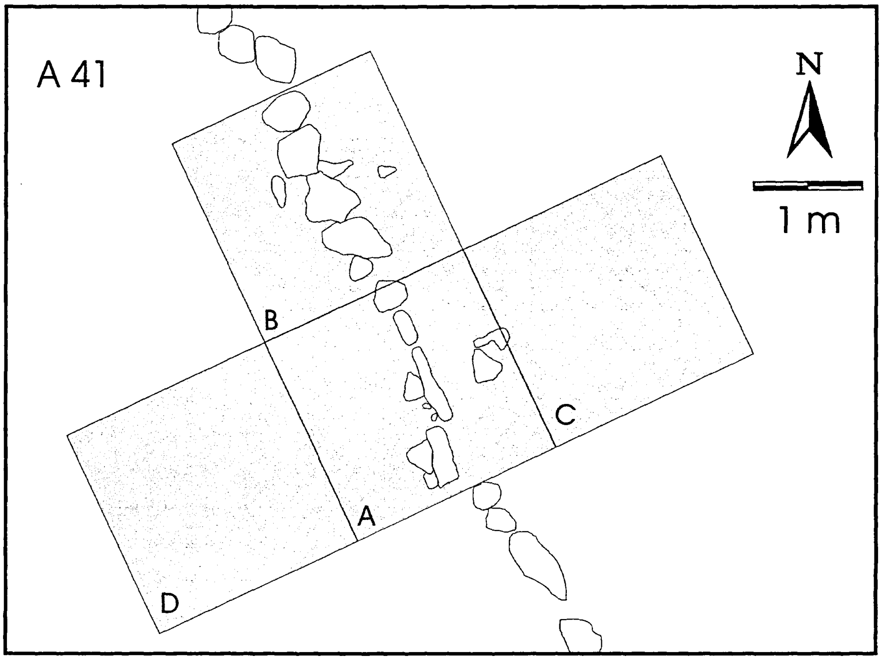

Figure 5. Plan view of Alignment 41 after excavation.

ments of what appear to be coarse redware ceramics were recovered from excavation Units A and B, but cannot be identified as to form or type.

Alignment 42

Alignment 42 (Type 2) was constructed along the southern margin of a natural depression in the limestone bedrock that measures about 30 m in diameter (FIG. 7). The depression is dominated by sawgrass and contains standing water during most of the year. The terrain surrounding the depression is primarily exposed bedrock with patches and pockets of thin soil that support a sparse swamp forest association. The lowest edge of the depression is the southern margin which faces the main body of the wetland to the south. A series of similar depressions are scattered along a low corridor that runs north from the northern end of the wetland. Three units were excavated at Alignment 42 (FIG. 8). The intensive recovery methods described above were used during the excavation of Unit A, while Units B and C were excavated by the less intensive method.

Depth from surface to bedrock averaged about 7 cm with a silty clay loam soil, that was dark reddish brown in color (Munsell color 5YR 3/4). The bedrock exposed at the bottom of each unit was broken and uneven. Excavations revealed that Alignment 42 was constructed of limestone boulders and slabs that ranged between 20 cm and 40 cm in diameter. The arrangement suggests that many of the slabs were originally placed in an upright position and supported by surrounding boulders, similar to the construction of Alignment 41. The broken character of the bedrock at Alignment 42 prohibited distinguishing whether there was a concentration of gravel along the alignment as was noted at Alignment 41. No artifacts were recovered in association with Alignment 42.

Alignment 57

Alignment 57 (Type 3) is the northernmost of a series of three alignments (53, 54, and 57) that appear to run perpendicular to a slight slope gradient that runs downward to the ssw. Alignment 57 has a distinctive zigzag shape to it. This portion of the wetland appears to flood only during the height of the rainy season, and is dominated by tasiste palm and nance trees. Soils in this zone are relatively deep in comparison with most of the wetland as well as the surrounding uplands. Two units were excavated at Alignment 57 (FIG. 9). The intensive recovery methods described above were used during the excavation of Unit A, while Unit B was excavated by the less intensive method.

Depth from surface to bedrock averaged about 20 cm. The soil was silty clay loam and dark reddish brown in color (Munsell color 5YR 3/4). Bedrock exposed at the bottom of the excavation units was very uneven and broken. Excavation revealed that Alignment 57 consists of many more rocks than are visible at the ground surface. It ap-

Figure 6. Alignment 41 after excavation to bedrock. Note boulders bracing slabs at the right end of the excavation. View facing NE.

pears that rocks were piled up to form an alignment with a fairly consistent top elevation, while compensating for low areas in the bedrock. A small amount of friable red mineral material was collected from Unit A during excavation and may represent degraded ceramics. No other artifacts were recovered in association with Alignment 57.

Alignment 11

Alignment 11 (Type 4) is one of a series of alignments (8 through 11 and 30 through 31) that run parallel to the longer margins of a wide linear depression within the southern part of the wetland. Within the linear depression, vegetation is dominated by sawgrass and cattail, while the alignment is situated on slightly higher ground to the east, where sawgrass and calabash trees predominate.

One unit was excavated at Alignment 11 (FIG. 10). Owing to difficulties with the water pump, the matrix excavated at Alignment 11 was dry-screened with 1/4-inch mesh. Samples were collected according to the intensive recovery methods described above.

Depth from surface to bedrock averaged about 20 cm. The soil was a silty clay, dark yellowish brown in color (Munsell color 5Y 4/1). The bedrock exposed at the bottom of the excavation units was undulating with some fragmentation. The excavated part of Alignment 11 was constructed of limestone boulders and cobbles that ranged from 20–50 cm in diameter. Only a few small limestone slabs were present, and the alignment is best characterized as a line of boulders with cobbles piled along the sides. No artifacts were recovered in association with Alignment 11.

Discussion and Interpretation

Human versus Natural Origin of Rock Alignments

One of the central debates over evidence for ancient Maya wetland management is the ability of researchers to distinguish features that are the result of human construction rather than products of natural formation processes (e.g., Dunning 1996: 57; Harrison 1996: 188–190; Pope, Pohl, and Jacob 1996). The rock alignments recorded as features within the El Edén wetland are of definite human construction, and can not be explained by natural processes. Excavation of Alignment 41 in particular demonstrates a consistent pattern in which limestone slabs were placed in an upright position and braced on one or both sides with boulders to hold them in place. At Alignment 41, ex-

Figure 7. Alignment 42 facing west. The alignment follows the southern margin of a small natural depression shown on the right side of the photograph.

cavations revealed that the rocks forming the alignment rested on a smooth, hard cap of bedrock, with no evidence of natural bedrock breakage or exfoliation.

The limestone slabs that were often used in the construction of the alignments can be found exfoliating around the margins of the wetland and along the margins of smaller depressions within the wetland. In a few locations, these exfoliating slabs separated from the stratified bedrock at natural "steps" in the terrain and sometimes produced an "alignment" of several flat-lying slabs. This natural formation process was easily recognizable, and could not explain the origin of any alignments recorded as features.

During survey we noted a few cases in which fallen trees had pulled several boulders and slabs into upright positions that could possibly remain erect after the tree would have rotted away. This circumstance, however, could only produce an alignment of a couple of meters at most, and we were careful not to record alignments of only a few slabs or boulders as archaeological features.

Chronology of Wetland Use

The test excavations at rock alignment features did not recover artifacts that could have been useful for assigning dates to the construction or use of the features. Only a small amount of fragmentary, red, and sometimes friable material that may represent degraded ceramic sherds was recovered. Chronological assessment of wetland use must therefore depend on dating of other nearby sites and activities associated with the wetland.

The only known human activity in the vicinity of El Edén that dates to the Historical period is associated with the *chicle* (a tree sap used for chewing gum production) and logging industry during the late 1800s and early 1900s (Andrews 1985). Rail lines were constructed in the region to transport chicle and wood for export, and one of these rail lines, known to have crossed the El Edén wetland (Fedick, Reid, and Mathews 1995), is still visible. The tracks ran along the top of a raised bed constructed of limestone boulders and gravel; still present are many wooden ties and in some places remnants of metal rails. The raised bed of the rail line is distinctly different from the rock alignments, and there is no evidence that the alignments have any association with the chicle and logging industries. An abundance of historical artifacts is associated with the rail line, and no historical artifacts were recovered in asso-

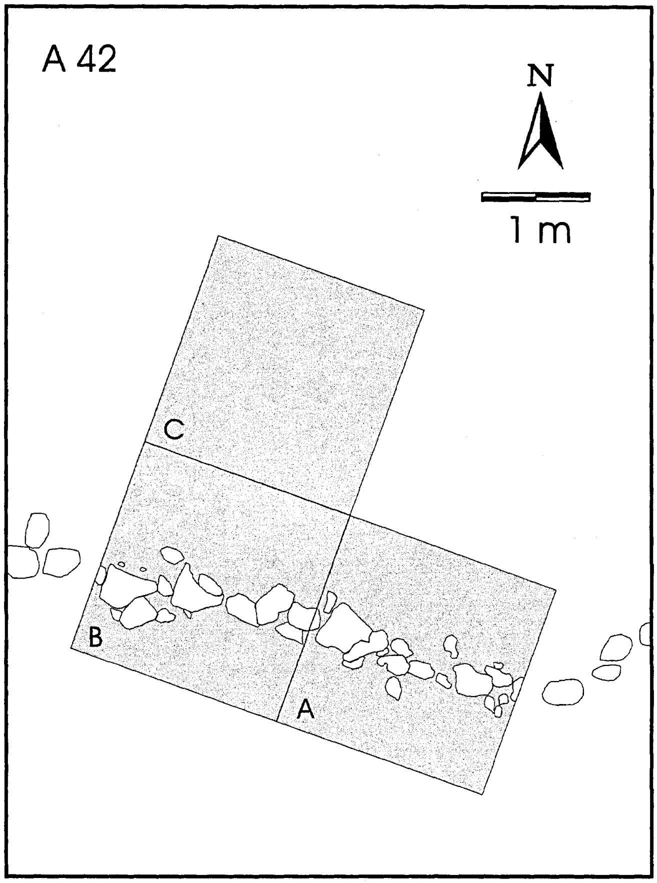

Figure 8. Plan view of Alignment 42 after excavation.

ciation with the rock alignments. Additionally, no historical artifacts were noted during survey anywhere in the wetland except with the rail line.

The closest investigated prehistoric site to the El Edén wetland is the small ancient community of Makabil, mapped and excavated by Morrison as part of a settlement study in the El Edén area (Morrison 2000). For the settlement study, a total of 64 ha was surveyed along a transect that stretches between the eastern margin of the El Edén wetland and the small center of Cenote Azul, situated 4.1 km east of the wetland (FIG. 2). Investigations focused on Makabil, a community of 60 structures with an associated cenote, located 2.7 km from the wetland margin. The site lies just east of a ridge that defines the apparent extreme high-flood zone of the wetland. A total of 17 test units was excavated off the edges of 15 structures at Makabil. A total volume of about 20 liters of ceramics was recovered during excavations, and chronologically diagnostic sherds were identified from excavation units associated with 14 of the 15 tested structures (TABLE 1). Preliminary type-variety analyses of the ceramics by Sylviane Boucher and Kevin Hovey identified the assemblage as corresponding to the Añejo complex as described by Robles Castellanos (1990) at Cobá. This complex, developing out of Preclassic complexes, but containing bichromes and showing an absence of polychromes, has been referred to as both Late Preclassic and as Protoclassic, with approximate dates of 100 B.C. to A.C. 350 (Andrews et al. 1988; Robles Castellanos 1990). Following the range of dates that is most often given for this chronological transition in northern Quintana Roo, we use A.C. 350 as the approximate termination for the Late Preclassic in the Yalahau region, while recognizing that refinement of the ceramic chronology for the northern lowlands is an ongoing process (Bey et al. 1998; Brady et al. 1998; Canché Manzanero 1992; Hernández Hernández and Chung 1995; Kepecs 1998; Peraza Lope 1999; Suhler, Ardren, and Johnstone 1998).

The ancient community of T'isil is situated about 10 km south of Makabil, and 3 km east of a large wetland that is very similar to El Edén (FIG. 2). Reconnaissance of the wetland next to T'isil has revealed a system of rock-alignment features similar to that of the El Edén wetland. Extensive surface collections made at T'isil during 1999 and 2000 provide an expanded chronology when compared to Makabil, while maintaining evidence for a mainly Late Preclassic occupation. At T'isil, surface collections from a stratified random sample of 62 structures produced a total of 2519 sherds that have been identified through type-variety analysis by Ceja Acosta (TABLE 1). Approximately 95% of the ceramics, representing all 62 collected structures, are diagnostic of the Late Preclassic period. Evidence for occupation after the Late Preclassic is sparse. Only about 1% of the ceramics, scattered among 7 structures, are diagnostic of the Early Classic period (ca. A.C. 350–600). The Terminal Classic/Early Postclassic (ca. A.C. 1000–1200) is represented at three structures by less than 1% of the total ceramics. The Late Postclassic (ca. A.C. 1200–1550) is represented at three structures, by approximately 4% of the total ceramics.

The chronology developed for the sites of Makabil and T'isil indicates that the strongest evidence for settlement in the vicinity of the El Edén wetland is during the Late Preclassic period between approximately 100 B.C. and A.C. 350. We tentatively assign these dates to the construction and use of features in the El Edén wetland, recognizing the need for further testing of this hypothesis in the future. The little evidence for Early Classic occupation at T'isil may represent a minor presence that extended into that period. It is interesting to note that 98% of the total ceramics that are diagnostic of the Terminal Classic/Early Postclassic and Late Postclassic periods were recovered from two structures that are next to each other, suggesting that

Table 1. Ceramic types identified at the sites of Makabil and T'isil.

Site	Late Preclassic	Early Classic	Terminal Classic/Early Postclassic	Late Postclassic
Makabil	Carolina Bícromo Inciso Chan Cenote Estriado Flor Crema/Huachinango Bícromo Inciso Flor Acanalado Habana Club Inciso Punzonado Huachinango Bícromo Inciso Sierra Rojo Tancah Burdo			
T'isil	Chan Cenote Estriado Carolina Bícromo Inciso Flor Huachinango Bícromo Inciso Laguna Verde Inciso Lagartos Punzonado Polvero Negro Repasto Negro Sobre Rojo Sierra Rojo Tancah Burdo Xabaná Rojo	Actuncan Naranja Policromo Batres Rojo Saban Burdo Tituc Naranja Policromo	Dzibiac Rojo Xcanchacán Negro Sobre Crema	Chen Mul Modelado Impresión Textil Burdo Mama Rojo Matillas Naranja Fino Navúla Burdo Payil Rojo

they might represent a small group of people that reoccupied the site after a long abandonment (see Lorenzen 1999 for a discussion of Late Postclassic presence in the Yalahau region). Known activities of the Historical period in the vicinity of El Edén are restricted to chicle and logging operations that would not have involved wetland management.

Environmental Change

The interpretation of ancient use of the El Edén wetland must take into account evidence that the climate and hydrology of the region has probably not remained constant over time. Recent studies suggest that climate (and by extension, seasonal variability in the water table) in the northern Maya Lowlands has fluctuated through the last 3000 years (Curtis, Hodell, and Brenner 1996; Hodell, Curtis, and Brenner 1995; Leyden et al. 1994; see also Gill 2000). Analysis and interpretation of a lake sediment core from Punta Laguna, just south of the Yalahau region, indicate a rather dramatic shift to drier conditions beginning about A.C. 280, and continuing until about A.C. 1080 (Curtis, Hodell, and Brenner 1996: fig. 6). The onset of the dry period at about A.C. 280 coincides quite closely with the apparent abandonment (or near abandonment) by about A.C. 350 of the two settlements (Makabil and T'isil) most closely associated with the El Edén wetland.

Other studies have identified a trend in sea-level rise that continued at a gradual rate after the Pleistocene, in turn raising the water table of the karstic Yucatán Peninsula (Alcala Herrera et al. 1994; Coke, Perry, and Long 1991; Dunn and Mazzullo 1993; Fairbanks 1989; Folan, Kintz, and Fletcher 1983: 43–48; McKillop 1995). Current evidence suggests that the water table of the Yalahau region may have been lower than today, possibly by as much as a meter, when nearby settlements were occupied during the Late Preclassic/Early Classic periods. If this were the case, the El Edén wetland would still have been a wetland, but with lower flood levels and shorter hydro periods.

Construction Technique and Function

Ancient rock-alignment features in non-wetland settings are widespread in the northern lowlands, but the context, form, and apparent function differ significantly from the features recorded in the El Edén wetland. Elsewhere in the northern lowlands, rock alignments have been recorded in well-drained upland settings as *albaradas* (stone walls), and are interpreted as ancient boundary markers, most often enclosing household compounds, and sometimes delineating nearby plots apparently used for intensive cultivation or for protection and cultivation of useful trees (e.g., Andrews and Andrews 1975; Bullard 1952, 1954; Fletcher 1983; Fletcher and Kintz 1983; Freidel and Sabloff 1984; Gómez Pompa, Flores, and Sosa 1987; Goñi Motilla 1993; Kepecs and Boucher 1996; Morrison 2000; Sierra Sosa 1994; Silva Rhodes and María del Carmen Hernández 1991; Vlcek, Garza de González, and Kurjack 1978). In Maya villages today, enclosed household compounds are known as *solares*, and contain the various domestic structures used by a family, as well as open activity space, a variety of useful trees, enclosures for domestic animals, and

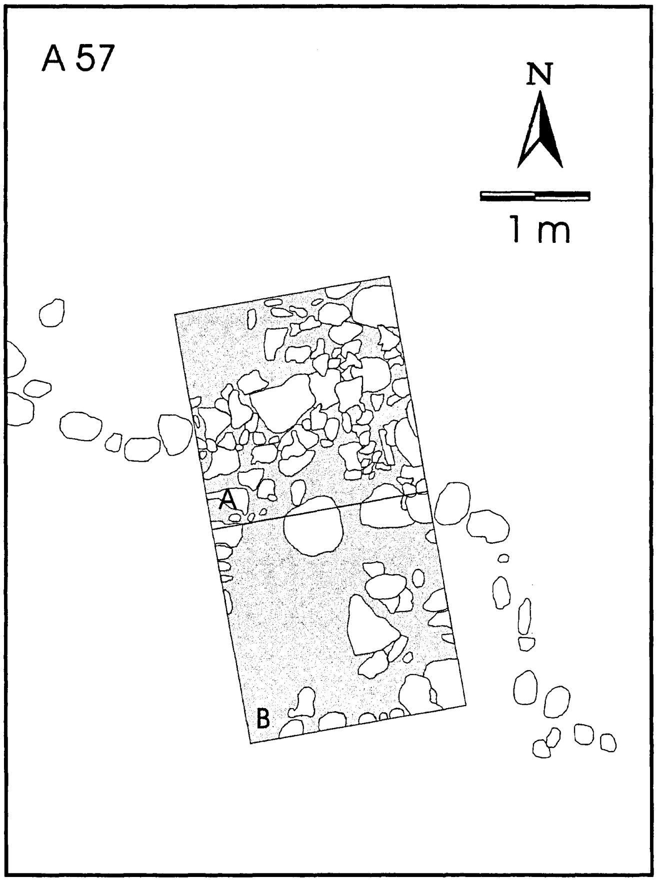

Figure 9. Plan view of Alignment 57 after excavation.

home gardens (Acosta Bustillos, Flores, and Gómez Pompa 1998; Anderson 1993, 1995; de Jong 1999; Fletcher and Kintz 1983; Herrera Castro 1994; Herrera Castro et al. 1993; Ortega et al. 1993). Wall systems such as these have been recorded within the Yalahau region at the ancient communities of Makabil and T'isil, and we interpret those features as boundary markers that define ancient solares (Morrison 2000). In contrast, the rock-alignment features within the El Edén wetland are in a very different physical context (a wetland), do not enclose spaces, and are not in direct association with any domestic architecture or other features.

The El Edén wetland features are not reminiscent of the salt pans described by Anthony Andrews (1983) for the coastal marshes, where earthen berms are constructed, sometimes over or around logs, wooden stakes, and rock alignments, to form rectilinear evaporation enclosures (see also Sierra Sosa 1999: 43). The El Edén wetland is far enough from the coast to exclude brackish water intrusion. It is highly unlikely that salt production could ever have been a function of the El Edén wetland features, as sea level in the past was lower than today, limiting brackish water intrusion in the past to areas farther north than we see currently in the Yalahau wetlands.

The features most similar to anything in the El Edén wetland are the features interpreted as dikes within the shallow margins of Lakes Cobá and Macanxoc, located within the site of Cobá, about 50 km south of the Yalahau region at the terminus of the Holbox fracture zone (Folan 1983: 43–44, figs. 3.14, 3.15). The Cobá dikes appear superficially similar to El Edén Alignment 41, the 700 m alignment that closes off the northern end of the wetland. The Cobá dikes seem to be more substantial features, and are associated with a body of water that is significantly deeper than the Yalahau wetlands. There is no evidence that the Cobá lakes were ever modified for agricultural purposes, and sediment studies at Lake Cobá suggest to investigators that the dikes were constructed at about A.C. 380 in order to form a reservoir (Leyden, Brenner, and Dahlin 1998).

Further studies will be necessary in order to determine the exact function of the rock-alignment features and the nature of wetland management at El Edén. Some preliminary hypotheses, however, have been developed and are currently being investigated. Based primarily on the results of excavations at Alignment 41, it is suggested that at least some of the rock alignments represent the foundations, or internal support structures, for earthen berms that were constructed to control the flow of water in the wetland during rains.

Most of the rock alignments identified so far are situated around the sloping margins of two large depressions in the northern and southern ends of the wetland (FIG. 3) that represent the most extensive tracts of relatively deep soil, now dominated by sawgrass and cattail. If the water table was significantly lower during the time when the wetland was under management, then a major portion of the wetland would have been spared from flooding, except perhaps during the height of the rainy season. The long alignments closing off the north end of the wetland may have served as breakwaters or dikes to protect cultivated areas from runoff being channeled by natural relief into the wetland from the north. Within the main body of the wetland and between the two largest depressions, alignments that run perpendicular to gentle slopes may have functioned to slow runoff and encourage sediment deposition. Where natural channels occur within the wetland, the cross-channel alignments would have functioned as check dams to slow the rush of rainwater into the large, lower depressions. The check dams would also facilitate the buildup of sediments behind their walls and within associated depressions, which could also have been used for cultivation.

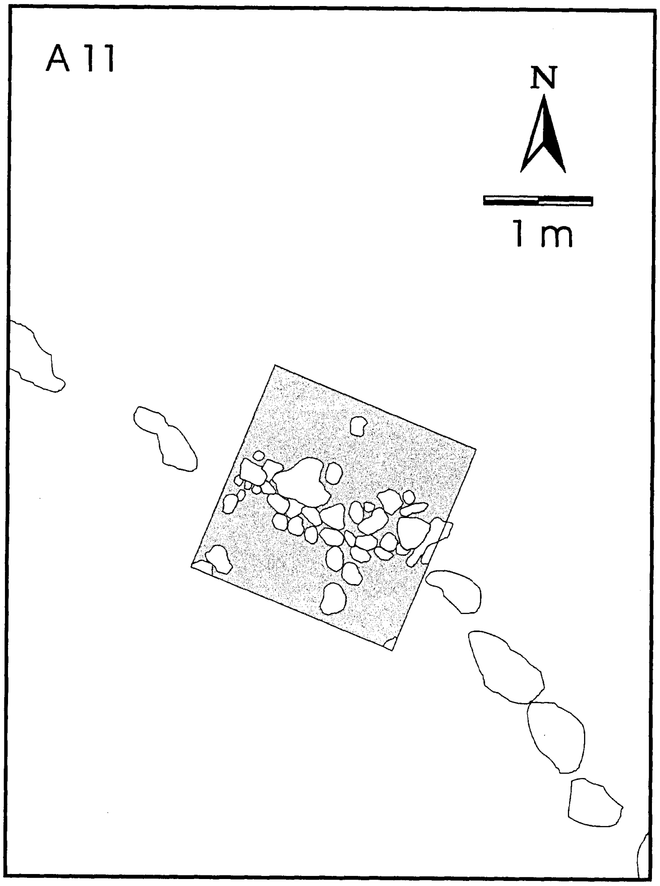

Figure 10. Plan view of Alignment 11 after excavation.

The seasonality of cultivation would have been dependent on the hydrological regime active at the time of use, but it is likely that planting would have been scheduled either as a flood-recessional system at the close of the rainy season, or as a late dry-season crop, referred to today as a *marceño* (March), that involves the planting of maize varieties (or other crops such as cotton) that are tolerant of flooding (see Carter 1969; Culbert, Magers, and Spencer 1978; Gliessman 1991; Wilk 1985; Wilken 1987: 149–151). Unfortunately, pollen preservation in samples from the excavations at the rock alignments was very poor and provided no evidence of domestic crops.

We are also exploring the possibility that ancient management of the wetlands may have functioned to increase the productivity of wetland resources as an alternative or supplement to cultivation of domestic crops such as maize or cotton. The abundance of edible wetland resources such as cattail, tasiste palm, and apple snails is determined in large part by hydrological conditions that could have been manipulated by the ancient Maya to increase productivity of these resources. Another intriguing possibility is that the abundant periphyton that grow within the El Edén wetland may have had a significant role in the agricultural ecology of the region. Preliminary analysis of periphyton samples from El Edén by Ana Luisa Anaya, a chemical ecologist with the National Autonomous University of Mexico, indicates very high levels of phosphorus, nitrogen, and organic matter, and a very high cation exchange capacity—all indicators of high fertility for plant growth (Vymazal and Richardson 1995). Moreover, phosphorus is the primary limiting nutrient for agriculture in the northern Maya Lowlands. We are exploring the possibility, along with our colleagues, that periphyton could have functioned as a natural, renewable, and manageable source of agricultural fertilizer. Dried periphyton could have easily been transported and applied as fertilizer in home gardens or upland agricultural fields.

Extent and Intensity of Wetland Manipulation and Comparison with Other Areas

Based upon the evidence collected from the El Edén wetland, it is anticipated that other wetlands of the Yalahau region were also managed, with techniques varying to suit the specific physical settings of the individual wetlands. Reconnaissance has already identified a system of rock-alignment features within the wetland located just south of El Edén, on the lands of Rancho Santa Maria and in association with the ancient community of T'isil.

The extent of wetlands within the Yalahau region is comparable to that of the wetland zone associated with the New River and Río Hondo of northern Belize, currently the most studied area of ancient wetland management in the southern Maya Lowlands (e.g., Berry and McAnany 1998; Harrison 1996; Pohl 1990; Pohl and Bloom 1996; Pohl et al. 1996; Pope, Pohl, and Jacob 1996; Turner and Harrison 1983). Although comparable in geographic scale, the wetland management systems of northern Belize and the Yalahau region are very dissimilar. The wetlands of northern Belize, as is the case with other reported sites of ancient Maya wetland management in the southern lowlands (e.g., Culbert, Levi, and Cruz 1990; Culbert et al. 1997; Gliessman et al. 1983), were manipulated either by digging canals through the deep soils of the wetland margins, or by constructing raised planting platforms within the main body of the wetland. Neither of these management techniques is evident in the El Edén wetland, where control of water and retention of sediments was facilitated by check dams, dikes, and various other features represented today by rock alignments.

How intensively the Yalahau wetlands were managed is not yet known. Although the features recorded at El Edén do represent a substantial investment of labor, the features would certainly represent a lower labor investment than the construction of raised-bed wetland cultivation systems, and may be comparable with lower-intensity systems of channelized fields.

Conclusions

Investigations within the El Edén wetland and at sites in the immediate vicinity provide evidence for a previously unreported form of wetland management in the Maya Lowlands, most likely to have been in use during the Late Preclassic period, between approximately 100 B.C. and A.C. 350. The numerous rock alignments recorded in the wetland apparently represent features that functioned to control the movement of water and soil within the natural depression, allowing either the cultivation of domestic crops or the encouragement of edible or economically useful wetland resources. Features similar to those in the El Edén wetland are known to exist in at least one adjacent wetland, and if common throughout the wetlands of the Yalahau region, would represent a major region of wetland management.

The cause of the apparent abandonment of settlements associated with the El Edén wetland by about A.C. 350 is not known, although a strong possibility exists that the hydrology of the wetlands may have been altered by the onset of an extended dry period at about that time, in combination with a gradually rising water table. Changes in hydrology may have rendered the El Edén wetland unsuitable for management, as has been suggested for wetland systems in northern Belize (Pohl, Bloom, and Pope 1990; Pohl et al. 1996; Pope, Pohl, and Jacob 1996). Rather than focusing on the abandonment of the El Edén wetland management system, it may be more useful to view use of the wetlands during the Late Preclassic as taking advantage of natural conditions when they were at an optimum for economic production. The management of wetlands in the Yalahau region represents another innovative form of landscape manipulation and resource use within the complex mosaic of ecosystems that constitute the Maya Lowlands.

It is increasingly apparent that ancient Maya agriculture was not based on any single cultivation system or even on a fixed set of techniques. Rather, it was an innovative and flexible system that took advantage of local resource endowments and was able to adjust and adapt to changing conditions in a manner that sustained large regional populations over many centuries within a landscape best considered a managed mosaic (Fedick, ed. 1996).

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