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Ancestral Maya domesticated waterscapes, ecological aquaculture, and integrated subsistence

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Abstract

Ancestral Maya engineered wetland fields and canals in floodplains for plant cultivation and water management. Canals and reservoirs, however, also provide aquatic resources to supplement agriculture. Maya created multi-trophic ecological aquaculture by modifying the waterscape to increase the amounts of foods and useful materials, such as fish, turtles, waterfowl, and reeds. While archaeological and ethnographic investigations across the Maya area explore aquatic constructions, technology, and foodstuffs, they have not focused on aquaculture. In the western Maya lowlands, including the site of Mensabak, Chiapas, Mexico, ancestral Maya modified floodplains around lakes and rivers for farming fish and aquatic resources near their settlements and fields. These extensive modifications for ecological aquaculture enhanced the productivity and resiliency of natural ecosystems. The domesticated waterscapes near the ritually important Mirador Mountain at Mensabak also followed pan-Mesoamerican beliefs in origin mountains that generated water, plants, and fish for humans. Importantly, Maya integrated subsistence is illuminated by research on domesticated landscapes and ecological aquaculture that examines a range of resources rather than just plants. Certainly across Mesoamerica, ecological aquaculture allowed people to intensify production of "farms" of aquatic species, particularly fish.

Resumen

Este artículo trata sobre la subsistencia integrada de la cultura maya que ha incorporado recursos acuáticos de los canales y reservas de agua asociadas con los campos agrícolas. La agricultura fue central para la civilización maya a través del tiempo, sin embargo, en algunos sitios alrededor de ríos, lagunas, y pantanos se practicaba y la acuicultura ecológica que consiste en el manejo multitrófico de las especies de plantas y animales asociados con los canales, reservas de agua y los campos agrícolas. En lugar de enfocarse solamente en la agricultura en estos campos, algunas poblaciones mayas domesticaron sus paisajes acuáticos y terrestres para obtener una variedad de comidas y materiales útiles, como el pescado, las tortugas, los patos, los moluscos, las palmas, y los carrizos, entre otros. En el caso de las modificaciones del paisaje acuático en el sitio de Mensabak, Chiapas y, en las tierras bajas mayas occidentales, se muestra la importancia de la subsistencia integrada desde tiempos antiguos hasta el presente con los mayas lacandones. En Mensabak, los mayas crearon y domesticaron su paisaje cultural alrededor de la montaña de agua (*altepetl*) sagrada, como la de Aztlan de los aztecas, que los lacandones actuales llaman *Chak Aktuun* (Rojo-Cueva/Tortuga/Montaña de agua) o El Cerro Mirador. Según las prácticas y creencias mesoamericanas de modificación del paisaje acuático, éstas ayudaron a los mayas a obtener más proteínas y recursos para ampliar su "listado de comidas" (*subsistence spreadsheet*) según los estudios comparativos de "paisajes domesticados," "acuicultura ecológica," y "ecología de subsistencia." La acuicultura ecológica maya que envuelve los canales y reservas de agua extensas, ayudó a mantener los ecosistemas modificados a lo largo del tiempo porque se parecía a la ecología natural de aguas, tierras, especies de animales y plantas nativas. La importancia de estos paisajes acuáticos domesticados se observa en los sitios arqueológicos a través de la iconografía del pescado y el paisaje y los huesos de pescado, tortugas y patos. La existencia de canales, aguadas y trampas de pescado en varios sitios mayas investigados como Edzná, Lagartero, y Kaminaljuyú, puede vincularse también a otras regiones de Mesoamérica, como en el Altiplano central mexicano, Jalisco, y Veracruz, donde el paisaje domesticado y la acuicultura ecológica se encuentra en campos agrícolas (chinampas o *camellones*) al lado de obras hidráulicas.

Keywords: Maya; ecological aquaculture; aquatic resources; fish; integrated subsistence; Mesoamerica

Introduction

Analyses of ancestral Maya canals, reservoirs, and raised fields solely for agriculture has prevailed in archaeological research. Yet Maya populations, like other people living near modified waterscapes, have focused on integrated subsistence from various sources, not just agriculture. Maya indeed cultivated plants across time, but they also gathered and "farmed" much food from their domesticated environments, including wetlands. Furthermore, while water management is crucial for agriculture and drinking water, the waterscapes are also important for fish, insects, and water

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(a)

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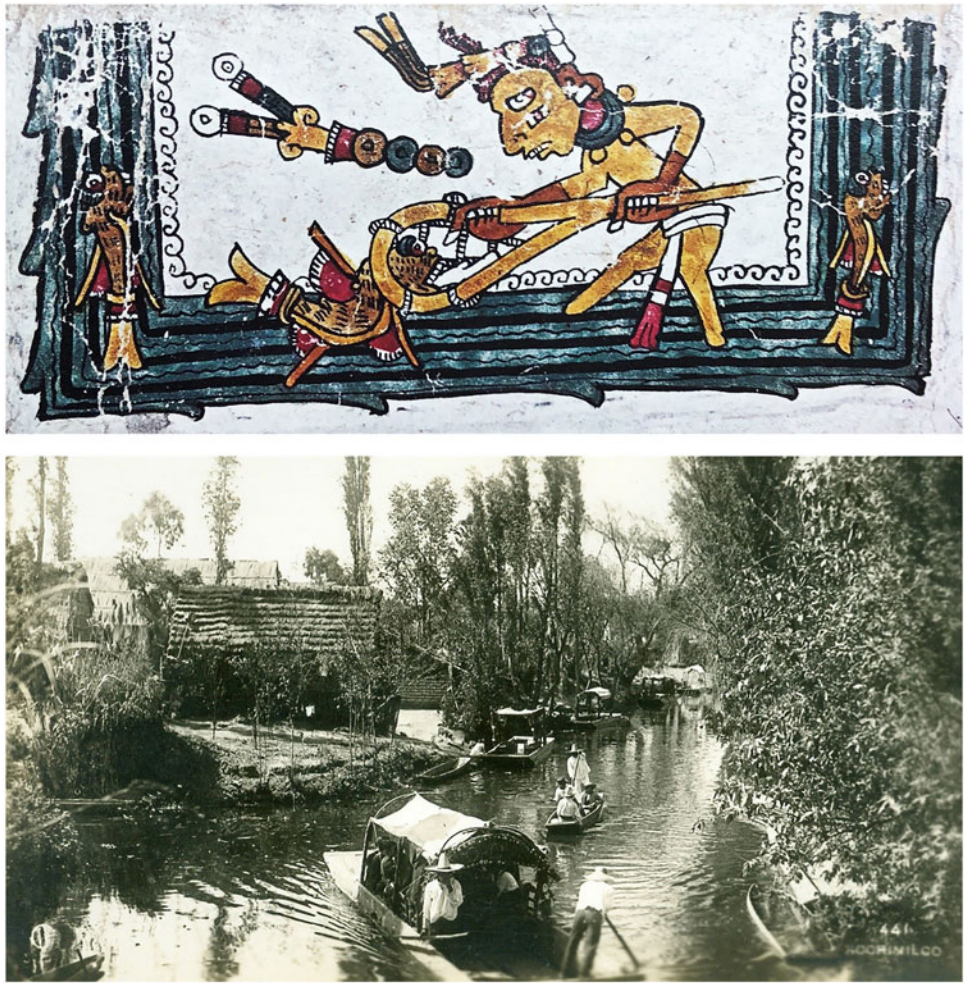

Figure 1. Fishing and integrated subsistence in central Mexican domesticated waterscapes. (a) Postclassic noose or net fishing in a shallow canal or at a *chinampa* raised field. Codex Borgia, p. 13. Public domain, Wikipedia. (b) Fishers and farmers at Xochimilco *chinampa* wetlands, ca. 1900. Historic photograph courtesy of the author.

plants useful to humans. Significantly, aquatic and terrestrial resources are intertwined in the use of human-modified lakes, *chinampa* raised fields, and canals (Figure 1) in central Mexico (De Lucia 2021; Gómez-Pompa et al. 1982; Parsons 2006; Pérez Espinosa 1985). In this article, I focus on similar, but often-neglected, ancestral Maya domesticated waterscapes and aquaculture dietary resources, particularly fish. I advocate for an aquaculture-based Maya subsistence regime where aquatic resources from canals and reservoirs supplemented irrigation agriculture in many areas. Select Maya populations, such as modern Lacandon communities in Chiapas and Chontal Maya in Tabasco, Mexico, for example, include fishing as a main dietary practice. New archaeological, ethnohistoric, and ethnographic insights presented here, in addition to comparative studies on modern Maya ecological aquaculture and integrated subsistence, indicate that both plant and fish resources, and not just agriculture, should be considered when researching ancestral canals, wetland cultivation, and raised fields.

Insights on ancestral Maya water management and intensive agriculture, including ecological aquaculture, help explain why Maya canals and raised fields pre-date large cities and ruling elites (Pohl et al. 1990, 1996). Waterscape domestication by Maya families allowed increased access to aquatic, forest, and terrestrial products besides cultivated crops. Maya and Mesoamerican people following integrated subsistence express connections culturally between aquatic and agricultural resources, like the Nahua "water mountain" (*altepetl*), Huichol "green corn is fish [with both] carried in nets," and Mixtec creation places combining land, maize, water, and fish symbolism (Taube 1986:58). Mesoamerican iconography also attests to integrated aquatic and terrestrial subsistence practices and not just agriculture. I refer to Maya and Olmec art that illustrates fish, crustaceans, and water plants, in addition to the Tepantitla murals at Teotihuacan (Figure 2) depicting a cleft water mountain on a lake with canals supporting fish and plants in wetland fields and fish ponds (*camellones*) harvested by people (Taube 1986). Elite ancient Maya art (Figure 3) depicts fish and headdresses with fish and water-lilies (Arroyo and Henderson 2020; Puleston 1977; Taube 1986), symbolizing elites' divine ties to aquatic origin places

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Figure 2. Integrated Mesoamerican subsistence at a cleft sustenance-water mountain (*altepetl*) with canals with fish leading to a fishpond (not shown; see Lozoya 1999:Figure 1) and wetland *chinampas* or *camellones* on the Tepantitla Mural, Teotihuacan, central Mexico. Public domain, Wikipedia.

and resources for their communities. Similarly, modern Lacandon Maya make ceramic figurines for the guardian of the fish (*xok*; Figure 3), who releases her fish children for community consumption in exchange for ritual offerings.

In this article, I discuss Maya ecological aquaculture and integrated subsistence with wetland fields, canals, and fish ponds in the context of intensive fish farming and domesticated landscapes. Essential information from previous research on ancestral Maya wetland features and archaeological fish bones are also outlined. I then examine domesticated waterscapes through evidence from the western Maya lowlands of Chiapas and Tabasco while focusing on new archaeological and ethnographic information from Mensabak in Chiapas, Mexico. While created in the past, some large-scale ancestral Maya canals and raised fields are still used for cultivation and fishing, like canals and reservoirs at Edzna, Campeche, and Pulltrouser Swamp in Belize (Faust 1999; Harrison 1993; Matheny et al. 1983; Puleston 1978), which emphasizes their ecological sustainability. Furthermore, I present Maya domesticated waterscapes in the contexts of research on water management and intensive integrated subsistence. I add insights through comparative studies of ecological aquaculture and domesticated landscapes, which recognize the integration of terrestrial and aquatic resources when available. I will concentrate on how ancestral Maya in the western lowlands have harvested fish, but also turtles, water fowl, and reeds, from managed waterscapes near their agricultural fields, like other global populations exploiting large-scale aquaculture ecosystems for intensive, integrated subsistence. Information on Maya canals and wetland fields will be presented along with findings of fish in the Maya diet across time. For lack of space and data, I do not treat issues related to political or historical ecology, sustainability, environmental science, and evolutionary biology. Furthermore, I leave considerations of inherited ecologies, labor and resource management, and religious landscape ideology for future publications.

For my discussion of Maya aquatic resources and integrated subsistence, I follow the comparative perspectives of "domesticated landscapes" in anthropology and biological sciences, where humans enable mutual benefits between plant and animal populations through ecosystem modifications (Baker 2007; Erickson 2000b; Fedick 1996; Puleston 1978; Roosevelt 2000; Smith 2011; Varela Scherrer and Liendo Stuardo 2022). In domesticated landscape studies, investigators contextualize resource utilization and knowledge for human survival in an interactive species matrix (Terrell and Hart 2008:331; Terrell et. al 2003:323, 333). Domesticated landscapes (and waterscapes) allow societies to adapt to their surroundings, flourish in particular environments, and diversify their provisioning of everyday foods and useful materials. This analysis results in a complete subsistence "spread sheet" for a bigger picture of human adaptations and modifications of their surroundings for survival. Furthermore, knowledge of integrated subsistence from domesticated waterscapes with both terrestrial and aquatic resources is critical to biological and ecological studies of freshwater aquaculture (Brugere 2006; Costa-

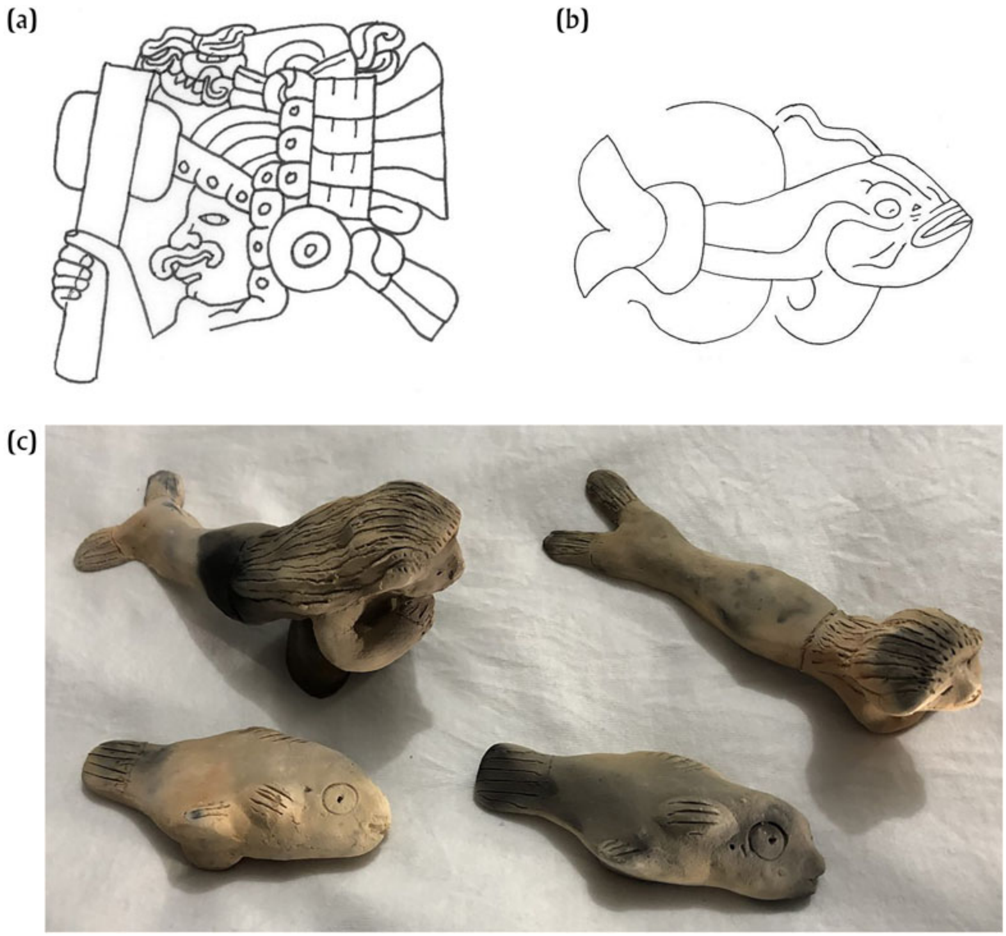

Figure 3. Fish in Maya art. (a) Catfish (?) on a ruler's headdress, Sculpture 24, Kaminaljuyu, Guatemala. Redrawn from Arroyo and Henderson (2020:149). (b) A bass (*robalo blanco)* or cichlid (*mojarra*) as the main motif on Kaminaljuyu Stela 3. Redrawn from Parsons (1986:Figure 9). (c) Modern Lacandon ceramic figurines of fish (*mojarra*) and human female-fish deities (*xok*). Photograph by the author.

Pierce 2014a; Li 1994; Yang 1994a) on which I focus. These specialists do not just examine water management and wetland agriculture, they consider aquatic foods and domesticated waterscapes with fish, plants, invertebrates, and crop management in integrated ecological aquaculture (Chopin 2013; Costa-Pierce 2014b; Edwards 2015; Renard et al. 2012; Welcomme 2003; Yang 1994b). The interactions between aquatic and terrestrial realms for human subsistence are more complex than watering plants with canals and controlling water. The aquatic plants and organic matter in the waterscapes, especially nitrogen from fish, provide crucial nutrients for cultivated plants. The plants in turn provide shade and sustenance from insects and detritus to fish, turtles, frogs, and aquatic birds subsequently captured in the restricted canals and reservoirs. Hence, many ancestral Maya people domesticated their waterscapes for the benefit of aquatic species, especially fish, and ultimately for themselves.

Research on ancestral Maya wetland cultivation and monumental raised-field and canal works, for instance, does not pay sufficient attention to the fish, turtles, birds, and plants in the integrated subsistence regime created by people over time. Several investigators have mentioned the potential of domesticated waterscapes for fish protein and plant resources, including useful palms and reeds, and even insects (Parsons 2006; Varela Scherrer and Liendo Stuardo 2022; Williams 2022a, 2022b; Wiseman 1983), but few scholars have explored their complete subsistence and resource potential. Subsequently, future investigators can study ecological aquaculture and integrated subsistence by recognizing the potential in the domesticated waterscapes, water management, and wetland agriculture in the Maya area and across the world as a managed resource mosaic (Fedick 1996; Ford and Nigh 2015; Gómez-Pompa 2003).

Background: Maya wetland agriculture and water management

In examining domesticated waterscapes, a summary of research on ancestral Maya wetland agriculture and water management is necessary. Ancestral Maya waterscape studies have kept a taut focus on wetland agriculture and cultivated fields (Beach et al. 2013; Dunning et al. 2020; Hansen et al. 2002; Lentz et al. 2022; Lucero 2006; Turner and Harrison 2000). In specific areas, ancestral Maya dug canals in floodplains and placed sediments on adjacent fields or

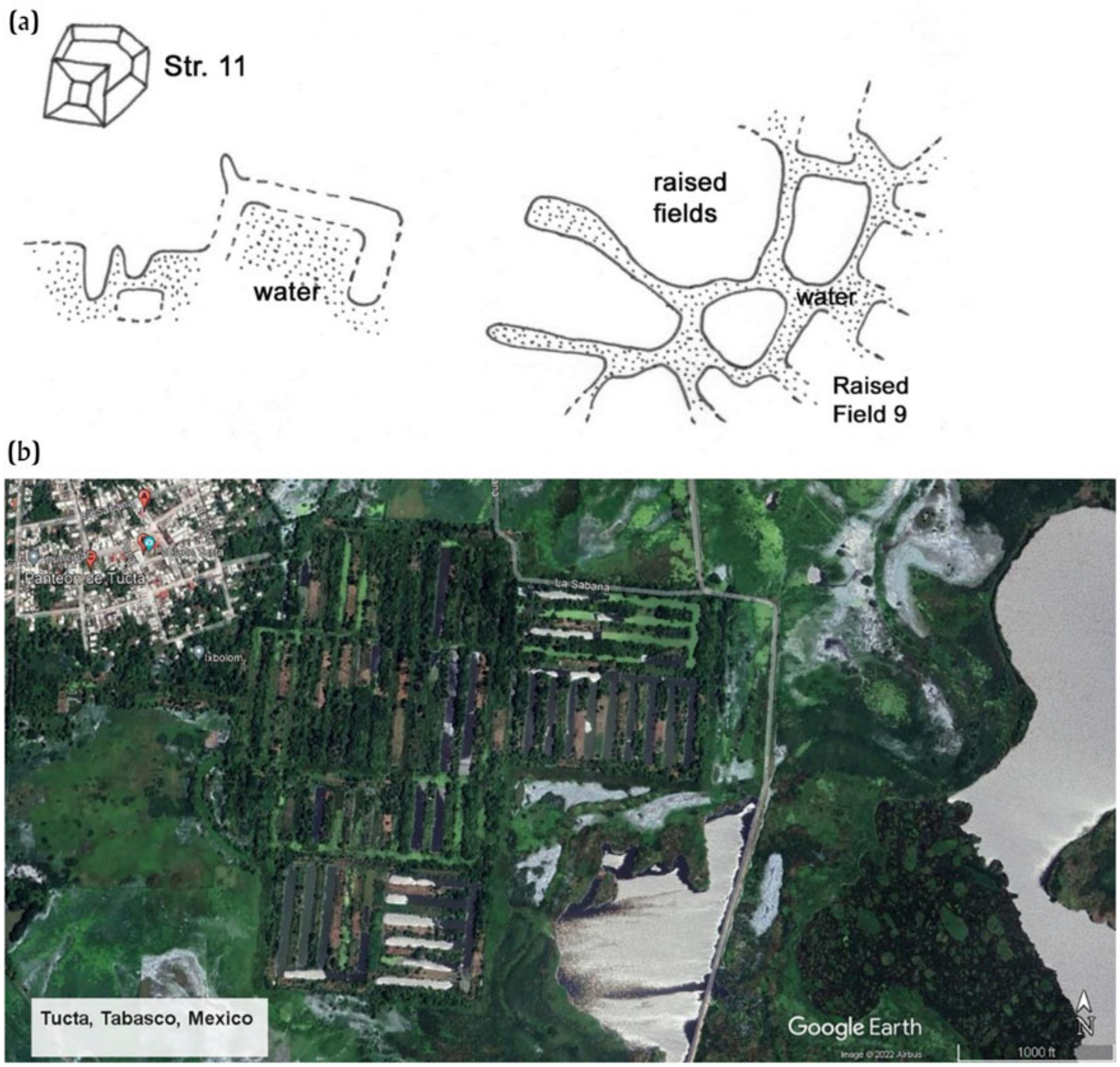

Figure 4. Maya Wetland features. (a) Raised fields and canals at the ancestral Pulltrouser Swamp site, Belize. Redrawn from Harrison and Fry (2000:Map 6). (b) Modern Chontal Maya *camellones* near reservoirs for farming and fishing at Tucta, Nacajuca District, Tabasco, Mexico. Image from Google Earth.

agricultural zones. Investigators have studied how intensive wetland agriculture was undertaken (Figure 4) by Maya managing canal construction and irrigation since Preclassic times (ca. 1000 B.C.–A.D. 200; Hansen et al. 2002; Pohl et al. 1996). They have also examined Classic period (ca. A.D. 200–950) canals and reservoirs to examine ancestral Maya water control, elite labor management, and intensive agriculture in wetlands and adjacent lands (Beach et al. 2013; Canuto et al. 2018; Gunn et al. 2014; Pohl et al. 1990; Scarborough 1998). Furthermore, scholars have investigated reservoirs for water storage and canals for drainage for Maya agriculture while briefly mentioning that they teemed with fish (Arroyo and Henderson 2020; Beach et al. 2019; Harrison 1993; Harrison-Buck 2014; Masson 2004; Matheny et al. 1983; Pohl 1985; Wiseman 1983). Researchers have even noted that Maya people still fish in the canals and reservoirs (Faust 1999; Harrison 1993; Puleston 1978; Thompson 1974). Scholars studying Postclassic Maya societies (A.D. 950–1525) who shifted their settlements near water have examined fish resources, particularly in marine environments (Alexander et al. 2013; Jiménez-Cano 2019). Few researchers, however, have investigated reservoirs, canals, and lakes for Maya ecological aquaculture and integrated subsistence. They typically do not examine hydraulic engineering to maintain fish, turtle, and mollusk populations, among other plant and animal species. Like domesticated landscapes where terraces and fields support plant and human communities, people domesticate waterscapes for reliable food.

Earlier studies of waterscapes incorporating ethnographic observations briefly explored Maya fishing in canals with substantial fish populations (Denevan 1970; Harrison 1996; Matheny et al. 1983; Puleston 1977; Siemens and Puleston 1972; Thompson 1974; Turner and Harrison 2000). These observations were bolstered with historic Maya sources mentioning fishing in river floodplain canals and lagoons in Tabasco (Figure 4; Gómez-Pompa et al. 1982; Pohl 1985). Yet, scholars have not synthesized

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archaeological, ethnographic, or scientific data on Maya fishing in canals and reservoirs diachronically, as I do here. Additionally, few investigators mention Maya domesticating extensive waterscapes for integrated ecological aquaculture for supplemental protein for agriculture (Chopin 2013; Costa-Pierce 2014b; Li 1994). Archaeologists excavating wetland fields and canals, however, have demonstrated the importance of fish for ancestral Maya through the recovery of fish bones (Carr 1985; Thornton 2012). Additionally, a project at Albion Island, Belize, retrieved fish bones in canal and raised-field deposits dominated by catfish (*bagres*) and cichlid species (*mojarras*; Pohl et al. 1990:263), which thrive in ecological aquaculture. Specific fish species, however, are difficult to identify from small bones.

Investigators working on Maya canals, wetlands, and raised fields have not acquired much cultural and scientific data on ancient to modern fishing and aquaculture. Instead, they concentrate on wetland cultivation, water storage in reservoirs, canals for draining fields, and water management to mitigate flooding and drought, which were important for Maya civilization (Dunning et al. 2022; Hansen et al. 2002; Gunn et al. 2014; Lucero 2006; Luzzadder-Beach et al. 2016). Investigators also concentrate on crop productivity, soil qualities, and plant diversity for human use on the shores of lakes and canals (Beach et al. 2019; Darch 2000; Harrison 1993; Lentz et al. 2022). But through aquaculture perspectives, plants near canals and ponds were also important for maintaining fish populations, since they give shade, food, nutrients for invertebrates, in addition to water filtration. Where rivers, lakes, and seasonal waterscape flooding are found, canals and reservoirs produce many useful plants in addition to fish (Denevan 1970, 1982; Harrison-Buck et al. 2020; Turner and Harrison 2000). The canals connecting to rivers effectively bring in freshwater, nutrients, and fish to the reservoirs. In one case, an array of canals, raised fields, and reservoirs adjacent to the Candelaria River at the site of El Tigre presents an example of Maya floodplain agriculture and integrated ecological aquaculture over the last 2,000 years (Siemens 1978). These features were dug in swamps with fluctuating water levels between rainy versus dry seasons. Their extensive sizes, which add air exposure, increase water oxygenation for fish. Their ample constructions also allow for extensive foliage growth within the waterscapes providing food to invertebrates and fish to power the subsistence system.

Archaeologists have also found construction features, including berms, walls, and stone alignments, in Maya waterscapes (Berry and McAnany 2007; Fedick 2003; Hansen et al. 2002; Harrison 1996; Matheny and Gurr 1979; Pohl et al. 1990; Scarbourough 1991; Siemens and Hebda 2009; Turner and Harrison 2000). Variable Maya dredging techniques and filling with clay, sand, and stone have been noted. These investigations also identified stacked stone retention walls, clay liners, and earthen berms for dams, clay canal walls, and probable linear stone weirs or fish traps. In some projects, wooden poles, or possible fish weirs, were recovered in waterlogged deposits (Lowe and Alvarez Asomoza 2007; Pohl et al. 1990:218–221), but their function was not explored. Archaeologists also found carbonized and waterlogged plants from the canals and fields (Darch 2000). The burning effectively fertilized the aquaculture system. The findings demonstrate that ancestral Maya cultivated a variety of plants, including maize, squash, cassava, and cotton (Beach et al. 2019; Puleston 1977:454–455), which also benefitted fish populations.

Cross-cultural studies also provide informative perspectives on wetland resources, especially fish. In this vein, African artificial floodplain fish pools ("finger ponds") and Amazonian fish ponds used for ecological aquaculture are similar to ancestral Maya canalized wetland cultivation and raised fields (Erickson 2000a, 2000b; Welcomme 1975:26). Comparative Amazonian floodplain reservoirs farmed by communities have produced between 100,000–400,000 fish per hectare or 1,000 kg of fish per hectare per year (Erickson 2000a:191). In Africa and Asia, some 500–700 kilograms of fish per hectare have been raised (Welcomme 2001:139). Similar amounts of fish could have been extracted in ancestral Maya ecological aquaculture. Comparative research in the Americas has also demonstrated that many types of fish remains, in addition to wooden posts and stones for fish weirs, materials for smoking fish, cooking areas, stone cutting tools for processing fish, net fragments and weights, projectile points, and hooks can be archaeologically recovered (Connaway 1982; Lyons 2015; McKillop and Aoyama 2018; Rice et al. 2017; Rodríguez Galicia 2017; Yu 2015). Therefore, people living in sites on floodplains or near wetland fields, reservoirs, and canals in various parts of Mesoamerica may also have intensified aquatic resource production (Ebel 2019; Guzmán and Polaco 2002; Morehart 2016; Sluyter 1994; Stoner et al. 2021; VanDerwarker 2006; Weigand 1993) giving ecological aquaculture and integrated subsistence significant research potential. Instead of just agriculture, human actions following the extraction of sediment and earth in the waterscape mutually impacted human, plant, and animal communities. Canals and reservoirs held water for humans, fish, and plants. Berms and rock alignments trapped fish and turtles for human use. The identification of fish as important in some ancestral Maya diets is a crucial step for understanding Maya domesticated waterscapes.

Integrated subsistence: fish in the Maya diet

Comparative evidence for the importance of freshwater fish, in addition to other aquatic species such as turtles, waterfowl, and mollusks, has been presented from archaeology, historic documents, and ethnographies across the Maya region (Harrison-Buck et al. 2020; Ruz 1998; Sharpe et al. 2020; Thompson 1974). For instance, through excavations and ethnography, Dillon (1981) indicates that Classic-period Maya at Camelá near the Chixoy River in lowland Guatemala could not have raised many crops in the swampy terrain around a large lagoon. Instead, he argues Maya inhabitants practiced fish farming in the abundant shallow waters of oxbow lakes and swamps like fishermen do today (Rivas and Odum 2019). Contemporary fishers at Camelá capture various species of catfish (including *Ictalurus* and *Lacantunia* sp.) *mojarras* (cichlids; *Cichlasoma*

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or *Vieja* sp.), tarpon (unknown sp.), and gar (*Atractosteus tropicus*) with nets and hooks. They also take turtles, turtle eggs, and crocodiles. The fish are salted and dried for transportation to market. One fisher camp took eight tons of fish from the area in three months (Dillon 1981:79). Dillon implies that ancient Maya could have created water control features, such as dams and sluice gates, to manage fish populations for large-scale harvesting. In a recent study at the adjacent center of Salinas de los Nueve Cerros, archaeologists suggest that Classic Maya fish processing and salting took place due to the abundant obsidian blades for descaling fish (Woodfill and Wolf 2020). Interestingly, a Classic Maya ceramic figurine depicting a god of maize, plants, water, and fish (integrated subsistence) emerging from a cleft sustenance and water mountain possibly came from this site, which is near sacred Maya hills (Figure 5).

Other ancestral Maya sites near floodplains, lagoons, and rivers present evidence for aquatic resource consumption (Sharpe et al. 2020) and human-modified waterscapes for fish (Harrison-Buck et al. 2020), like at Edzna and Pulltrouser Swamp mentioned above. Investigators examining nitrogen isotopic levels from bone collagen from Classic Maya human burials, for instance, have additionally shown that cities near large rivers often utilized freshwater fish (Scherer et al. 2007:97). High levels of nitrogen isotopes in human bone also occur at sites in the interior, however, indicating that Maya transported fish to these sites from rivers, lagoons, and domesticated waterscapes. At the Classic-period site of Piedras Negras, for instance, Maya consumed more fish during a time of political instability and population reduction (Scherer et al. 2007:98–99). Many fish bones, especially catfish from the nearby Usumacinta River, were recovered in excavations (Emery 2007; Scherer et al. 2007:97). A similar pattern of reliance on local fish during social changes and less food resource availability occurred at Pueblo Grande, Arizona, where people extracted fish from local irrigation (and fish farming) canals (James 2003).

Figure 5. Classic Maya maize god, water, fish, and plants emerging from a cleft sustenance-water origin mountain on a ceramic figurine from the Museo Miraflores, Guatemala, possibly from the Salinas de los Nueve Cerros site in Peten, Guatemala. Photograph by the author.

Furthermore, Alexander et al. (2013) have demonstrated the importance of aquatic resources in the Postclassic Maya community at Cilvituk (Silvituc), Campeche, Mexico. Cilvituk is an island between a large lagoon and seasonal marshes. Canals have not been reported in the marsh, but human modifications of the island and the reliance on freshwater aquatic resources point to Maya domesticated waterscapes, including fish management practices. The authors point out that Maya populations at Cilvituk had access to highly diversified terrestrial and aquatic, in addition to domesticated and collected, plant and animal species in a resilient resource exploitation strategy. Faunal bone from household excavations across the island indicates that the acquisition of fish, turtles, mollusks, and water fowl matched that of terrestrial animals, including deer, dogs, and turkeys (Alexander et al. 2013:312). Ray-finned fish abound in the archaeological deposits, as do gar (Alexander et al. 2013:296–298). Since cichlids are common today in the Cilvituk watershed, especially in shallower waters (Flores Ramos 2014), it is likely many bones belong to these species. Maya household clusters likely organized the procurement of aquatic resources (Alexander et al. 2013:313) since no evidence exists that elites managed the ecological aquaculture system and its resources.

Likewise, archaeologists excavating at Preclassic Kaminaljuyu in the Guatemalan highlands discovered extensive hydraulic engineering. While the canals and shallow lakes were important for agriculture and controlling the movement of and access to water for Maya populations, these hydraulic features allowed fish populations to thrive and be "farmed." The water also provided turtles, mollusks, and water fowl (Emery et al. 2013:388). The Maya populations here connected the lake with extensive canals leading to reservoirs that were partially forested, or supported fields and gardens (Arroyo and Henderson 2020). These features would have facilitated water circulation and purification. The movement of earth for water management was extensive. The domesticated waterscapes at Preclassic Kaminaljuyu are an example of ecological aquaculture and its integration of human, plant, and fish populations that minimized negative environmental impacts for the system's resilience. The archaeological fauna at the site demonstrate the importance of fish in the human diet (Valdés and Wright 2004). Fish bones from gar, cichlids, and other bony fishes were common (Emery et al. 2013:394, 399–400). Importantly, Preclassic stone monuments depict fish, likely cichlids, that thrive in such aquaculture canals and reservoirs (Figure 3; Gamboa-Pérez and Schmitter-Soto 1999). Water imagery appeared with rulers' portraits on monuments showing their connection to the spiritual and perhaps practical maintenance of the waterscapes (Arrroyo and Henderson 2020:149). At Izapa, a contemporary site on the Pacific coast of Chiapas, a stela (Figure 6) depicts a person or a water god wading in a shallow canal or reservoir like at Kaminaljuyu to extract fish with a basket (Norman 1973:87). Classic Maya carved bones from Tikal, Guatemala (Figure 6), also depict Maya gods alongside canoes grabbing fish (*tzak chay*, like the Maya "fish-in-hand" hieroglyph; Ruz 2020:167), apparently cichlids and catfish, in shallow waters and putting them in baskets, just like people did (Trik 1963:13). Capturing fish by hand and with baskets is a subsistence strategy seen across the Maya region (Figure 7) and around the world.

Archaeologists in lowland Guatemala have pointed to the importance of aquatic foods, mainly fish, turtles, crocodiles, and water fowl, in Maya societies over time around the central Petén lakes (Rice et al. 2017). At Trinidad de Nosotros, archaeologists found that 23 percent of the faunal remains consisted of fish bones, particularly in commoner contexts (Thornton 2012:339, 344, 353). Cichlids were dominant in the bone collections, while gar, catfish, and eels were present in significant numbers. Additionally, many net weights fashioned from ceramic sherds have been recovered in Maya households across the habitational sequence. Maya used the ceramic sinkers to weigh down nets or lines with hooks. Coves and ponds dot the waterscape, which may have been transformed by Maya to obtain aquatic resources. Ancestral Maya modified the waterscape to facilitate canoe traffic, hence fishing, between some lakes (Rice and Rice 2016). Importantly, fields for wetland agriculture and fish farming have been discovered in shallow portions of several lakes, which may have been extensive in the past (Rice et al. 2017:45). These waterscape features and aquatic subsistence regimes can also be seen in other parts of the Maya area, particularly in the western lowlands.

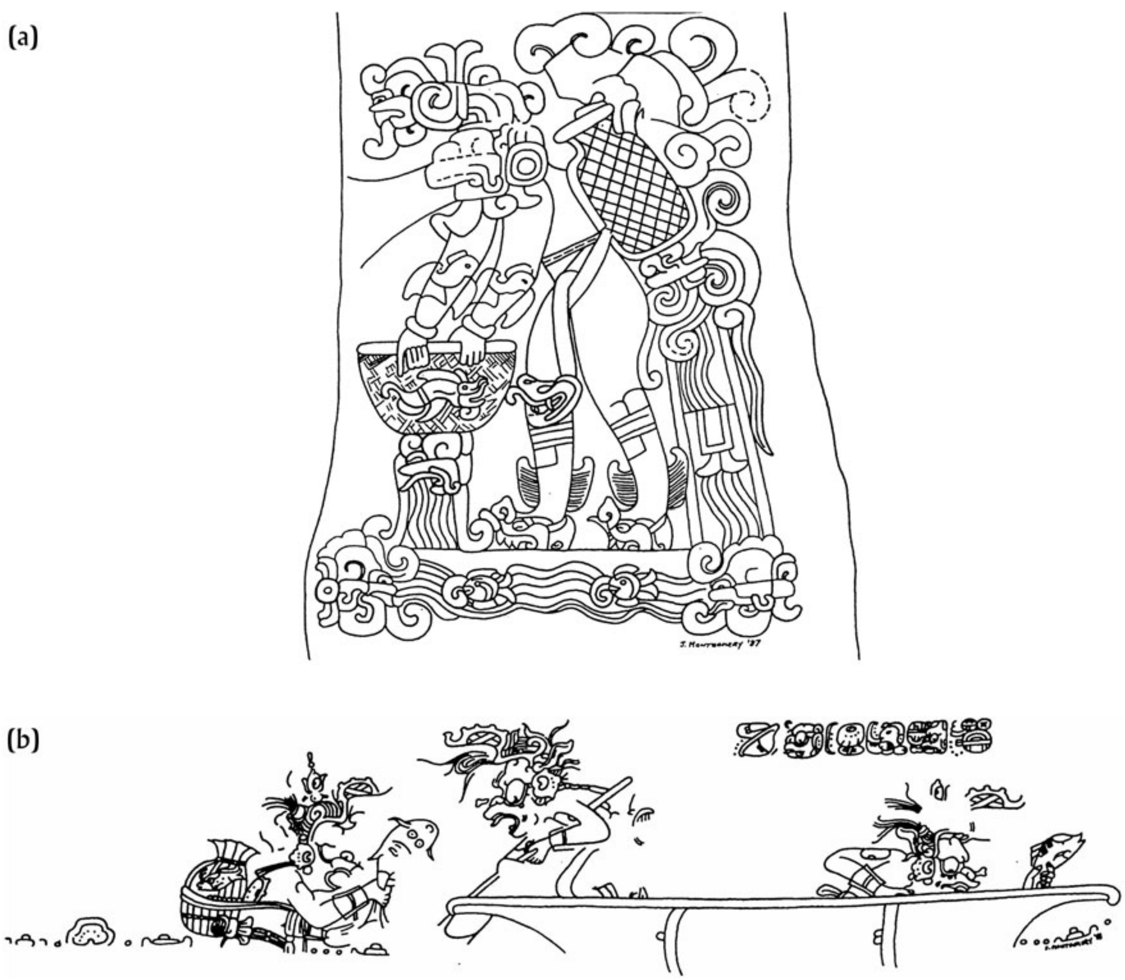

Figure 6. Gods fishing in shallow waters. (a) A rain, water, and fishing god wading in a wavy canal catching fish (cichlids?) in a basket and creel. Note the fish imagery on the head, arms, and feet. Izapa Stela 1. Courtesy of the John Montgomery drawing collection (Famsi.org). (b) Tikal carved bone depicting Maya rain, water, and fishing gods (*Chaak*) grabbing cichlids and a catfish (left) alongside a canoe (see Trik 1963:13). Courtesy of the John Montgomery drawing collection (Famsi.org).

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Figure 7. Catching fish and crustaceans with baskets in a shallow canal near an ancestral Maya sustenance mountain and settlements at Yalmutz, Chiapas. Note adjacent reed beds and maize cultivation for integrated subsistence. Photograph courtesy of Ramón Folch.

Canals, reservoirs, and fishing in the western Maya lowlands

Research in the Maya western lowland region in Tabasco, Campeche, and Chiapas, Mexico, provides insights on the use of ancestral Maya wetland agricultural fields, canals, and reservoirs to obtain crucial terrestrial and aquatic resources beginning in Preclassic times (Dunning et al. 2020; Siemens and Puleston 1972). New ethnographic and archaeological investigations, like at Mensabak, Chiapas, have produced data on aquatic species in the Maya diet over time. The first studies of Maya canals and raised fields took place in this region, including the Candelaria River watershed and experimental raised fields (*camellones*) in swamps (Pérez Sánchez 2007). Recent projects here increased attention to Maya aquaculture and highlight the importance of Maya aquatic food resources (Gómez-Pompa et al. 1982; Martínez-García et al. 2022; Palma-Cancino et al. 2019). For instance, fisher-farmers at Tucta, Tabasco, have told me that the large-scale canals among their *camellones* provide much aquatic and terrestrial foods. Importantly, they do not have to feed the fish, turtles, and manatees in this resource-rich environment, and they only have to clean the canals of unwanted plants. Furthermore, travelers in Tabasco and Chiapas in the sixteenth century described the combined agricultural and

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aquatic resources in the Indigenous quotidian diet in the area:

> "Then they gave each of us two tortillas and a small piece of fish and another piece of sweet potatoes. [The first day] they gave us plenty of fish, which cost them nothing. During several months they have an abundance of fish, and turtles so large. Of this and other fish they gave us every day and also plenty of tortillas. The chief also gave us tortillas and oranges and bananas, of which they have many, and about two pounds of fish" (paraphrased from Blom 1973:533–553).

These travelers also mentioned the frequent trips Maya took by canoe through rivers, lakes, and what appear to be canals in the region, when they gathered aquatic foods.

In my recent ethnographic observations on ecological aquaculture at Mensabak (or Metzabok), Chiapas (Figure 8), modern Maya benefit from aquatic resources in a waterscape modified extensively by their ancestors. Several lakes and many reservoirs at this site are interconnected with a lattice of streams and several canals (Figure 9). The small Naja River and several streams drain into the waterscape. The area consists of a wide, active productive floodplain with little long-term stagnant water, which is recharged with annual rainy season floods that add between five and fifteen meters of water. The large-scale, open, domesticated waterscape allows for much oxygen, sunlight, and freshwater to support the ecosystem (Costa-Pierce 2014a; Hickling 1968). Ancestral Maya modified the Mensabak waterscape by digging out reservoirs, ponds, and canals in the floodplain. The waterscape features have feeder and exit canals to maintain water and nutrient quality for abundant aquatic plants and animals. Many canals, including four longer ones, and at least 23 reservoirs around the lakes can be seen in aerial imagery, especially in the southern areas. Ancestral Maya utilized the sediment from the canals, ponds, and reservoirs to construct earthen mounds at the Preclassic city of Noh K'uh located just south of the lakes (Juarez et al. 2019). The terraforming for construction and subsistence was a community effort not organized only by elites, but by commoner corporate groups as well (Juarez 2022). In some parts of Noh K'uh the floodplain sediment fill is more than three meters under mounds and plaza floors (Figure 10). Furthermore, water from urban Noh K'uh drained into the Naja River to the west providing much nutrients and fertilizers to enhance the aquatic life in the ponds, reservoirs, and lakes (Yang 1994a). Potable water was available in cenotes, springs, and streams to the east and south.

Maya later built house platforms around the lakeshores during Postclassic times, but they used less lake sediment in their low platforms. Therefore, they may have cleaned

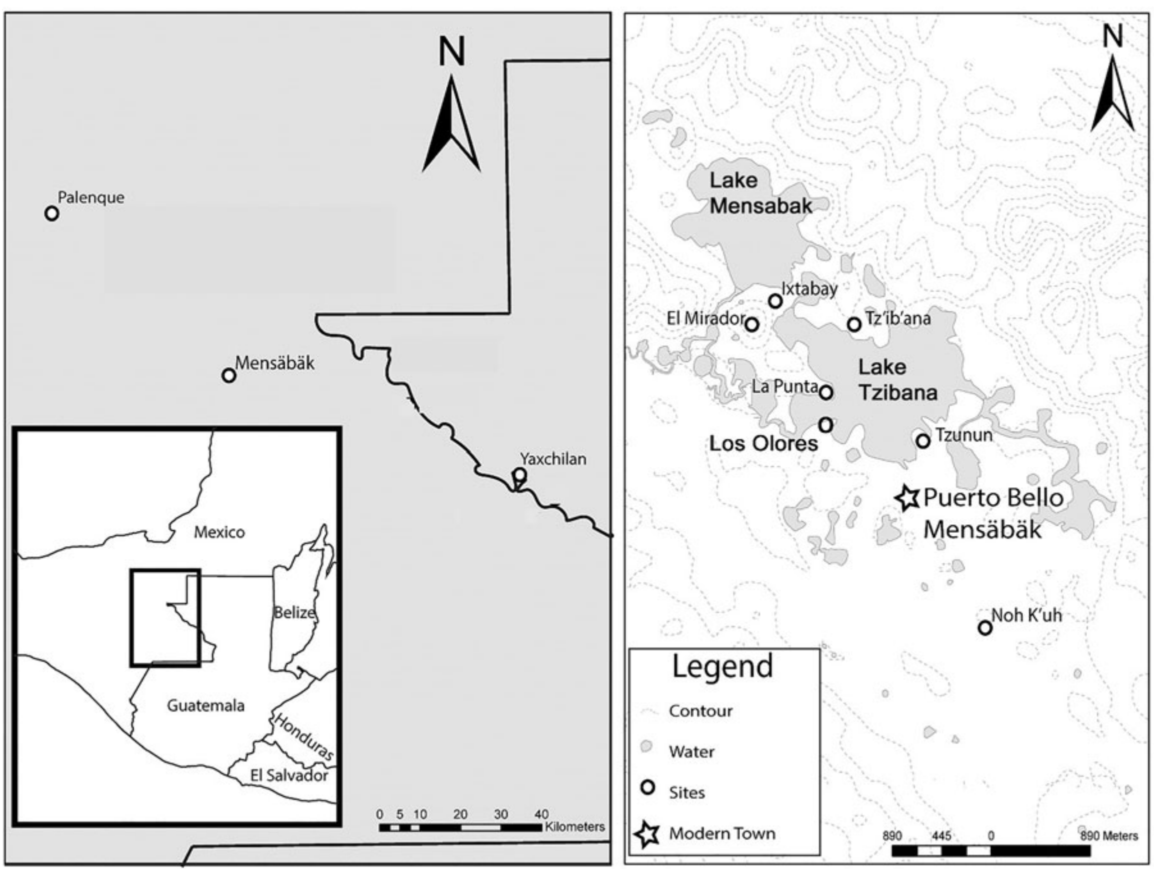

Figure 8. The location of Mensabak, Chiapas, Mexico, and archaeological sites around Lake Tzibana. Redrawn from Juárez et al. (2019: Figure 1).

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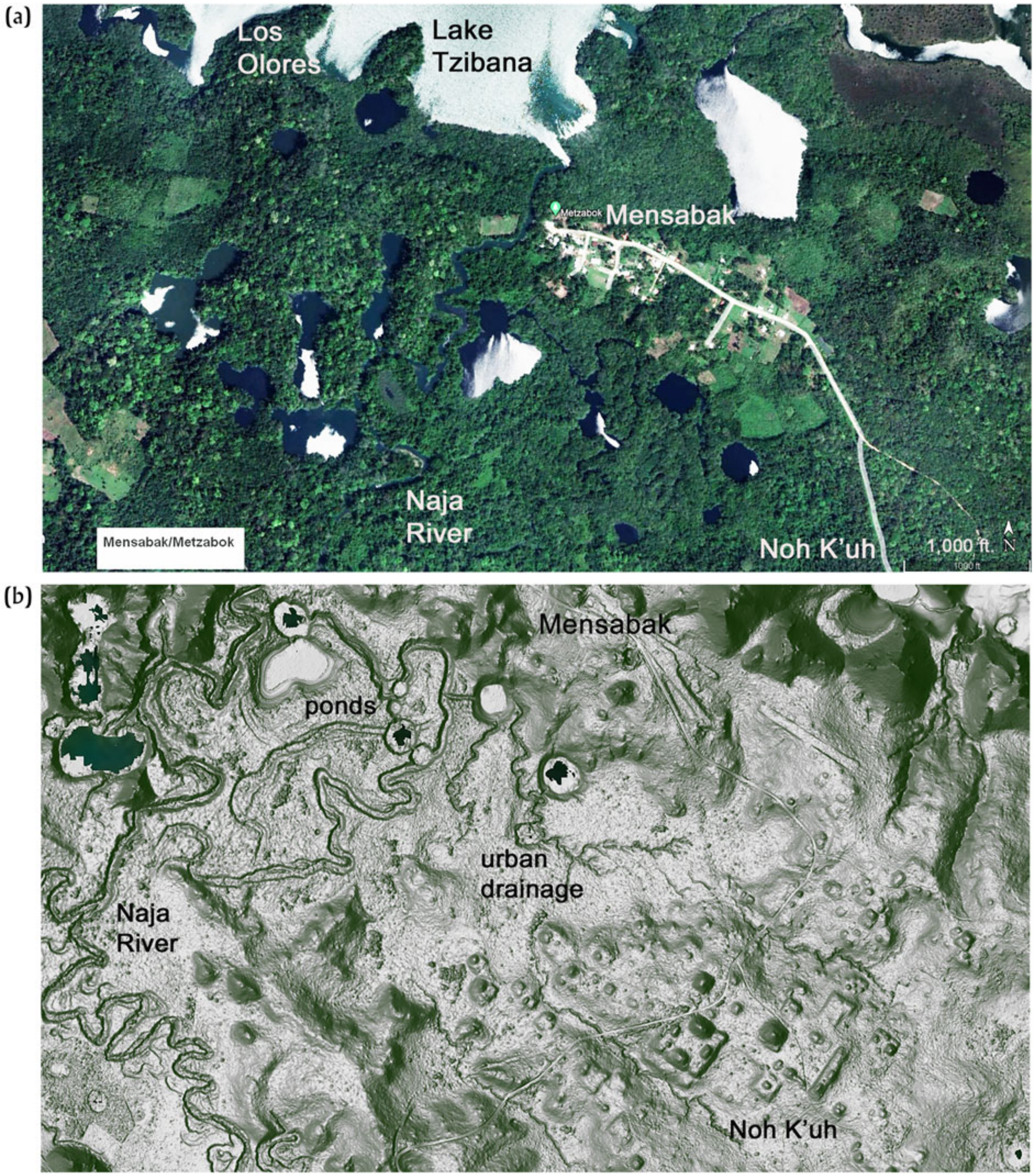

Figure 9. Waterscapes near the Lacandon village of Mensabak (Metzabok). (a) Lakes, canals, and ponds near the Los Olores and Noh K'uh sites. Google Earth. (b) Ponds, canals, and drainage near Noh K'uh. Light detection and ranging (LiDAR) map by Jackson Krause and Chris Hernandez, courtesy of the Mensabak Archaeological Project.

but not created waterscape features. Postclassic Maya living around the lakes and canals also tossed considerable amounts of household trash, such as animal carcasses, mollusk shells, and broken cookware, into the water providing nutrition for plankton, fish, turtles, insects, and water plants (Gamboa-Pérez and Schmitter-Soto 1999). Waste waters draining from these Maya settlements also fertilized the aquaculture system as seen in other areas (Gamboa-Pérez and Schmitter-Soto 1999; Lozano and López 2001; Yang 1994a). During the rainy season, the Mensabak floodplain fills with water and fish, fowls, mollusks, crustaceans, and turtles expand to the canals, ponds, and reservoirs. Here the animals can be more easily captured. In the dry season the water level drops, leaving aquatic animals in the shallow features to be gathered with baskets, harpoons, nets, or by hand, like Lacandon Maya do. Additionally, project members have recovered bones of turtles and water fowl in excavations at

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Figure 10. Excavation in plaza floor fill (Operation NK-1, north profile) at Noh K'uh, Mensabak. Note the fine, light-brown sediment fill layers with ceramic sherds above and below a gravel plaza floor. Photograph by Sebastián Salgado Flores, courtesy of the Mensabak Archaeological Project.

Mensabak, and some fish (Kestle 2021; Sánchez López 2021a, 2021b), but we need to conduct fine wet-screening of excavated soil to recover more fish bones (Prestes-Carneiro et al. 2019; Varela Scherrer 2021). Interestingly, cichlids and catfish, which thrive in ponds and canals of ecological aquaculture, dominate the Mensabak collections (Kestle 2021:98, 214).

Project members have mapped several Mensabak canals and ponds while investigating two canals with earthen berms and stone and wooden post features (Figure 11). The Late Postclassic site of Los Olores (Kestle 2021:63) near the concentration of canals and reservoirs on the south end of Lake Tzibana has several small constructions near a main canal (Figure 12). In this area, archaeologists explored and mapped several fish ponds of different sizes with interconnecting canals. Some canals are lined with stones and some reservoirs appear to have impermeable clay and stone linings like at other Maya sites (Dunning et al. 2022:23–24; Freidel and Scarborough 1982:140–142). The canals contain various linear stone features (Dunning et al. 2022:27; Fedick 2003), including dams, sluices, and weirs seen in the Maya area (Figure 13). One excavation inside the main canal at Los Olores uncovered a series of small post holes with woven cane and packed clay that

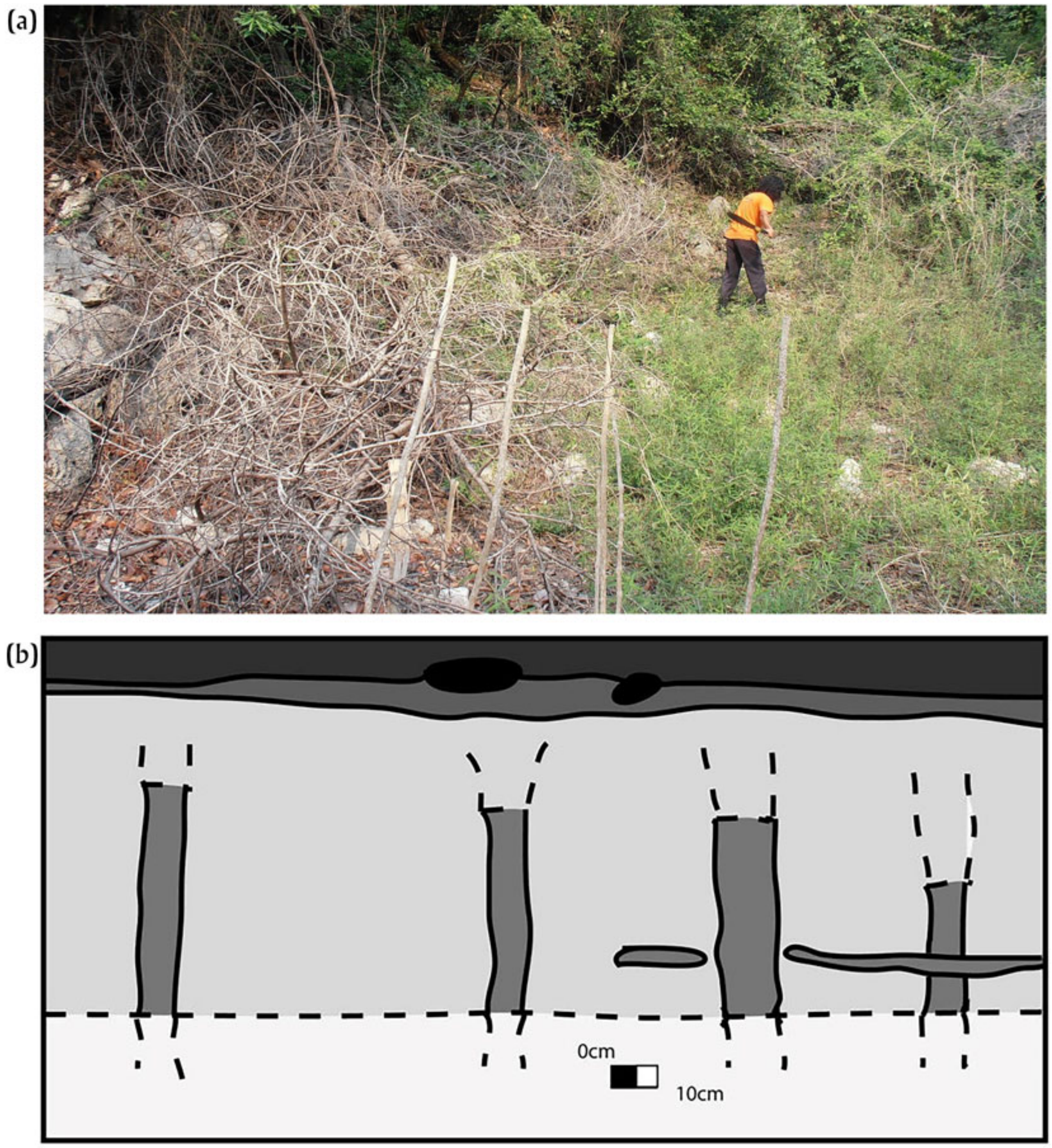

Figure 11. Ancient canal constructions at Los Olores, Mensabak. (a) Linear stone and earthen berm features. Photograph by the author. (b) Possible fish weir or trap posts in an excavation profile (Operation LO-2-A-4; Kestle 2013). Courtesy of the Mensabak Archaeological Project.

could have been a wooden fish weir or trap (Connaway 1982; Kestle 2013; Ringer 2008). An excavation of the canal near a platform recovered artifact deposits (Figure 14) with Late Postclassic pottery fragments, trash, and dark brown ceramic figurines in the upper layers. The dark stained figurines depict women, or more likely feminine water deities associated with water in Mesoamerican societies (Durán 1951:219–221; Sandstrom 2021:35–37), which could have been used in ceremonies at the canal for the benefit of water, fish, and the fertility of the waterscapes, aquatic species, and humans. Contemporary Lacandon Maya at Mensabak, for example, believe fish populations and access to them are controlled by the guardian "mother of fish" named *Xok* (or *sirena*), a divine mermaid-like being, like in other Mesoamerican societies. Lacandon still make ceramic figurines representing these women with fish tails (Figure 3) who live in rivers, lakes, and reservoirs (Kováč 2013). Possible fishing gear, such as small ceramic net or fish line weights (not spindle whorls, and similar in size to fish net weights at K'axob, Belize; Bartlett 2004:266–268) and small obsidian fish arrow or points for reed harpoons (historic Lacandon used small thin chert fish arrow points; Rodríguez Galicia 2017:33–34; Ruz 2020:161), were also recovered in the upper levels of the Los Olores canals (Figure 15). Further down in the sediments excavators recovered Late Preclassic ceramic sherds (Figure 14) likely dating to the original canal construction and use. Few fish bones were found since the excavated earth was not fine-screened. Limited excavations on the low ground (*bajo*) between ponds and canals at Los Olores recovered ceramic sherds and animal bone, which may indicate trash mulching for cultivation here during the dry season and for fertilizing the aquatic system.

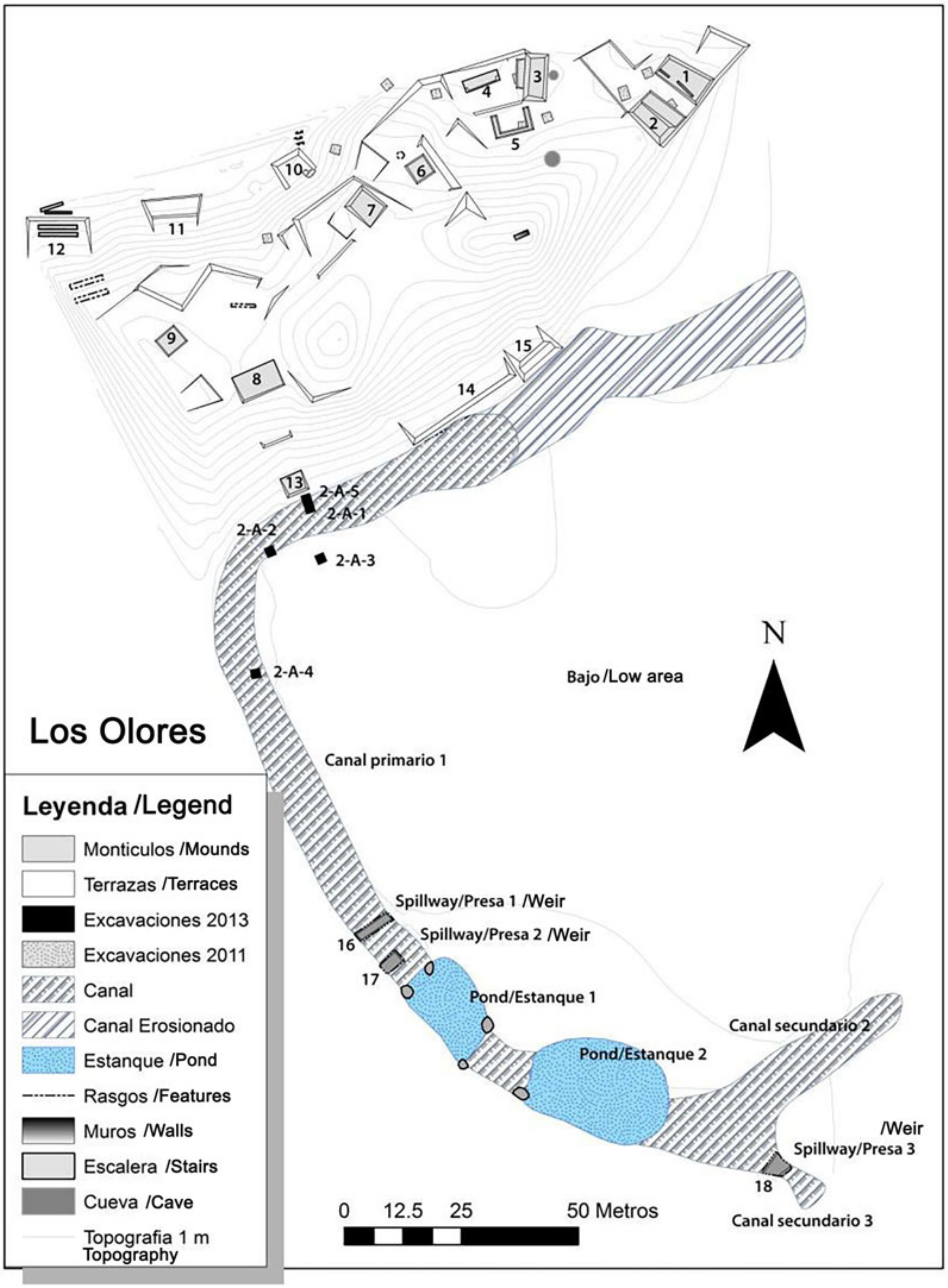

Figure 12. Map of ancestral Maya stone canal features, fishpond reservoirs, spillways/dams or weirs, and cultivation spaces on the floodplain (*bajo*) at Los Olores, Mensabak. Map by Kestle, Deeb, Hernandez, and Palka. Courtesy of the Mensabak Archaeological Project.

Interestingly, the Mensabak waterscape effectively combined subsistence practices and religious ideology for Maya people. The religious connections to an origin place strengthened Mensabak as a site for Maya to create fields and fish ponds. Mensabak exemplified the Mesoamerican symbolic sustenance and water mountain (*altepetl* in Nahuatl) as seen in the cleft mountain in the Tepantitlan mural described above (Figure 2). At Mensabak (Figure 16), Mirador Mountain, called Chak Aktuun (Red Cave [Turtle] Mountain [with water]; Ruz 2020:141) by contemporary Lacandon, rises abruptly from the lake waters to dominate the local landscape (Palka 2014). This pyramidal mountain is cleft and red-stained on its east side, riddled with large caves, and has an underwater sinkhole at the mountain's base that initiates the Tulijá River, a major waterway leading to Tabasco and the Gulf of Mexico, just to the west. Mesoamerican lore regarding gods splitting sustenance mountain to release maize, water, fish, and food (Taube

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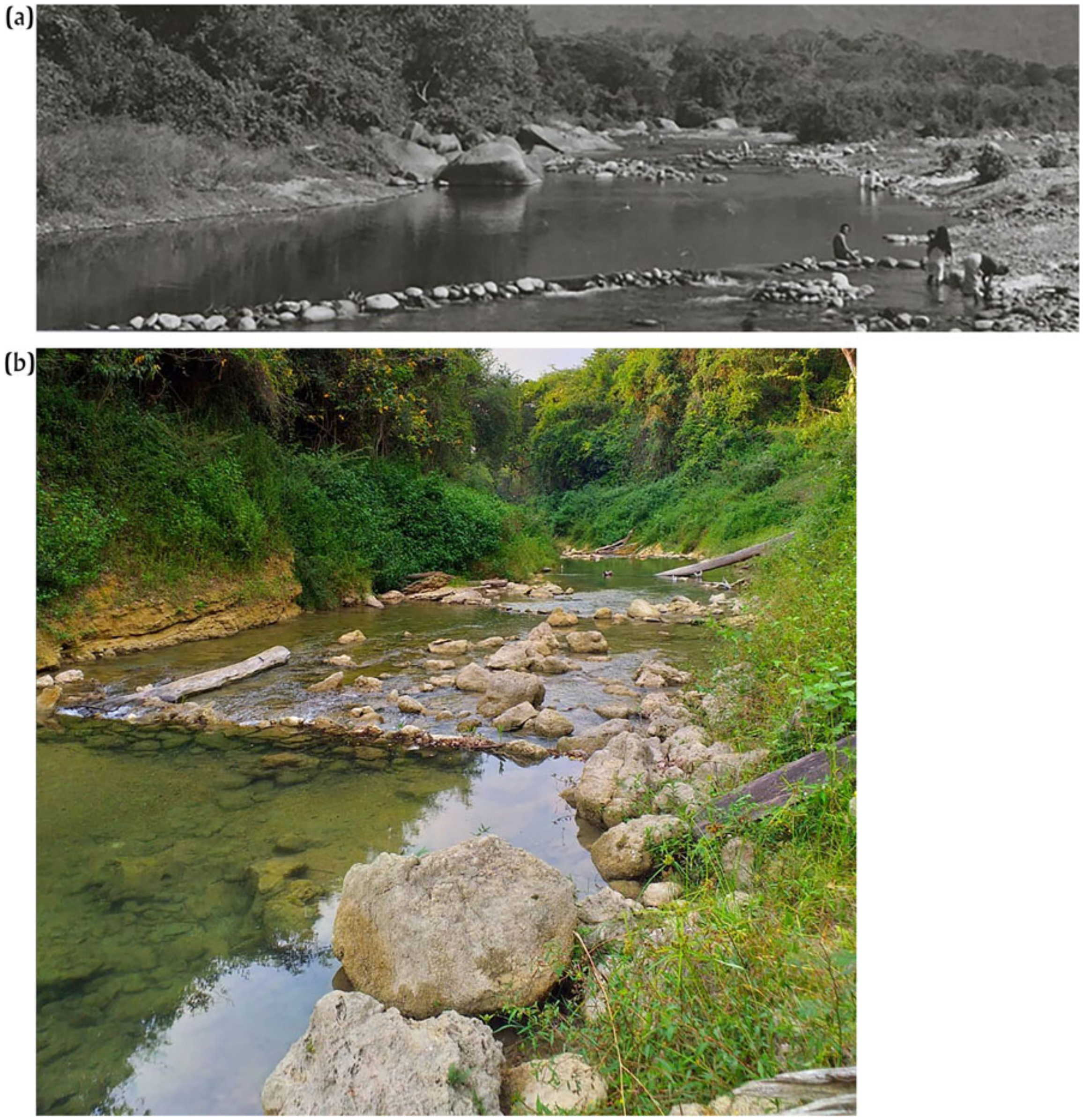

Figure 13. Maya linear stone fish traps or weirs in Chiapas. (a) Weirs in a river at Huixtla. Courtesy of The Bancroft Library, University of California, Berkeley, Estado de Chiapas 75, Tapachula Huixtla, PIC 1979.057; public domain. (b) Ancestral Maya stone weirs in a Mensabak stream. Photograph courtesy of the Mensabak Archaeological Project.

1986) is materialized here. Indeed, Mirador Mountain (or El Mirador) is similar physically and religiously to Postectli ("Broken") Mountain of Nahua people in Veracruz, who believe a water god broke its peak with thunderbolts (Sandstrom 2021:35–38). In this tall, pyramidal Postectli mountain with caves, the resident deity "our honored mother" (*tonantzin*) maintains a garden. "Water dweller" (*apanchaneh*), a mermaid-like feminine god with a fish tail, also resides in the mountain where she releases rain, fish (her children), and water plants to worshipers. Mensabak also parallels Aztec myth-histories regarding Aztlan: "In this place [in distant forests] there is a great mountain, in the middle of the waters…[and] in this mountain there are caves. [Here are] many ducks, herons, and water hens… [and] the people have enjoyed beautiful and large fishes and the freshness of the greenery on the lake's edges. They travel in canoes and make "canalized raised fields" (*camellones*, not "agricultural fields" as often translated) on top of the water to plant the vegetables that they ate, [together with] the great abundance of many species of fish" (paraphrased by the author; Durán 1951:219–228).

The Aztlan origin mountain and watery place that formed a river was governed by a dark female deity called Coatlicue, recalling the Mensabak figurines. In ancient Maya art, the sustenance mountain can appear as a turtle shell (*aktuun*), which connects maize, water, and aquatic resources (Taube 1985). Additionally, at Mensabak a monumental, Late Postclassic Quetzalcoatl feathered serpent,

Figure 14. Ancestral Maya pottery from canal excavations at Los Olores, Mensabak. (a) Late Postclassic ceramics from upper levels, including a Matillas Fine Orange bowl sherd and a dark-stained female figurine. (b) Late Preclassic Chicanel ceramic rim sherds from lower levels. Photographs courtesy of the Mensabak Archaeological Project.

who removed maize from sustenance mountain for people to consume in Mesoamerican mythology, was carved into a lakeside cliff to the east of Mirador Mountain (Lozada Toleda 2017; Palka 2014:217; Taube 1986). Hence, ancestral Maya dug canals and fish ponds, in addition to planting fields and gardens, across the waterscape to recreate an archetypical Aztlan sustenance water mountain and a Tlalocan-like paradise. To this day, Lacandon Maya believe that their rain god Mensabak, who resides in the land of the dead at a cliff with a Tlaloc design and many human burials at its base (Palka 2014:290), split Mirador Mountain with a shooting star or lightning releasing its water, which recalls Mesoamerican beliefs. They also continue to use the ancestral fish ponds and cultivate crops around the modified waterscapes near this sacred mountain.

For Lacandon Maya in Chiapas and Petén, Guatemala, fish have been an important protein source (Marion 1991). Early ethnographers recorded several Lacandon fish capturing techniques (Tozzer 1907) that originated in ancient times. Their fishing strategies varied over the seasons and the fisher's skill sets. Generally, ethnographers described fish traps in different Lacandon settlements. The traps were constructed in conical shape from flexible vines and twigs that included a door. Embedded stakes fixed the traps in the water. Lacandon baited the trap with maize dough and closed the door with a cord when fish and crustaceans went inside. Many Lacandon also employed fish poison. They blocked parts of a stream, canal, or reservoir, where they added pieces of toxic (for fish only) vines. The vines caused the fish to suffocate and float to the surface. Moreover, skilled Lacandon took large numbers of fish in high or low waters with lances and arrows with chert, metal, or wood points while standing in canoes or on shore. Recently, hooks and nylon fish line have replaced many native Lacandon fishing

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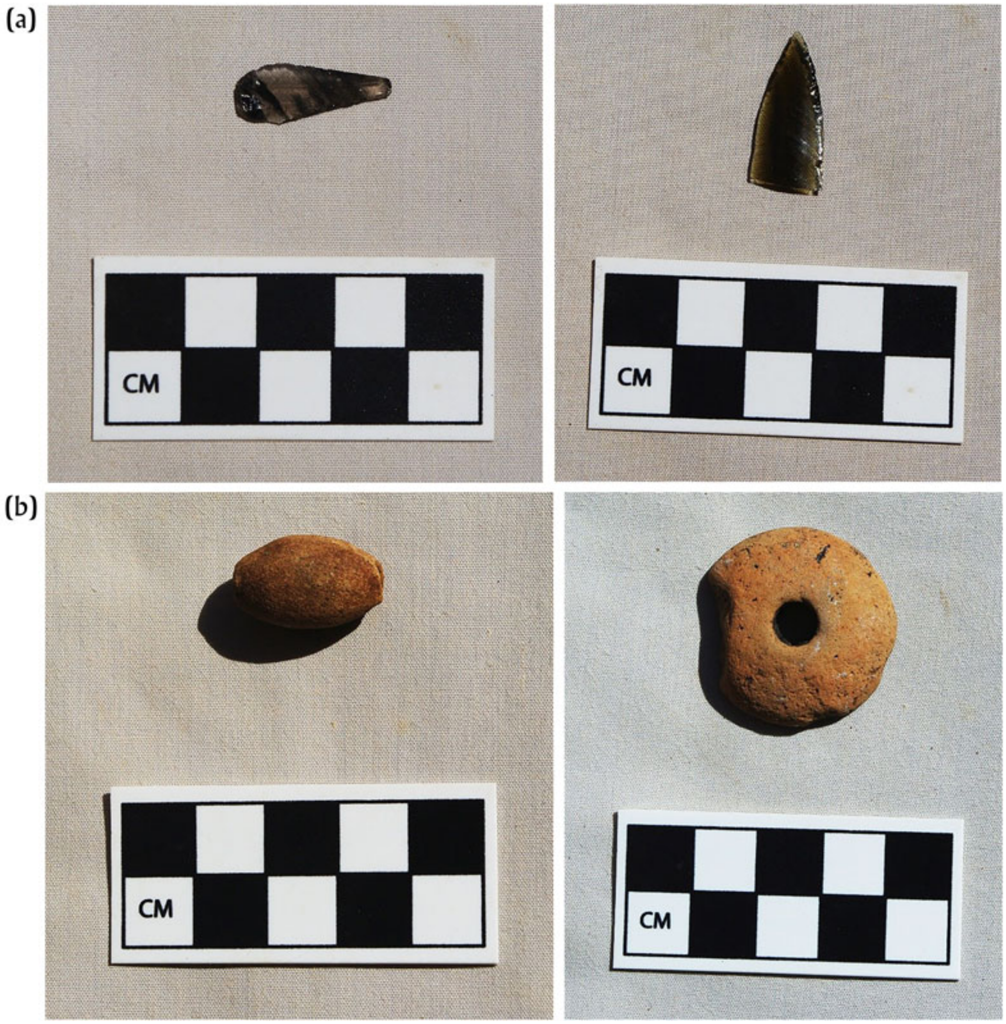


Figure 15. Late Postclassic Maya fishing gear from canal excavations at Los Olores, Mensabak. (a) Small obsidian arrow points. (b) Small rounded ceramic net or fish line weights (not spindle whorls). Photographs courtesy of the Mensabak Archaeological Project.

techniques. People use hooks in canoes or from the shoreline to capture significant amounts of fish, but mostly during low water when fish take the bait more. It is possible past Maya used cords with thorn or bone hooks to fish as well. Today, Lacandon also utilize rubber band powered harpoons when underwater visibility is good.

At Mensabak, Lacandon Maya utilize streams, lakes, and ancient canals and ponds to acquire large amounts of fish. They have taken waterfowl, crustaceans, mollusks, and turtles as well. Lacandon people are still able to exploit the ancestral domesticated waterscapes at the site due to the durability of the ecological aquaculture system. Mensabak Lacandon mostly fish during the dry season when the waters are clearer and fish bite more. They currently use hooks, harpoons, cloth, buckets, their hands, and nets to obtain fish. They also occasionally use the bow and arrow, explosives, and even guns. The use of hook and line is the most common means of fishing as this gear is inexpensive and can be used by anyone. Considerable quantities of fish of different species and sizes, even tiny fish, are taken with this equipment. Importantly, Lacandon people obtain larger amounts of fish, including cichlids (including *Cichlasoma urophthalmus*, also *Vieja* and *Archosentrus sp.*; *Petenia splendida*), catfish (including *Ictalurus furcates*; *Lacantunia enigmatica*), and eels (*Synbranchus* sp.?) with long nets strung across streams, canals, ponds, and reservoirs for extensive fish capture in these restricted spaces (Figure 17). Importantly, the domesticated waterscapes support large numbers of native and introduced cichlids (especially tilapia, *Oreochromis niloticus*), which are omnivorous fish that thrive within and frequently reproduce in managed aquaculture environments. Cichlids (*mojarras*) likely were important aquaculture fish in ancient Mensabak, as they are today throughout Latin America (Gamboa-Pérez and Schmitter-Soto 1999; Lozano and López 2001). Several hundred pounds of cichlids are obtained with nets in a few hours. The fish swim into the nets or people scare them with poles towards the nets, which is a common fishing technique around the world. Additionally, Mensabak Lacandon acquire birds, turtles, crustaceans, crocodile eggs, mollusks, palms, wooden poles, reeds, and firewood (particularly hard dye wood) from the extensive Mensabak waterscapes and shorelines. They also place fields and gardens

Figure 16. The split Mirador sustenance-water mountain of origin on an Aztlan-like island (top center) and Tlalocan paradise with canals, fish reservoirs, vegetation, and fields around lakes at Mensabak, Chiapas. Photograph courtesy of the Mensabak Archaeological Project.

on the edges of canals and reservoirs, much like ancestral Maya wetland agriculture. The plant communities of the Mensabak domesticated waterscapes also provide shade for cooler water temperatures, water filtration, and food for aquatic animals in this ecological aquaculture system.

The importance of fish and other aquatic animals, such as turtles, waterfowl, crustaceans, and mollusks, has also been identified in zooarchaeological and ethnographic research at the lowland Maya center of Palenque, Chiapas (Varela Scherrer and Liendo Stuardo 2022). In a revealing study, Varela Scherrer (2021) demonstrates that fish bones remain encased in dirt clumps if they are not water-screened with fine mesh. In his faunal analysis at a Classic Maya elite residential group at Palenque, Varela Scherrer (2021:175–177) discovered that around 80 percent of the animals consumed were aquatic. Besides turtles, waterfowl, and manatees, however, the largest number of specimens were fish at 70 percent of the bone assemblage—much more than deer and birds. Interestingly, the majority of the fish bones belonged to cichlids. As discussed above, various species of cichlids are native to the streams and lagoons of Chiapas, and they thrive in waterscapes modified by humans, making them perfect for ecological aquaculture (Gamboa-Pérez and Schmitter-Soto 1999; Prestes-Carneiro et al. 2019). Catfish, white bass, and gars were also present in the Palenque faunal assemblages. Although these fish species can also live in aquaculture, cichlids dominate since they are omnivores, grow and reproduce quickly, thrive in different water conditions, and can be captured with a variety of methods in canals and reservoirs.

Significantly, evidence exists at Palenque for ancestral Maya modifications of the waterscapes for resource management and intensive subsistence. Liendo Stuardo (2002) identified wetland agricultural fields and canals in swampy areas near the site. He suggests that Maya elites organized labor to build the canals and harvest crops in the wetlands due to the presence of temples for elite ritual near these features. While providing drained land, water, and raised fields for crops, the waterscapes supported large amounts of fish, turtles, fowls, and other aquatic animals. It is likely that fish remains from the elite household middens mentioned above originated in these canals and reservoirs. Other investigators (French et al. 2012) studied the stone block tanks at Palenque to analyze how they stored water. These tanks allow for the circulation of water, making them also ideal for small fish ponds for intensive fish farming (Varela Scherrer 2021; Varela Scherrer and Liendo Stuardo 2022). Elite Maya made these tanks near their buildings; hence, they would have consumed the fish, turtles, and mollusks within them. In sum, the extensive waterscapes near Palenque provided predictable food and resources beyond agriculture and forest products for ancestral Maya living there.

(a)

(b)

Figure 17. Lacandon Maya fishing at Mensabak. (a) Canoe and net trap in a shallow canal and reservoir. (b) Native and invasive cichlids were netted, grabbed by hand, or speared. Photographs by the author.

In similar waterscapes northwest of Palenque and Mensabak, experimental raised fields and canals in Chontal Maya communities in Tabasco, Mexico, provide key comparative contexts for past Maya ecological aquaculture, domesticated waterscapes, and integrated subsistence. The Chontal *camellones*, or small artificial camel-back islands in wetlands, produce economically important food plants for Maya, in addition to large numbers of reeds and palms. The Chontal communities also raise large amounts of fish and turtles in cages and in blocked areas in the canals that they often release to augment natural populations (Pérez Sánchez 2007). Chontal Maya concentrate on *mojarra* cichlids, white bass, crustaceans, and gars for fish farming, and they capture them with nets, cloths, and vine baskets in the shallow canal waters between the *camellón* fields and lagoons (Figure 4; Gómez-Pompa et al. 1982). Multiple families, and not elites or governments, organize the labor to maintain the raised fields and canals, in addition to the harvesting of plants and animals. Hence, besides being wetland fields, Chontal Maya domesticated waterscapes have served for ecological aquaculture and integrated subsistence, especially for the intensive harvesting of fish.

Comparisons: domesticated waterscapes, ecological aquaculture, and integrated subsistence

Following the background on Maya wetland agriculture and aquatic resources presented above, this section outlines new research perspectives and models regarding ancestral Maya integrated subsistence from studies of domesticated waterscapes and ecological aquaculture. Ecological aquaculture functions within local ecosystems for the development of human, plant, and animal communities in a wider context of the natural environment, and not within small aquaculture enclosed tanks (Bravo-Utrera 2009; Costa-Pierce 2014a:343; Li 1994; Ling 1977; Yang 1994a, 1994b). Ecological aquaculture is oriented to the creation and monitoring of intensive aquatic farming systems that enhance, not degrade, their natural environments. These large-scale systems produce valuable resources within a local ecology that are organized for people's subsistence and the resilience of the existing ecosystem; the natural ecosystem features, interactions, and functions are preserved. Ecological aquaculture works in multi-trophic levels with numerous interconnections between several inputs and outputs involving local resources, endemic species, and recycled wastes and materials (Costa-Pierce 2014a:344). People design and construct the monumental hydraulic systems to maintain natural water and nutrient quality over time for the benefit of plankton, plant, fish, and other aquatic species (Lozano and López 2001). This subsistence system does not discharge artificial chemical pollution harmful to humans and the environment like other intensive farming and small enclosed aquaculture systems. Ecological aquaculture also focuses on the diversity of native plant and animal species that parallels the local ecology (Serrano et al. 2006; Yang 1994a). Plants, animals, and fish are provided with their natural foods and exist in a local food chain (Hutchinson 2005:3–4). The various species are not impacted by unnatural stress, confinement, nor chemicals like in small-scale artificial aquaculture. Once an ecological aquaculture system has been created, it can be easily maintained as it functions as a long-lasting natural ecosystem, like lakes connected to streams (Hutchinson 2005:4). Human communities benefit greatly from the products and organization of ecological aquaculture, as do the animal and plant species in the domesticated waterscapes. Labor and resource organization are organized within communities, often in lineages or groups with occupational specializations, and not at the family level as with small household aquaculture tanks. Ecological aquaculture exemplifies one of the world's most efficient protein producers: inland fish farming.

Specialists examining the extensive inland fisheries in different societies have drawn attention to the utility of large-scale, multi-trophic ecological aquaculture and the presence of integrated subsistence (Bond 1988; Chopin 2013; Costa-Pierce 2014b; Ling 1977; Welcomme 1979; Yang 1994a, 1994b). Ecological aquaculture across the world involves monumental waterscape modifications by humans for subsistence purposes. Lagoons, large reservoirs, and canals for fish are combined with extensive drained lands to grow plants. Ecological aquaculture systems benefit from moving water from streams or changing flood levels, which recharge the system with freshwater, nutrients, and animal populations (Lozano and López 2001). Feeder and exit canals circulate the water and nutrients so that aquatic plants and algae can thrive to feed insects, fish, turtles, water fowl, and other animals. The water provides nutrients for plants to grow within the waterscape and on its edges. The plants give shade, food, clean water, and oxygen to the aquatic animal and plant communities. The shade and large amounts of water reduce evaporation and excessive heating of the waters. Wind circulates across the expansive system providing oxygen to the water (Hickling 1968). Sunlight on the open waterscape enables the growth of water lilies, grasses, and algae that feed the plankton and insects at the base of the aquatic food chain. People living near *chinampa* canals and raised fields in central Mexico, for instance, understood these complex connections (Pérez Espinosa 1985) as seen with fish consuming human excrement and plant matter in canals near a raised field in the Borgia Codex (Figure 18). Ecological aquaculture systems utilize such wastes for fertilizer for plants and plankton to maintain the biomass in the engineered aquatic features (Gamboa-Pérez and Schmitter-Soto 1999; Yang 1994a).

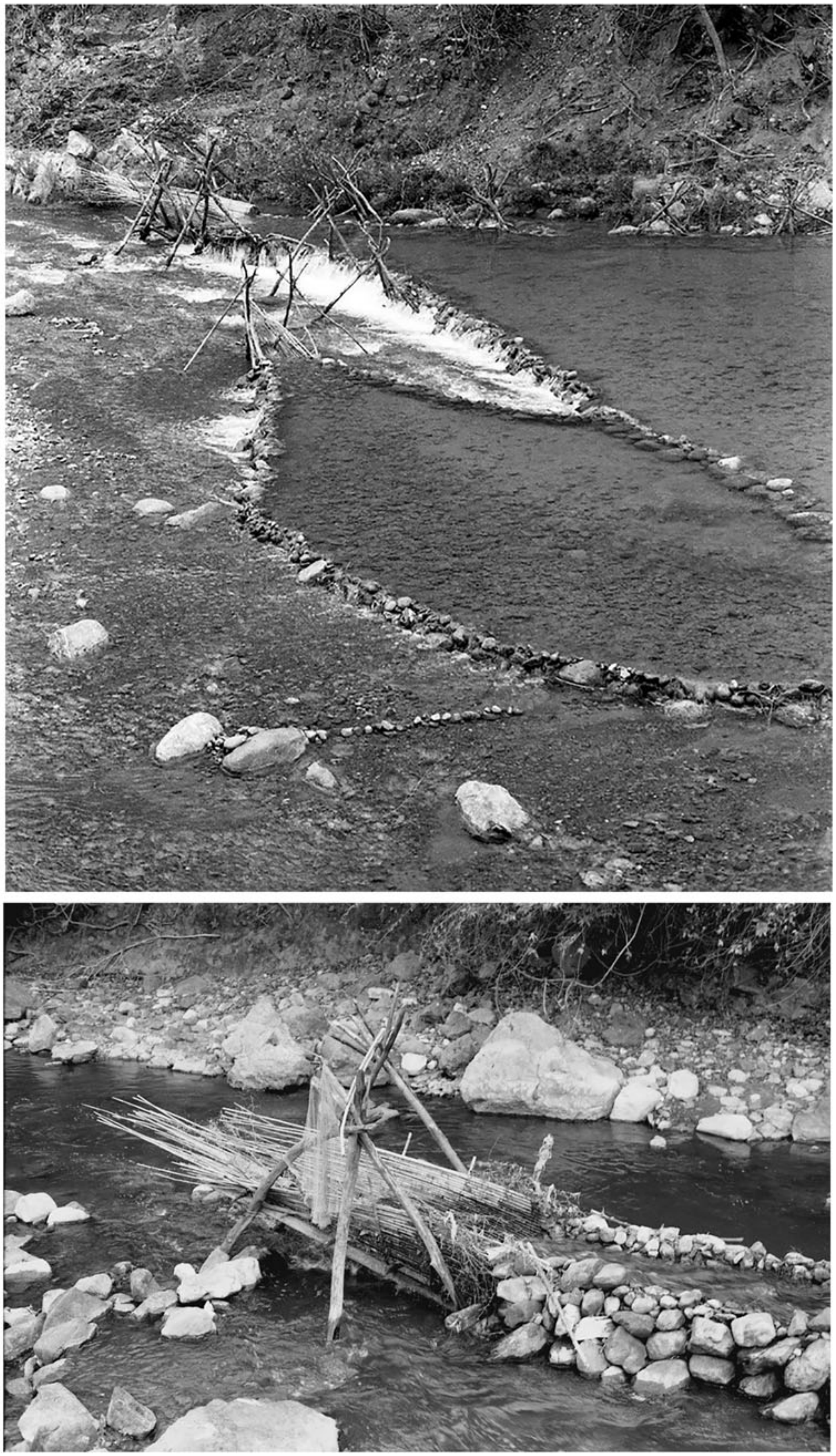
This type of domesticated waterscape is resilient with humans constructing and cleaning canals and setting up blockage points with weirs, nets, and dams to capture fish and animals, as seen in modern Maya communities (Figure 19). The fish and plants do not need to be fed, nor the water filtered as with small aquaculture tanks. Fish eat the plants and invertebrates, and humans eat the fish and plants. Some fish and plants are consumed by non-human species, or die, but the large-scale domesticated waterscapes still provide ample resources for people. The system is also large enough to allow canals and ponds to be set aside for fish and plant reserves that, if not harvested, can spread into the system during flooding, stocking, migration, or when people open canals. For comparison, the domesticated waterscapes at Mensabak and other Maya sites resemble the modern fish ponds, canals, orchards, and fields on a monumental scale near villages at Doñana, Spain, where terrestrial and aquatic foods are abundant (Serrano et al. 2006). These domesticated waterscapes have provided much aquatic and terrestrial resources for humans across time due to the systems durability and high productivity. In this manner, ecological aquaculture can be linked to domesticated landscapes and waterscapes were people modify their environment for the sustainability of plant and animal

Figure 18. Postclassic central Mexican *chinampa* raised fields (*camellones*) with fish in canals consuming human excrement and corn husks. The center fish and maize husk may serve as fertilizer on a wetland field for ecological aquaculture (Codex Borgia, p. 24; Public domain, Wikipedia).

populations for human subsistence, as discussed in the introduction (Terrel et al. 2003). People enable plant and animal communities to thrive in local ecological settings to put more food on the table and acquire adequate materials for their everyday lives (Baker 2007; Nietschmann 1973; Terrell and Hart 2008). People domesticate their physical and biotic environments to expand and integrate their subsistence regimes as much as they assist in the domestication of species. Clearly, fishing and aquatic resource management can be added to the "subsistence spreadsheet" in a subsistence ecology (Nietschmann 1973; Terrell et al. 2003) from domesticated waterscapes and ecological aquaculture in the Maya region.

In a comparative example of domesticated waterscapes, researchers reported a large-scale canal and fish weir system for ecological aquaculture and integrated subsistence at Bangweulu, Zambia (Hickling 1961; McKey et al. 2016). Here people enabled the growth of aquatic resources by making extensive canals and permanent earthen fish weirs across 7,000 km^2 of floodplain (McKey et al. 2016:14939, supporting information Figures S3, S6). Some earthen fish weirs are five km long and constructed from sediments from nearby canals, all providing much fish. The seasonal floodwaters from the river and canals are only up to 1.5 meters deep, like Maya canals, thus making for prime conditions to capture fish, including cichlids and catfish (Hickling 1961:231). Importantly, fish are taken in nets and weirs year-round in both high and low waters (Hickling 1961:229–230). One annual yield on 22,500 hectares of floodplain was 800,000 kg of fish, or 35.5 kg per hectare (McKey et al. 2016:14941). For total dried fish, 500 to 900 tons per year have been the norm (Hickling 1961:236). Palms with edible fruits, large snails, water birds, reeds, and antelopes and other potential economically important species are also found in this ecological aquaculture system (McKey 2016:1–2 of the supporting information file).

Similar ecological aquaculture and integrated subsistence regimes are also seen on the Ouémé River floodplain in Benin (Jackson et al. 2013). In this region, people have managed waterscapes and adjacent lands for fishing and



(a) (b)

Figure 19. Modern K'iche' Maya fish weirs in a stream in highland Guatemala. (a) Linear stone features and wooden poles. (b) Close up of trap and fish nets. Photographs courtesy of Jean Pierre Courau.

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cultivation, mainly through the excavation of extensive *whedo* finger-shaped fish ponds and interconnecting canals in the watershed. Part-time fishermen and small holders of different communities manage the system (Brugere 2006:49; Welcomme 1979:180). When floodwaters expand, ponds fill with water and fish for human use, like in the Maya area. People remove sediment from the ponds and then block them to retain the fish. Traps are used, often concealed in vegetation islands, in addition to nets, baskets, and weirs to capture fish (Welcomme 1979, 2003). Fish yields are impressive with ranges between 2,000 and 1,500 kilograms of fish per hectare (Welcomme 1975:28). People along the Ouémé River also pursue agriculture by cultivating maize, tomatoes, and peppers between the ponds (Welcomme 1979:242). Additionally, rice is grown in the water works (Welcomme 1975:43) showing the importance of wetland agriculture combined with ecological aquaculture. Furthermore, people raise cattle for food and aquatic fertilizer on levees built to manage local flooding.

The ancestral Hawaiian multi-trophic ecological aquaculture and integrated subsistence system also resembles the Maya case with fields, fish ponds, and water circulation from canals (Figure 20). An early visitor described the impressive Hawaiian domesticated waterscapes:

> "The whole distance to the village of Whyeete is taken up with innumerable fishponds extending a mile inland...the fish seem to thrive and fatten...The ponds are several hundred in number and are the resort of ducks and water fowl" (Bloxam quoted in Costa-Pierce 1987:322).

The Hawaiian waterscapes also supported large fields of taro, fruit, and other valuable plants. Fish and animal waste fed the plants and plankton; plant detritus, plankton, and insects fed the fish. Large fish ponds were also dug out near rivers in upland integrated farming zones and along the coastline to produce aquatic resources (Costa-Pierce 1987). These ponds were often excavated by hand in natural depressions or lakes like ancestral Maya did. The earth was piled to form embankments around the water features (Costa-Pierce 2014b:35). Sluice gates, dams, and ditches among the canals and reservoirs allowed for the control of water input and drainage to recharge the system. In the ponds, people maintained large freshwater fish populations, such as mullet, perch, and gobies, in addition to prawns and algae for consumption (Costa-Pierce 1987:325). The fish were caught in nets, traps, baskets, and by hand. Fish yields from the ponds range from 500,000 to 2,000 kilograms per year, depending on the size of the ponds and human intervention for their upkeep and exploitation (Costa-Pierce 1987:324–325).

Conclusions: Ancestral Maya domesticated waterscapes and integrated subsistence

Maya populations over time domesticated their terrestrial landscapes to obtain reliable food supplies, construction materials, and goods for trade. Researchers have stressed the importance of integrated land resources in ancestral Maya subsistence, such as the maintenance of gardens and plant diversity in fields and forests to maximize their ecological potential and resiliency (Fedick 1996; Ford and Nigh 2015; Gómez-Pompa 2003). They have shown that ancestral Maya populations intensified their cultivation techniques and modified their landscapes, as with terracing, for increased agricultural yields. Additionally, archaeologists and anthropologists have studied Maya hunting practices, often in agricultural plots, which brought additional protein to the Maya diet. Past research has also shown that ancestral Maya wetland cultivation features and canals enabled people to modify their landscape to acquire agricultural plant staples and products to maintain Maya civilization. The canals supported intensive plant cultivation and ancestral Maya settlement by draining water from

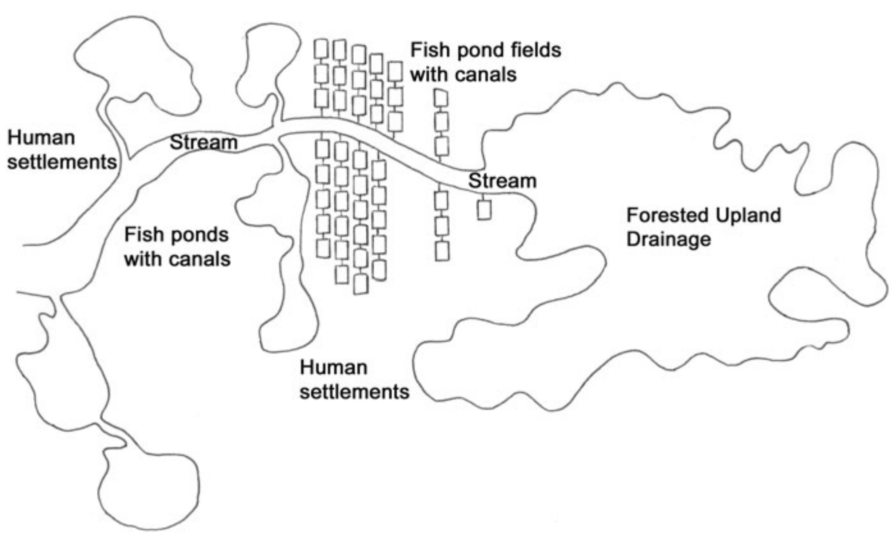

Figure 20. Ancestral Hawaiian domesticated landscape and waterscape with shallow canals, fishpond fields, and fish reservoirs in an integrated subsistence system with ecological aquaculture. Redrawn from Costa-Pierce (1987:324).

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inundated landscapes. Furthermore, reservoirs fed by this drainage sustained Maya populations during the dry season and in times of drought.

As pointed out in this article, however, Maya also relied on aquatic resources from intensively domesticated waterscapes in the right ecological conditions, such as communities near rivers, lakes, and swamps. These Maya populations obtained food and useful materials from both aquatic and terrestrial ecosystems like a resource "spread sheet" in a fully domesticated landscape and not just agriculture (Harrison-Buck et al. 2020; Sharpe et al. 2020; Williams 2022b). The combined archaeological, cultural, and iconographic information points to the importance of domesticated waterscapes in Maya societies. Archaeologists working at select sites have found evidence of aquatic foods, like the bones of various fish, waterfowl, mollusks, and turtles. These animals added nutrients to the ancestral Maya diet, in addition to providing famine foods and readily available meals. The ethnographic information in this article fortifies the thesis that aquatic resources were mixed with terrestrial products for an integrated Maya subsistence base in many areas. Classic Maya art too demonstrates the connections between people and their aquatic ecosystems. Stone monuments and portable objects depict ancient Maya elites with waterlily and fish headdresses. These plants and fish live together in shallow, clean, and slow-moving waters in the region, including canals and reservoirs, and they collectively thrive in domesticated waterscapes (Wiseman 1983). Maya elites also were often depicted sitting on altars or thrones with aquatic symbols, enhancing their connections to the fertility and productivity of water. Additionally, gods and elites in the Maya area have even been shown grabbing fish in shallow waters, echoing the importance of aquatic resources for communities.

A main contribution of this article is the finding that many western Maya lowland communities, in addition to other areas, practiced ecological aquaculture with extensive modified waterscapes and integrated subsistence in local ecosystems. They intensified aquatic resource acquisition by domesticating the waterscape (Terrell et al. 2003) in what I have demonstrated as large-scale ecological aquaculture from the comparative literature on the subject. Maya communities utilizing water management and intensive wetland agriculture practiced monumental ecological aquaculture to gain substantial aquatic resources over time. Fish were grown and stored in the canals and ponds, then collected like vegetables in fields. The canals and reservoirs of the ecological aquaculture modifications thus acted as intensive fish farms for Maya people harvesting fish when needed. Inland sites away from riverine and lacustrine environments, however, did not often have opportunities for ecological aquaculture with their small, enclosed, or isolated reservoirs. But ones with moving water did. Flowing water from rivers and rainy season flooding recharged the natural ecosystem by introducing water, nutrients, microorganisms, and fish to the canals and reservoirs. Water, nutrient-rich sediment, and organic matter were added to the wetland fields that supported plants. The plants on the shoreline provided shade, food, and filtered water to organisms in the canals, ponds, and reservoirs. Fish, turtles, waterfowl, in addition to other waterscape plants, such as reeds, palms, and dye wood, could then proliferate in such an ecosystem and be harvested by Maya people. Hence, the domesticated waterscapes enhanced the local environment rather than being a contained artificial one with small enclosed aquaculture tanks requiring constant human intervention. Maya could periodically keep the canals clean and the fields mounded with fertilizing sediment with the requisite minimal labor. Also, large numbers of wetland fields, canals, and reservoirs are still visible and usable after centuries of Maya abandonment since the monumental constructions are durable and water movement helps keep canals open by shifting water and sediment. Small tanks or enclosed ponds can fill with sediment and eventually not hold sufficient water for fish.

The practice of domesticating waterscapes to acquire resources can be examined with further research at ancient and contemporary Maya communities. Evidence for ecological aquaculture and integrated subsistence has been found at many Maya sites in ongoing investigations. Archaeologists, for instance, have recently identified extensive canals, reservoirs, wetland modifications, and raised fields, among other modified waterscapes throughout the Maya region following light detection and ranging and satellite mapping techniques (Beach et al. 2019; Canuto et al. 2018; Dunning et al. 2020; Garrison et al. 2019; Hansen et al. 2022). Some investigators believe the water features could have supported aquaculture, but they have not studied nor described this subsistence system (Dunning et al. 2017). Many types of aquaculture have existed and their management practices are equally diverse (Li 1994; Welcomme 2001). Many Maya specialists also emphasize the centralized control of hydraulic constructions due to the standard focus on Maya elites in archaeology, but labor and resource allocation for extensive land modifications for subsistence purposes could also have been a community or lineage endeavor, as pointed out above (Blanton and Fargher 2016; Carballo 2013; Erickson 200b; Juarez 2022). Ancestral Maya at many of these sites domesticated their waterscapes for ecological aquaculture for collective integrated subsistence besides just creating raised fields for intensive agriculture to underwrite elite economies. Today, community members at Lagos de Colon, Chiapas, for instance, have many large fish ponds to raise cichlids for regional consumption. This intensification of fish protein may have historic antecedents in the rich floodplains: archaeologists have reported extensive canals, dams, reservoirs, and mounded fields and living spaces in the waterscape of the ancient site of Lagartero nearby (Matheny and Gurr 1979). I also have viewed earthen berms around several cleaned-out Maya reservoirs, mounded sediments near ancient canal excavations, and numerous stone fish weirs in the Lagartero domesticated waterscape, like at other Maya sites. Similar conditions are found at Edzna, Campeche, where contemporary Maya communities grow plants near ancestral modified ponds and numerous canals across the site where they obtain water, fish, and aquatic resources like their ancestors did (Faust 1999:89).

Significantly, scholars researching South American floodplain civilizations have viewed the importance of human-modified landscapes and large-scale domesticated waterscapes to exploit varied terrestrial and aquatic resources to maximize integrated subsistence (Erickson 2000a, 2000b; Heckenberger 2005; Mackey and Pillsbury 2013; Roosevelt 2000). With comparative research, Maya researchers can further reconstruct subsistence practices, which social segments consumed certain resources, and who managed the labor necessary to maintain the domesticated waterscape ecosystems and harvest the terrestrial and aquatic animal and plant species in ecological aquaculture. Investigators can also continue to investigate modern ecosystems, ancestral domesticated waterscapes, and diachronic Maya integrated subsistence strategies to further comprehend ecological aquaculture. Additionally, archaeologists can excavate the waterscape features and adjacent past Maya settlements to better understand the local ecosystems, their use, and how the waterscapes and Maya societies changed together over time in a more complete picture of their subsistence ecology. In this manner, scholars can reconstruct ancestral Maya political ecology and labor organization, examine long-term environmental change, and analyze the exploitation of specific plant and animal populations by Maya societies for their mutual survival. Hence, continued research on Maya domesticated landscapes and waterscapes will provide significant insights towards Maya ecological aquaculture and integrated subsistence, in addition to how and why they played an important role in the development and resiliency of Maya civilization.

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References

Alexander, Rani T., John A. Hunter, Sean Arata, Ruth Martínez Cervantes, and Kristen Scudder
2013 Archaeofauna at Isla Cilvituk, Campeche, Mexico: Residential Site Structure and Taphonomy in Postclassic Mesoamerica. In *The Archaeology of Mesoamerican Animals*, edited by Christopher M. Gotz and Kitty F. Emery, pp. 281–314. Lockwood Press, Atlanta.

Arroyo, Barbara, and Lucia Henderson
2020 The Monumental Aquascape of Kaminaljuyu: Water in the Archaeology of an Early Highland Site. In *Approaches to Monumental Landscapes of the Ancient Maya*, edited by Brett A. Houk, Barbara Arroyo, and Terry G. Powis, pp. 131–151. University Press of Florida, Gainesville.

Baker, Jeffrey L.
2007 The Wet or the Dry?: Agricultural Intensification in the Maya Lowlands. In *Seeking a Richer Harvest: The Archaeology of Subsistence Intensification, Innovation, and Change*, edited by Tina L. Thurston and Christopher T. Fisher, pp. 63–90. Springer Press, New York.

Bartlett, Mary Lee
2004 Artifacts of Fired Clay. In *K'axob: Ritual, Work, and Family in an Ancient Maya Village*, edited by Patricia A. McAnany, pp. 263–274. Cotsen Institute of Archaeology, University of California, Los Angeles.

Beach, Timothy, Sheryl Luzzadder-Beach, Samanth Krause, Tom Guderjan, Fred Valdez Jr., Juan Carlos Fernández-Díaz, Sara Eshleman, and Colin Doyle
2019 Ancient Maya Wetland Fields Revealed Under Tropical Forest Canopy from Laser Scanning and Multiproxy Evidence. *Proceedings of the National Academy of Sciences* 116:21469–21477.

Beach, Timothy P., Sheryl Luzzadder-Beach, and Jon Lohse
2013 Landscape Formation and Agriculture in the Wetlands of Northwestern Belize. In *Classic Maya Political Ecology: Resource Management, Class Histories, and Political Change in Northwestern Belize*, edited by Jon C. Lohse, pp. 43–68. Cotsen Institute of Archaeology, University of California, Los Angeles.

Berry, Kimberly A., and Patricia A. McAnany
2007 Reckoning with the Wetlands and Their Role in Ancient Maya Society. In *The Political Economy of Ancient Mesoamerica: Transformations During the Formative and Classic Periods*, edited by Vernon L. Scarborough and John E. Clark, pp. 149–162. University of New Mexico Press, Albuquerque.

Blanton, Richard, and Lane F. Fargher (editors)
2016 *How Humans Cooperate: Confronting Challenges of Collective Action*. University Press of Colorado, Boulder.

Blom, Frans
1973 Travelling in 1544 from Salamanca, Spain, to Ciudad Real, Chiapas, Mexico: The Diary of Friar Tomás de la Torre. *The Sewanee Review* 81:429–569.

Bond, C. James.
1988 Monastic Fisheries. In *Medieval Fish, Fisheries, and Fishponds in England*, edited by Michael Aston, pp. 69–112. British Archaeological Reports, Oxford.

Bravo-Utrera, Miguel Angel
2009 Monitoring Aquatic Ecosystems at Doñana Natural Space. In *Conservation Monitoring in Freshwater Habitats*, edited by C. Hurford, M. Schneider, and I. Cowx, pp. 339–355. Springer Press, New York.

Brugere, Cecile
2006 A Review of the Development of Integrated Irrigation Aquaculture (IIA), with Special Reference to West Africa. In *Integrated Irrigation and Aquaculture in West Africa: Concepts, Practices, and Potential*, edited by Matthias Halwart and Anne A. van Dam, pp. 27–60. Food and Agriculture Organization of the United Nations, Rome.

Canuto, Marcello A., Francisco Estrada-Belli, Thomas G. Garrison, Stephen D. Houston, Mary Jane Acuña, Milan Kováč, Damien Marken, Philippe Nondédéo, Luke Auld-Thomas, Cyril Castanet, David Chatelain, Carlos R. Chiriboga, Tomás Drápela, Tibor Lieskovoký, Alexandre Tokovinine, Antoín Velasquez, Juan C. Fernández-Díaz, and Ramesh Shrestha
2018 Ancient Lowland Maya Complexity as Revealed by Airborne Laser Scanning of Northern Guatemala. *Science* 361. http://dx.doi.org/10.1126/science.aau0137.

Carballo, David M. (editor)
2013 *Cooperation and Collective Action: Archaeological Perspectives*. University Press of Colorado, Boulder.

Carr, Helen S.
1985 Subsistence and Ceremony: Faunal Utilization in a Late Preclassic Community at Cerros, Belize. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl,

pp. 115–132. Papers of the Peabody Museum of Archaeology and Ethnology, Vol. 77. Harvard University, Cambridge.

Chopin, Thierry
2013 Integrated Multi-Trophic Aquaculture. In *Sustainable Food Production*, edited by Christou, Paul, Roxana Savin, Barry Costa-Pierce, Ignacy Misztal, and Bruce Whitelaw, pp. 184–205. Springer Press, New York.

Connaway, John M.
1982 The Sturdivant Fishweir, Amite County, Mississippi. *Southeastern Archaeology* 1:138–163.

Costa-Pierce, Barry A.
1987 Aquaculture in Ancient Hawaii. *BioScience* 37:320–331.
2014a Ecology as the Paradigm for the Future of Aquaculture. In *Ecological Aquaculture: The Evolution of the Blue Revolution*, edited by Barry A. Costa-Pierce, pp. 339–372. Wiley Blackwell, Hoboken.
2014b The Ahupua'a Aquaculture Ecosystems in Hawaii. In *Ecological Aquaculture: The Evolution of the Blue Revolution*, edited by Barry A. Costa-Pierce, pp. 30–44. Wiley Blackwell, Hoboken.

Darch, Janice P.
2000 Vegetation Associations at Pulltrouser Swamp. In *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize*, edited by B.L. Turner and Peter D. Harrison, pp. 21–29. University of Utah Press, Salt Lake City.

De Lucia, Kristin
2021 Household Lake Exploitation and Aquatic Lifeways in Postclassic Xaltocan, Mexico. *Journal of Anthropological Archaeology* 62. https://doi.org/10.1016/j.jaa.2021.101273

Denevan, William M.
1970 Aboriginal Drained-Field Cultivation in the Americas. *Science* 169:647–654.
1982 Hydraulic Agriculture in the American Tropics: Forms, Measures, and Recent Research. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by Kent V. Flannery, pp. 181–204. Academic Press, New York.

Dillon, Brian D.
1981 Camelá Lagoon: Preliminary Investigations at a Lowland Maya Site in El Quiché, Guatemala. *Journal of New World Archaeology* 4:55–87.

Dunning, Nicholas, Jeffrey Brewer, Christopher Carr, Amando Anaya Hernández, Timothy Beach, Jennifer Chmilar, Liwy Grazioso Sierra, Robert Griffin, David Lentz, Sheryl Luzzadder-Beach, Kathryn Reese-Taylor, William Saturno, Vernon Scarborough, Michael Smyth, and Fred Valdez Jr.
2022 Harvesting *Ha*: Ancient Water Collection and Storage in the Elevated Interior Region of the Maya Lowlands. In *Sustainability and Water Management in the Maya World and Beyond*, edited by Jean T. Larmon, Lisa J. Lucero, and Fred Valdez Jr., pp. 13–51. University Press of Colorado, Louisville.

Dunning, Nicholas., Thomas Ruhl, Christopher Carr, Timothy Beach, Clifford Brown, and Sheryl Luzzadder-Beach
2020 The Ancient Maya Wetland Fields of Acalán. *Mexicon* 42:91–105.

Dunning, Nicholas P., Robert E. Griffin, Thomas L. Sever, William A. Saturno, and John G. Jones
2017 The Nature and Origin of Linear Features in the Bajo de Azúcar, Guatemala: Implications for Ancient Maya Adaptation to a Changing Environment. *Geoarchaeology* 32:107–129.

Durán, Fray Diego
1951 *Historia de las Indias de Nueva-España y Islas de Tierra Firme: Tomo I*. Editorial Nacional, Mexico City.

Ebel, Roland
2019 Chinampas: An Urban Farming Model of the Aztecs and a Potential Solution for Modern Megalopolis. *American Society for Horticultural Science* 30:13–19.

Edwards, Peter
2015 Aquaculture Environmental Interactions: Past, Present, and Likely Future Trends. *Aquaculture* 447:2–14.

Emery, Kitty F.
2007 Aprovechamiento de la fauna en Piedras Negras: Dieta, ritual, y artesanía del período Clásico maya. *Mayab* 19:51–69.

Emery, Kitty F, Erin Kennedy Thornton, Nicole R. Cannarozzi, Stephen Houston, and Héctor Escobedo
2013 Archaeological Animals of the Southern Maya Highlands: Zooarchaeology at Kaminaljuyú. In *The Archaeology of Mesoamerican Animals*, edited by Christopher M. Gotz and Kitty F. Emery, pp. 381–416. Lockwood Press, Atlanta.

Erickson, Clark L.
2000a An Artificial Landscape-scale Fishery in the Bolivian Amazon. *Nature* 408:190–193.
2000b The Lake Titicaca Basin: A Precolumbian Built Landscape. In *Imperfect Balance: Landscape Transformations in the Precolumbian Americas*, edited by David L. Lentz, pp. 311–356. Columbian University Press, New York.

Faust, Betty Bernice
1999 *Mexican Rural Development and the Plumed Serpent: Technology and Maya Cosmology in the Tropical Forest of Campeche, Mexico*. Bergin and Garvey, Westport.

Fedick, Scott L.
1996 Introduction: New Perspectives on Ancient Maya Agriculture and Resource Use. In *The Managed Mosaic: Ancient Maya Agriculture and Resource Use*, edited by Scott L. Fedick, pp. 1–16. University of Utah Press, Salt Lake City.
2003 Archaeological Evidence for Ancient and Historic Use Associated with the El Edén Wetland, Northern Quintana Roo, Mexico. In *The Lowland Maya Area: Three Millenia at the Human-Wildland Interface*, edited by Arturo Gómez-Pompa, M.F. Allen, Scott L. Fedick, and J.J. Jiménez-Osornio, pp. 339–360. Food Products Press, New York.

Flores Ramos, Edson F.
2014 Relación de los grupos tróficos ícticos con la heterogeneidad ambiental de la Laguna Silvituc, Campeche, México. Master's thesis, Departmento de Ciencias Químico-Biológicas, Universidad Autónoma de Campeche, Campeche.

Ford, Anabel, and Ronald Nigh
2015 *The Maya Forest Garden: Eight Millennia of Sustainable Cultivation of the Tropical Woodlands*. Left Coast Press, Walnut Creek.

Freidel, David A., and Vernon Scarborough
1982 Subsistence, Trade, and Development of the Coastal Maya. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by Kent Flannery, pp. 131–155. Academic Press, New York.

French, Kirk D., Christopher J. Duffy, and Gopal Bhatt
2012 The Hydroarchaeological Method: A Case Study at the Maya Site of Palenque. *Latin American Antiquity* 23:29–50.

Gamboa-Pérez, Héctor C., and Juan J. Schmitter-Soto
1999 Distribution of Cichlid Fishes in the Littoral of Lake Bacalar, Yucatan Peninsula. *Environmental Biology of Fishes* 54:35–43.

Garrison, Thomas G., Stephen Houston, and Omar Alcover Firpi
2019 Recentering the Rural: LiDAR and Articulated Landscapes among the Maya. *Journal of Anthropological Archaeology* 53:133–146.

Gómez-Pompa, Arturo
2003 Research Challenges for the Lowland Maya Area: An Introduction. In *The Lowland Maya Area: Three Millennia at the Human-Wildland Interface*, edited by Arturo Gómez-Pompa, M.F. Allen, Scott L. Fedick, and J.J. Jiménez-Osornio, pp. 3–12. Food Products Press, New York.

Gómez-Pompa, Arturo, Hector Luis Morales, Epifanio Jiménez Avilla, and Julio Jiménez Avilla
1982 Experiences in Traditional Hydraulic Agriculture. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by Kent V. Flannery, pp. 327–344. Academic Press, New York.

Gunn, Joel D., William J. Folan, Christian Isendahl, Maria del Rosario Domínquez Carrasco, Betty B. Faust, and Beniamino Volta
2014 Calakmul: Agent Risk and Sustainability in the western Maya Lowlands. In *The Resilience and Vulnerability of Ancient Landscapes: Transforming Maya Archaeology through IHOPE*, edited by Arlen F. Chase and Vernon Scarborough, pp. 101–123. Wiley Publishing, Hoboken.

Guzmán, Ana Fabiola, and Oscar J. Polaco
2002 Los peces del sitio arqueológico Altamirano, Veracruz. *Arqueología* 27:15–30.

Hansen, Richard D., Carlos Morales-Aguilar, Josephine Thompson, Ross Ensley, Enrique Hernández, Thomas Schreiner, Edgar Suyuc-Ley, and Gustavo Martínez
2022 LiDAR Analysis in the Contiguous Mirador-Calakmul Karst Basin, Guatemala: An Introduction to New Perspectives on Regional Early Maya Socioeconomic and Political Organization. *Ancient Mesoamerica* 1–40. https://doi.org/10.1017/S0956536122000244

Harrison-Buck, Eleanor
2014 Ancient Maya Wetland Use in the Eastern Belize Watershed. *Research Reports in Belizean Archaeology* 11:245–258.
Harrison-Buck, Eleanor, Sara Clarke-Vivier, Lori Phillips, and Astrid Runggaldier
2020 From Excavations to Educational Outreach: Presenting the History of Human-Wetland Interaction Around Western Lagoon, Belize. *Research Reports in Belizean Archaeology* 17:259–272.
Harrison, Peter D.
1993 Aspects of Water Management in the Southern Maya Lowlands. In *Research in Economic Anthropology: Economic Aspects of Water Management in the Prehispanic New World*, edited by Vernon L. Scarborough and Barry L. Isaac, pp. 71–122. JAI Press, Greenwich.
1996 Settlement and Land Use in the Pulltrouser Swamp Archaeological Zone, Northern Belize. In *Managed Mosaic: Ancient Maya Agriculture and Resource Use*, edited by Scott L. Fedick, pp. 177–192. University of Utah Press, Salt Lake City.
Harrison, Peter D., and Robert E. Fry
2000 *Pulltrouser Swamp: A Lowland Maya Community Cluster in Northern Belize: The Settlement Maps*. University of Utah Press, Salt Lake City.
Heckenberger, Michael J.
2005 *The Ecology of Power: Culture, Place, and Personhood in the Southern Amazon, A.D. 1000–2000*. Routledge, New York.
Hickling, Charles F.
1961 *Tropical Inland Fisheries*. Longmans, Green and Company, London.
1968 *The Farming of Fish*. Pergamon Press, Oxford.
Hutchinson, Laurence
2005 *Ecological Aquaculture: A Sustainable Solution*. Permanent Publications, Hampshire.
Jackson, Andrew T., Alphonse Adite, Katherine A. Roach, and Kirk O. Winemiller
2013 Fish Assemblages of an African River Floodplain: A Test of Alternative Models of Community Structure. *Ecology of Freshwater Fish* 22:295–306.
James, Steven R.
2003 Hunting and Fishing Patterns Leading to Resource Depletion. In *Centuries of Decline during the Hohokam Classic Period at Pueblo Grande*, edited by David R. Abbott, pp. 70–81. University of Arizona Press, Tucson.
Jiménez-Cano, Nayeli
2019 Pre-hispanic Maya Fisheries and Coastal Adaptations in the Northern Maya Lowlands from the Classic (500–900 A.D.) to Postclassic (900–1400 A.D.) Periods. *International Journal of Osteoarchaeology* 29:469–476.
Juarez, Santiago
2022 Viewing the World through Cosmovision at Late Preclassic Noh K'uh in Chiapas, Mexico. *Cambridge Archaeological Journal* 33:1–17.
Juarez, Santiago, Sebastian Salgado, and Chris Hernandez
2019 The Site of Noh K'uh, Chiapas, Mexico: A Late Preclassic Settlement in the Mensabak Basin. *Latin American Antiquity* 30:211–217.
Kestle, Caleb
2013 Operación LO-2: Excavaciones en el Sitio Los Olores, Operación 2 (LO-2). In *Informe temporada 2013, Proyecto Arqueológico Mensabak, Chiapas, Mexico*, edited by Santiago Juarez, Rebecca Deeb, Joel Palka, and Chris Hernandez, pp. 32–40. University of Illinois-Chicago, Chicago.
2021 *One Foot Out the Door: Late Postclassic Zooarchaeology of Lake Mensabak, Chiapas, Mexico*. Unpublished Ph.D. dissertation, Department of Anthropology, University of Illinois-Chicago, Chicago.
Kováč, Milan
2013 Ah Xok, Transfromaciones de un dios acuático: Del tiburón olmeca a la sirena lacandona. In *Water Management in Ancient Mesoamerica*, edited by Jaroslaw Zralka and Christophe Helmke, pp. 151–164. Polish Academy of Arts and Sciences, Krakow.
Lentz, David, Nicholas Dunning, Payson Sheets, Timothy Beach, Sheryl Luzzadder-Beach, Andrew Wyatt, and Cynthia Robin
2022 Ancient Maya Intensive Agriculture and Water Management Practices. In *Sustainability and Water Management in the Maya World and Beyond*, edited by Jean T. Larmon, Lisa J. Lucero, and Fred Valdez Jr., pp. 52–77. University Press of Colorado, Louisville.
Li, Sifa
1994 Introduction: Freshwater Fish Culture. In *Freshwater Fish Culture in China: Principles and Practice*, edited by Sifa Li and Jack Mathias, pp. 1–25. Elsevier, Amsterdam.
Liendo Stuardo, Rodrigo
2002 *The Organization of Agricultural Production at a Classic Maya Center: Settlement Patterns in the Palenque Region, Chiapas, Mexico*. Instituto Nacional de Antropología e Historia, Mexico City.
Ling, Shao-Wen
1977 *Aquaculture in Southeast Asia: A Historical Overview*. University of Washington Press, Seattle.
Lowe, Lynneth S., and Carlos Alvarez Asomoza
2007 Recent Explorations at the Postclassic Site of Los Cimientos de Las Margaritas, Chiapas. In *Archaeology, Art, and Ethnogenesis in Mesoamerican Prehistory: Papers in Honor of Gareth W. Lowe*, edited by Lynneth S. Lowe and Mary E. Pye, pp. 321–336. Brigham Young University, Provo.
Lozada Toleda, Josuhé
2017 *El arte rupestre y la temporalidad del paisaje en Laguna Mensabak y Laguna Pethá, Chiapas*. Unpublished Ph.D. dissertation, Department of Archaeology, Escuela Nacional de Antropología e Historia, Mexico City.
Lozano, Diego H., and Francisco López
2001 *Manual de pisicultura de la región amazonica ecuatoriana*. Mossaico, Quito.
Lozoya, Xavier
1999 Un paraíso de plantas medicinales. *Arqueología Mexicana* 39:14–21.
Lucero, Lisa J.
2006 Agricultural Intensification, Water, and Political Power in the Southern Maya Lowlands. In *Agricultural Strategies*, edited by Joyce Marcus and Charles Stanish, pp. 281–305. Cotsen Institute of Archaeology, University of California, Los Angeles.
Luzzadder-Beach, Sheryl, Timothy Beach, Scott Hutson, and Samantha Krause
2016 Sky-Earth, Lake-Sea: Climate and Water in Maya History and Landscape. *Antiquity* 90:426–442.
Lyons, Kevin J.
2015 Recognizing the Archaeological Signatures of Resident Fisheries: Considerations from the Pend Oreille Basin. In *Rivers, Fish, and the People: Tradition, Science, and Historical Ecology of Fisheries in the American West*, edited by Pei-Lin Yu, pp. 96–126. University of Utah Press, Salt Lake City.
Mackey, Carol J., and Joanne Pillsbury
2013 Cosmology and Ritual on a Lambayeque Beaker. In *Pre-Columbian Art and Archaeology: Essays in Honor of Frederick R. Mayer*, edited by Margaret Young-Sánchez, pp. 115–141. Denver Art Museum, Denver.
Marion, Marie-Odile
1991 *Los hombres de la selva: Un estudio de tecnología cultural en medio selvático*. Instituto Nacional de Antropología e Historia, Mexico City.
Martínez-García, Rafael, M. F. Cifuentes-Alonso, Maximiano Antonio Estrada Botello, Abel Santiago Lopez Torres, María de Jesús Contreras-Garcia, Alejandro Macdonal-Vera, Estuardo González-Arévalo, Wilfrido Miguel Contreras-Sánchez, and Kevin Fitzsimmons
2022 Development of Sustainable Aquaculture Practices in Tabasco, Mexico, Using Novel IAA Technology. Unpublished paper, University of Arizona, Tucson.
Masson, Marilyn A.
2004 Contribution of Fishing and Hunting to Subsistence and Symbolic Expression. In *K'axob: Ritual, Work, and Family in an Ancient Maya Village*, edited by Patricia A. McAnany, pp. 382–398. Cotsen Institute of Archaeology, University of California, Los Angeles.
Matheny, Ray T., and Deanne L. Gurr
1979 Ancient Hydraulic Techniques in the Chiapas Highlands: Strategies Used by the Maya in Southeastern Mexico for Efficient Management of Soil and Water Resources Provide Evidence of Cultural Change and Population Growth. *American Scientist* 67:441–449.
Matheny, Ray T., Deanne L. Gurr, Donald W. Forsyth, and F. Richard Hauck
1983 *Investigations at Edzna, Campeche, Mexico: Volume 1: The Hydraulic System*. New World Archaeological Foundation, No. 46. Brigham Young University, Provo.

McKey, Doyle B., Melisse Durecu, Marc Pouilly, Philippe Bearez, Alex Ovando, Mashuta Kalebe, and Carl F. Huchzermeyer
2016 Present-Day African Analogue of a Pre-European Amazonian Floodplain Fishery Shows Convergence in a Cultural Niche Construction. *Proceedings of the National Academy of Sciences* 113:14938–14943.

McKillop, Heather, and Kazuo Aoyama
2018 Salt and Marine Products in the Classic Maya Economy from Use-Wear Study of Stone Tools. *Proceedings of the National Academy of Sciences* 115:10948–10952.

Morehart, Christopher T.
2016 Chinampa Agriculture, Surplus Production, and Political Change at Xaltocan, Mexico. *Ancient Mesoamerica* 27:183–196.

Nietschmann, Bernard
1973 *Between Land and Water: The Subsistence Ecology of the Miskito Indians, Eastern Nicaragua*. Seminar Press, New York.

Norman, V. Garth
1973 *Izapa Sculpture, Part 2. Text*. Papers of the New World Archaeological Foundation, No. 30, Pt. 2. Brigham Young University, Provo.

Palka, Joel W.
2014 *Maya Pilgrimage to Ritual Landscapes: Insights from Archaeology, History, and Ethnography*. University of New Mexico Press, Albuquerque.

Palma-Cancino, David J., Rafael Martínez-García, Carlos A. Alvarer-González, Ronald Jesús Contreras, Eucario Gasca-Leyva, Emyr Peña, and Susana Camarillo-Coop
2019 Bioeconomic Profitability Analysis of Tropical Gar (*Atractosteus tropicus*) Grow-Out Using Two Commercial Feeds. *Latin American Journal of Aquatic Research* 47:433–439.

Parsons, Jeffrey R.
2006 *The Last Pescadores (Fishers) of Chimalhuacan, Mexico: An Archaeological Ethnography*. University of Michigan, Ann Arbor.

Parsons, Lee Allen
1986 *The Origins of Maya Art: Monumental Sculpture of Kaminaljuyu, Guatemala, and the Southern Pacific Coast*. Dumbarton Oaks Research Library and Collection, Washington, DC.

Pérez Espinosa, José G.
1985 La pesca en el medio lacustre y chinampero de San Luis Tlaxialtemalco. In *La cosecha del agua en la Cuenca de México*, edited by Teresa Rojas Rabiela, pp. 113–129. Centro de Investigaciones y Estudios Superiores en Antropología Social, Mexico City.

Pérez Sánchez, José Manuel
2007 El manejo de los recursos naturales bajo el modelo agrícola de camellones chontales en Tabasco. *Iberio Forum: Voces y Contextos* 4:1–9.

Pohl, Mary D.
1985 An Ethnohistorical Perspective on Ancient Maya Wetland Fields and Other Cultivation Systems in the Lowlands. In *Prehistoric Lowland Maya Environment and Subsistence Economy*, edited by Mary D. Pohl, pp. 35–46. Peabody Museum of Harvard University, Cambridge.

Pohl, Mary D., Kevin O. Pope, John G. Jones, John S. Jacob, Dolores R. Piperno, Susan D. deFrance, David L. Lentz, John A. Gifford, Marie E. Danforth, and J. Kathryn Josserand
1996 Early Agriculture in the Maya Lowlands. *Latin American Antiquity* 7:355–372.

Pohl, Mary D., Paul R. Bloom, and Kevin O. Pope
1990 Interpretation of Wetland Farming in Northern Belize: Excavations at San Antonio Río Hondo. In *Ancient Maya Wetland Agriculture*, edited by Mary D. Pohl, pp. 187–254. Westview Press, Boulder.

Prestes-Carneiro, Gabriela, Philippe Béatrez, Myrtle P. Shock, Heiko Prumers, and Carla J. Betancourt
2019 Pre-Hispanic Fishing Practices in Interfluvial Amazonia: Zooarchaeological Evidence from Managed Landscapes on the Llanos de Mojos Savana. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0214638.

Puleston, Dennis E.
1977 The Art and Archaeology of Hydraulic Agriculture in the Maya Lowlands. In *Social Process in Maya Prehistory*, edited by Norman Hammond, pp. 449–469. Academic Press, London.
1978 Terracing, Raised Fields, and Tree Cropping in the Maya Lowlands: A New Perspective on the Geography of Power. In *Pre-Hispanic Maya Agriculture*, edited by Peter D. Harrison and B.L. Turner, pp. 225–246. University of New Mexico Press, Albuquerque.

Renard, Delphine, José Iriarte, Jago J. Birk, Stephen Rostain, Bruno Glaser, and Doyle B. McKey
2012 Ecological Engineers Ahead of Their Time: The Functioning of Pre-Columbian Raised-Field Agriculture and Its Potential Contributions to Sustainability Today. *Ecological Engineering* 45:30–44.

Rice, Prudence M., and Don S. Rice
2016 *Ixlú: A Contested Maya Entrepot in Petén, Guatemala*. University of Pittsburgh, Pittsburg.

Rice, Prudence M., Don S. Rice, and Timothy W. Pugh
2017 *Small Things Forgotten: Artifacts of Fishing in the Peten Lakes Region, Guatemala*. Contributions in Ethnobiology, Tacoma.

Ringer, R. James
2008 The Atherley Narrows Fish Weir Complex: A Submerged Archaic-to-Historic-Period Fishing Site in Ontario, Canada. *Revista de Arqueología Americana* 26:131–151.

Rivas, Alexander E., and William G.B. Odum
2019 Ethnography and Archaeology of Water in the Maya Lowlands. *Open Rivers* 14:93–110.

Rodríguez Galicia, Bernardo
2017 *La pesca mesoamericana*. Universidad Nacional Autónoma de México, Mexico City.

Roosevelt, Anna C.
2000 The Lower Amazon: A Dynamic Human Habitat. In *Imperfect Balance: Landscape Transformations in the Precolumbian Americas*, edited by David L. Lentz, pp. 455–492. Columbia University Press, New York.

Ruz, Mario Humberto
1998 Los herederos de Zipacna: Notas sobre la pesca en cinco grupos mayas coloniales. In *Anatomía de una civilización: Approximaciones interdisciplinarias a la cultura maya*, edited by Andrés Ciudad Ruíz, pp. 353–375. Sociedad Española de Estudios Mayas, Madrid.
2020 *Herederos de Cabracán y Zipacna: Caza y pesca entre los mayas coloniales*. Universidad Nacional Autónoma de México.

Sánchez López, Yael
2021a El consumo de tortugas en una communidad del Posclásico en la Selva Lacandona. *Revista Chicomoztoc* 5:21–55.
2021b Estatus y consumo de animales en Laguna Mensabak: Un estudio de caso en el sitio Tzunun, Chiapas. Master's thesis, Departmento de Arqueología, Universidad de Ciencias y Artes de Chiapas, Tuxtla Gutiérrez.

Sandstrom, Alan R.
2021 Flower World in the Religious Ideology of Contemporary Nahua of the Southern Huasteca, Mexico. In *Flower Worlds: Religion, Aesthetics, and Ideology in Mesoamerica and the American Southwest*, edited by Michael D. Mathiowetz and Andrew D. Turner, pp. 35–52. University of Arizona Press, Tucson.

Scarborough, Vernon L.
1991 *Archaeology at Cerros, Belize, Central America: Volume III, The Settlement System in a Late Preclassic Community*. Southern Methodist University, Dallas.
1998 Ecology and Ritual: Water Management and the Maya. *Latin American Antiquity* 9:135–159.

Scherer, Andrew K., Lori E. Wright, and Cassady J. Yoder
2007 Bioarchaeological Evidence for Social and Temporal Differences in Diet at Piedras Negras, Guatemala. *Latin American Antiquity* 18:85–104.

Serrano, Laura, Marta Reina, Gonzalo Martin, Isabel Reyes, Arantza Arechederra, David León, and Julia Toja
2006 The Aquatic Systems of Doñana (SW Spain): Watersheds and Frontiers. *Limnetica* 25:11–32.

Sharpe, Ashley E., Takeshi Inomata, Daniela Triadan, Melissa Burham, Jessica MacLellan, Jessica Munson, and Flory Pinzón
2020 The Maya Preclassic to Classic Transition Observed through Faunal Trends from Ceibal, Guatemala. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0230892.

Siemens, Alfred H.
1978 Karst and the Pre-Hispanic Maya in the Southern Lowlands. In *Pre-Hispanic Maya Agriculture*, edited by Peter D. Harrison and B.L. Turner, pp. 117–144. University of New Mexico Press, Albuquerque.

Siemens, Alfred H., and Dennis E. Puleston
1972 Ridged Fields and Associated Features in Southern Campeche: New Perspectives on the Lowland Maya. *American Antiquity* 37: 228–239.

Siemens, Alfred H., and Richard Hebda
2009 Un río en tierra maya, el Río Candelaria. *Investigadores de la Cultura Maya* 17:213–230.

Sluyter, Andrew
1994 Intensive Wetland Agriculture in Mesoamerica: Space, Time, and Form. *Annals of the Association of American Geographers* 84: 557–584.

Smith, Bruce D.
2011 General Patterns of Niche Construction and the Management of 'Wild' Plant and Animal Resources by Small-scale Pre-industrial Societies. *Philosophical Transactions of the Royal Society B* 366:836–848.

Stoner, Wesley D., Barbara L. Stark, Amber VanDerwarker, and Kyle R. Urquhart
2021 Between Land and Water: Hydraulic Engineering in the Tlalixcoyan Basin, Veracruz, Mexico. *Journal of Anthropological Archaeology* 61. https://doi.org/10.1016/j.jaa.2020.101264.

Taube, Karl
1985 The Classic Maya Maize God: A Reappraisal. In *Fifth Palenque Round Table, 1983*, edited by Merle Greene Robertson, pp. 171–181. Precolumbian Art Research Institute, San Francisco.
1986 The Teotihuacan Cave of Origin: The Iconography and Architecture of Emergence Mythology in Mesoamerica and the American Southwest. *RES: Anthropology and Aesthetics* 12:51–82.

Terrell, John, and John P. Hart
2008 Domesticated Landscapes. In *Handbook of Landscape Archaeology*, edited by Bruno David and Julian Thomas, pp. 328–332. Routledge, New York.

Terrell, John E., John P. Hart, Sibel Barut, Nico Cellinese, L. Antonio Curet, Tim Denham, Chap Kusimba, David Kyle Latinis, Rahul Oka, Joel W. Palka, Mary E. D. Pohl, Patrick Ryan Williams, Helen Haines, and John E. Staller
2003 Domesticated Landscapes: The Subsistence Ecology of Plant and Animal Domestication. *Journal of Archaeological Method and Theory* 10:232–368.

Thompson, J. Eric S.
1974 'Canals' of the Río Candelaria Basin, Campeche, Mexico. In *Mesoamerican Archaeology: New Approaches*, edited by Norman Hammond, pp. 297–302. University of Texas Press, Austin.

Thornton, Erin Kennedy
2012 Animal Resource Use and Exchange at an Inland Maya Port: Zooarchaeological Investigations at Trinidad de Nosotros. In *Motul de San José: Politics, History, and Economy in a Classic Maya Polity*, edited by Antonia E. Foias and Kitty F. Emery, pp. 326–356. University Press of Florida, Gainesville.

Tozzer, Alfred M.
1907 *A Comparative Study of the Mayas and Lacandones*. MacMillan, New York.

Trik, Aubrey S.
1963 The Splendid Tomb of Temple I at Tikal, Guatemala. *Expedition* 6:3–18.

Turner, B.L., and Peter D. Harrison (editors)
2000 *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize*. University of Utah Press, Salt Lake City.

Valdés, Juan Antonio, and Lori E. Wright
2004 The Early Classic and Its Antecedents at Kaminaljuyu: A Complex Society with Complex Problems. In *Understanding Early Classic Copan*, edited by Ellen E. Bell, Marcello A. Canuto, and Robert J. Sharer, pp. 337–356. University of Pennsylvania Press, Philadelphia.

VanDerwarker, Amber M.
2006 *Farming, Hunting, and Fishing in the Olmec World*. University of Texas Press, Austin.

Varela Scherrer, Carlos M.
2021 *La vida cotidiana en un grupo residencial de élite durante el clásico tardío: Análisis de los materiales zooarqueológicos recuperados en el Grupo IV de Palenque, Chiapas*. Unpublished Ph.D. dissertation, Estudios Mesoamericanos, Universidad Nacional Autónoma de México, Mexico City.

Varela Scherrer, Carlos M., and Rodrigo Liendo Stuardo
2022 Aprovechamiento del paisaje y manejo de la fauna en Palenque, Chiapas. *Ancient Mesoamerica* 33:294–308.

Weigand, Phil E.
1993 Large-Scale Hydraulic Works in Prehistoric Western Mesoamerica. In *Economic Aspects of Water Management in the Prehispanic New World; Research in Economic Anthropology, Supplement 7*, edited by Barry Isaacs and Vernon Scarborough, pp. 223–262. JAI Press, London.

Welcomme, Robin L.
1975 *The Fisheries Ecology of African Floodplains*. Food and Agriculture Organization of the United Nations, Rome.
1979 *Fisheries Ecology of Floodplain Rivers*. Longman Group, London.
2001 *Inland Fisheries: Ecology and Management*. Blackwell Science, London.
2003 River Fisheries in Africa: Their Past, Present, and Future. In *Conservation, Ecology, and Management of African Fresh Waters*, edited by Thomas L. Crisman, Lauren J. Chapman, Colin A. Chapman, and Les S. Kaufman, pp. 145–175. University Press of Florida, Gainesville.

Williams, Eduardo
2022a *Aquatic Adaptations in Mesoamerica: Subsistence Activities in Ethnoarchaeological Perspective*. Archaeopress Publications, Oxford.
2022b The "Land of Fish": Reconstructing the Ancient Aquatic Lifeway in Michoacán, Western Mexico. *Ancient Mesoamerica* 33:347–382.

Wiseman, Frederick M.
1983 Subsistence and Complex Societies: The Case of the Maya. *Advances in Archaeological Method and Theory* 6:143–189.

Woodfill, Brent K.S., and Marc Wolf
2020 The Natural and Constructed Landscape of Salinas de los Nueve Cerros, Guatemala. In *Approaches to Monumental Landscapes of the Ancient Maya*, edited by Brett A. Houk, Barbara Arroyo, and Terry G. Powis, pp. 39–60. University Press of Florida, Gainesville.

Yang, Huazhu
1994a Integrated Fish Farming. In *Freshwater Fish Culture in China: Principles and Practice*, edited by Sifa Li and Jack Mathias, pp. 219–270. Elsevier, Amsterdam.
1994b Integrated Rice-Fish Culture. In *Freshwater Fish Culture in China: Principles and Practice*, edited by Sifa Li and Jack Mathias, pp. 368–385. Elsevier, Amsterdam.

Yu, Pei-Lin (editor)
2015 *Rivers, Fish, and the People: Tradition, Science, and Historical Ecology of Fisheries in the American West*. University of Utah Press, Salt Lake City.