Journal of Arid Environments 94 (2013) 59–67

Contents lists available at SciVerse ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Date palm as a keystone species in Baja California peninsula, Mexico oases

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ARTICLE INFO

Article history:
Received 3 October 2012
Received in revised form
29 January 2013
Accepted 13 February 2013
Available online 30 March 2013

Keywords:
Agro-ecosystems
Baja California peninsula
Cultural keystone
Date palm
Ecological keystone
Jesuit missionaries
Oases
Phoenix dactylifera

ABSTRACT

Based on historical records, Jesuit missionaries were the first to introduce date palm (*Phoenix dactylifera* L., Arecacea) to the mission oases of the Mexican Baja California peninsula. Seedling date palms readily naturalized and have partially, and in some cases almost entirely replaced the native fan palm, *Washingtonia filifera* and *Washingtonia robusta* in the oases. These wild and introduced palms form the over-story for smaller cultivated trees, shrubs, and open gardens of mixed perennial and annual cultivars in complex agro-ecosystems. They also grow in dense stands along the oases arroyos where they may be "owned" by various oasis residents and semi- to carefully managed, or comprise wild populations beyond the periphery of the oasis settlements. These palms serve as ecological and cultural keystone species, altering oasis microclimates and providing shade for understory crops, shelter and food resources for resident and migratory fauna, and building materials and food for oasis human residents. I explore the agro-ecological role of the date palm in Baja California peninsula oases.

1. Introduction

Jesuit missionaries first introduced agricultural crops to the Baja California peninsula of Mexico during their ecclesiastical reign from 1697 to 1768 (Clavijero, 2007; Crosby, 1994; Del Barco, 1980; Venegas 1757). Though Jesuit missionaries record only a few mentions of date palms in their meticulous historical inventories, the palm has gained such cultural and ecological status that many of the mission oases on the Baja California peninsula are known for their geographically extensive date palm groves and the harvest and sale of date products (Aschmann, 1957; Breceda et al., 1997; León de la Luz and Domínguez, 2006). Date palms, along with native fan palms form the over-story of oasis towns and field gardens, called *huertas*, and in many cases have filled the sandy arroyos of the oases upstream and downstream where water occurs close to the ground surface. These palms provide many eco-system services, including ameliorating oasis temperature, changing floodwater dynamics, and facilitating wildlife as well as providing food, fiber and building resources to the oasis inhabitants and a symbolic image by which many define a desert "oasis" on the peninsula (Cariño Olvera, 1996; Cariño Olvera, 2011; Rodríguez et al., 1997; Routson, 2012).

The date palm is emblematic of the oases of the Middle East, North Africa, and central Asia though few people associate palms with the remote desert oases of the Mexican Baja California peninsula. In the New World, date palms have acquired cultural and ecological significance, though the ways in which these manifest are unique to the region and the guilds of species and cultures into which they were introduced. Date palms in the peninsula oases grow in species guilds specific to the peninsula, with native, endemic and exotic palms, trees, shrubs and riparian herbaceous plants (Arriaga et al., 1997; León de la Luz and Domínguez, 2006). As I document in this research, the peoples of the oases also have methods of harvesting, drying, preparing, fermenting and storing dates that are part of a distinct cultural heritage developed over three centuries of mission, colonial and recent history. Desert oases on the Baja California peninsula can be seen as a counterpart to old world oases, isolated by the two seas and sheer distance from other world deserts. This isolation in time and distance, along with the biophysical characteristics of the peninsula have facilitated the evolution of unique oasis ecosystems and culture, within which I demonstrate that date palms play a prominent ecologic and cultural role.

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http://dx.doi.org/10.1016/j.jaridenv.2013.02.008

2. Geographical and historical context

2.1. Peninsula geography

The Baja California peninsula forms a splinter of the North American continent, reaching from latitudes 22°N to 33°N, a distance of 1300 km and varying in width from 30 to 240 km (109°–117° West longitude) (Davis, 2006). Extending between the narrow Gulf of California and the Pacific Ocean, the peninsula is attached to the continent by a narrow belt of land at its northernmost extent, and its southern tip crosses the Tropic of Cancer. The peninsula and its gulf islands have a combined area of 145,000 km^2 (Garcillán et al., 2010). Peninsular ecology ranges from northern temperate regions, through extensive intermediate deserts, to dry tropical forests of the southern cape (Peinado et al., 1995). The biotically diverse Gulf of California and Pacific Ocean isolate the peninsula, two contrasting marine environments that influence the climate, geomorphology and biota of the peninsula.

The Baja California peninsula was created as a sliver of continental crust separated from the mainland along the San Andreas Fault line (Riddle et al., 2000). The eastern shore of Baja California along the spreading zone of the gulf rises abruptly in a rocky, irregular coastline with a series of rugged islands left stranded in the sea. The western shore along the Pacific has a gentler gradient with stretches of salt flats, lower eroding alluvial hills, and sand beaches. Peninsular topography includes mountains, desert plains, and coastal plains of composed of predominantly intrusive and extrusive igneous bedrock, followed by sedimentary and metamorphic formations.

The two large bodies of salt water that almost surround the peninsula influence the climate, substrate and biota. The systems of the Pacific Ocean and Gulf of California and the interaction between the two affect the peninsula's biophysical process. The elongate, narrow peninsula exhibits a distinct east–west climatic and biotic transition. The California Current of the North Pacific Ocean flows south along coast of the peninsula, and cold waters drop temperatures and lift fog along the shore (Aschmann, 1967). Crossing the narrow peninsula from west to east toward the warmer gulf, temperatures increase and humidity decreases.

Three of five global desert mechanisms act on the Baja California peninsula (Laity, 2008). The peninsula spans the 30° parallel of the world's great deserts, including the Sahara, Arabian, and Great Australian Deserts; descending air of the equatorial Hadley cell warms and expands, holding more water vapor and diminishing the chances of precipitation. The California Current also creates a cold current desert effect on the western margin of the peninsula, with the chilled water condensing the air along the coastline into fog, but rarely warming enough to rain. The mountainous backbone along the length of the peninsula creates a topographic rain-shadow; ascending air cools as it lifts over the spine, vapor condenses and falls on the peaks, leaving the eastern flanks hot and dry (Hastings and Turner, 1965).

Rainfall, though erratic, generally favors the highest peaks at the northern and southern ends of the peninsula and shifts from dominant winter rains in the north, with a dry central region, to summer rains in the south (Adams and Comrie, 1997; Comrie and Glenn, 1998; Hastings and Turner, 1965; Minnich et al., 2000). Annual rainfall varies between 100 and 300 mm (León de la luz and Cadena, 2006). The central desert regions and the northeastern rainshadow desert are the driest areas of the Baja California Peninsula (Aschmann, 1967). In the south of the peninsula, the climate is highly variable, with intense summer heat, extreme droughts, and the northern reaches of tropical cyclones (Hastings and Turner, 1965; Sheppard et al., 2002). In late summer and fall, cyclones move up the west coast of Mexico, and those that hit the peninsula bring torrential rains and violent winds, flooding the steep canyons, recharging water tables, and destroying houses, retaining walls, bridges, highways, and scouring entire reaches of mesic vegetation.

Hydrologically, the mountainous spine divides pluvial flows between the two marine bodies of the gulf and the Pacific, with a few isolated, internal basins. Most precipitation flows across the surface and gathers in arroyos that cut directly to the sea. A small percentage filters into the soil and recharges aquifers; the peninsula has sixteen different aquifers with a combined area of 3666 square kilometers (Cariño Olvera and Monteforte, 2008).

Where aquifer and bedrock conditions coincide, water reaches the surface in the form of springs and seeps, often located in the deep canyons of the peninsula that form small oases. The peninsula has no perennial rivers, only a series of arroyos that can fill with floodwater during hurricane storms (Díaz and Troyo, 1997; Grismer and McGuire, 1993). Groundwater from subterranean aquifers and from the hurricanes emerges in these arroyos as springs, forming natural, isolated riparian systems. Maya et al. (1997) used aerial images to identify 184 permanent and ephemeral oases in Baja California Sur. The oases on the peninsula take diverse forms, though are usually located in canyons or valleys, elongate, following the physical shape of the drainage, with mesic, or riparian vegetation. Some are located high in the mountainous regions, and others close to the coast, where tidal fluxes blend the salty and sweet waters. The oases are highly subject to hurricanes and extreme hydrological events, which reshape local physical environment and biotic communities with quasi-periodic frequency. These diverse mesic ecosystems span the peninsula and served as the sites of indigenous, colonial and modern human use and settlement (Arriaga et al., 1997). Only a fraction of the oases in both the states of Baja California and Baja California Sur are actively cultivated and considered to be cultural oases.

2.2. Peninsula history

Jesuit Missionaries first reached the peninsula during the Spanish colonial period in 1697, and they began their work of converting the indigenous peoples and establishing missions on the peninsula to serve as religious centers (Cariño Olvera, 2007; Crosby, 1994). The indigenous peoples of the peninsula did not practice agriculture or keep domesticated animals, except for a region in the north near the Colorado River Delta (Wilken-Robertson and Laylander, 2006). The native peoples were nomadic hunter-gatherers who moved to take advantage of seasonal harvests of terrestrial and marine resources and available water sources. The indigenous peoples easily succumbed to the diseases introduced by the missionaries, and most of the population on the peninsula had disappeared within a century (Cariño Olvera, 1996; Crosby, 1994).

Jesuit missionaries first introduced many agricultural crops to the missions for religious reasons—to have wine for communion, palm fronds for Palm Sunday, and bread to feed their converts (Crosby, 1994; Popenoe, 1973; This et al., 2006). They also desperately needed an in-situ source of food to feed their neophyte populations—their evangelization process involved "reducing" nomadic tribes to a sedentary life at the missions and replacing indigenous hunter-gatherer practices with agriculture, the building of the missions and irrigation systems. The crops introduced by the missionaries, as documented in historic records-included perennial crops of grapes, figs, pomegranates, olives, date palms, limes, lemons, oranges, and bananas and annual crops of wheat, corn, barley, beans, chick peas, rice, cotton, watermelons, melons, squash, onions, beets, garlic, yams, tomatoes, lettuce, radishes and peppers (Baegert, 1979; Crosby, 1994; Del Barco, 1980; Del Rio, 2003; Engelhardt, 1908). These authors also describe the introduction of many species of livestock, including burros, mules,

horses, cattle, sheep and goats to use as pack and plow animals and to manage as a resource for food, milk, and leather in the desert terrain surrounding the missions.

The Jesuits implemented new agricultural systems on the peninsula, including the development of irrigation dams, holding ponds and canals, called *acequias* to establish fields along the floodplains of the peninsula's arroyos (Crosby, 1994; Vernon, 2002). They utilized lime cement and local stone to build the structures, and at times had to haul in soil by mule and burro to develop the fields. Many of the technologies and the crops themselves originally came from Old World oases in North Africa, the Middle East and China (Nabhan, 2012). Historic names from these diverse geographic origins are still encoded in perennial fruits and agricultural systems carried to the Spanish colonies: *aceituna*, from the Hispanic Arabic *az-zaytuna* and the classic Arabic *zaytūnah* (olive); *acequia*, from Arabic *as-saqiyah*, "the irrigator" (irrigation canal); *adaza*, from Arabic *duqsah* (sorghum); *albaricoque*, from Hispanic Arabic *al-barqúq* and classical *burqūq* meaning "plum" or "early-ripe" (apricot); *alfalfa*, from Hispanic Arabic *al-fasfas*, from the classical Arabic *fiṣfiṣah* "best kind of fodder" (alfalfa); *azafrán*, from Arabic *za'faran*, from *safra* (yellow) (saffron); and *limón* (lemon), from Arabic *laymoon*, from the Chinese *limung*. Similarly, the Spanish *naranja* (orange) comes from the Arabic *nāranja*, from Persian *nārang*, from Sanskrit *nāranga*, which can be traced to a Dravidian language *naṛu* meaning "fragrant" (Dworkin, 2012; Ramón Laca, 2003; Real Academia Española, 2009; Spaulding, 1943).

Many species of Mediterranean food crops, such as figs, pomegranates and olives came from the Middle East and North Africa, carried to Spain with the Moors, and across the Atlantic to the ports of Veracruz during the colonial period (Dunmire, 2004; Nabhan, 2012). Coconuts and mangos arrived directly from the Philippines to the western coast of Mexico (Mukherjee, 1953; Zizumbo-Villarreal, 1996). Citrus species from Asia and taro from the Pacific islands were transported via the silk roads, spice routes and frankincense trails over land and sea to Africa and Europe, and then via ship to New Spain (Dunmire, 2004; Ramón Laca, 2003). Land and water management techniques, cultural traditions and values, agricultural practices, and crop varieties can all be traced through these linguistic and geographic routes, although many times the knowledge or names did not accompany the travelers and had to be newly invented or improvised in the New World (De Herrera, 2006). Indigenous, mixed race and foreign people that managed the oases after the expulsion of the Jesuits also brought multiple practices and viewpoints. The riparian agro-ecosystems of the Baja California peninsula are a locally adapted mix of these distinct areas and perspectives, and in some ways can be thought of as end points in a geographical trajectory. These oases hold species, knowledges and technologies that originated in several continents and have become established over the last three centuries in the small, isolated oases on the peninsula.

Very little mention of the date palms exists in Jesuit records, but historical accounts indicate that date palms were introduced to the Mexican mainland by 1550 and became established on the peninsula during the Jesuit period between 1697 and 1768 (Aschmann, 1957; Baegert, 1979; Dunmire, 2004; Rivera et al., 2012). The 1774 Dominican records note a few date palms at the mission oases of Comondú (3 palms), Loreto (4 palms), and San Javier (4 palms) and a more at La Purísima (34 palms) (De Mora et al., 1774). The palms have now increased to over 3000 mature, producing offshoots and parents within the huertas, as I recorded in my surveys and perhaps over a hundred thousand in the arroyos (Fig. 1).

Throughout the colonial and ranchero history of the peninsula, date palms played an economic role, one that expanded as the palms became naturalized to the oasis arroyos (Ivanova Boncheva et al., 2002). Aschmann (1957) records a change in production from twenty *arrobas* of dried dates produced at San Ignacio in 1785 to 200 *arrobas* in 1800, and by 1957, 16,000 *arrobas* or 200 tons of dates. By 1857, Mulegé was producing 3000 *arrobas*. In Mexico, one *arroba* equals approximately 11.5 kg (Trejo Barajas, 2002). The Chinese-owned merchant company Yee Sing was established in the oasis of Mulegé in 1907 and exported on its sailing vessels from the peninsula to China dried figs, raisins, and sugared dates packed in rawhide containers, wooden barrels of cured olives, local wines, fruit preserves made from citrus rind, quince, guava and mango, and locally made molded dark sugar. The company imported perfumes, porcelain, and silk for the local residents (Yee, 1978).

Dominican missionaries described the original date palms as being similar to the dates of "Bereberia," from the territory of the Berbers on the North African Coast (De Mora et al., 1774). Date palm offshoots weigh too much (10–25 kg) to be easily transported and kept alive on the journey across the ocean, and date seeds rarely

Fig. 1. Seedling date palm groves in the mission-oasis valley of San Ignacio.

sprout true to their parents, so I believe it is unlikely that any true clones became established in the mission oases (Zaid and de Wet, 2002). Date palms did rapidly became naturalized on the Baja California peninsula and seedling date groves have in many cases grown along with or replaced native fan palms (*Washingtonia* spp.) (Arriaga et al., 1997).

3. Materials and methods

3.1. Study sites

I selected twelve of fifteen missions established by the Jesuits on the Baja California peninsula and occupied at the time of their expulsion in 1768. The twelve mission-oasis sites, in general order of founding are: San Francisco Javier de Viggé Biaundó; Santa Rosalia de Mulegé; San Jose/San Miguel de Comondú; La Purísima Concepción; Nuestra Señora de Guadalupe de Huasinapí; Nuestra Señora de los Dolores Apaté; Santiago de los Coras/Santiago el Apóstol Aiñiní; San Ignacio Kadakaamán; Santa Rosa de las Palmas/Todos Santos; San Luis Gonzaga Chiriyaqui; Santa Gertrudis; and San Francisco Borja de Adac (Fig. 2). I excluded Nuestra Señora de Loreto Conchó and San José del Cabo Añuití because of the extent of urban development and change and the last mission to be established, Santa Maria Cabujakaamung because it had been completely abandoned.

3.2. Oral histories and interviews

Within these mission-oasis towns and villages, I used a combination of oral histories and semi-structured interviews to generate individual and community knowledge repertoires of the cultural practices and symbolic significances associated with heritage crops. The first set of interview questions asked specifically of farmers involved information on planting and harvesting times, cover crop and rotation strategies, irrigation methods, fertilizer inputs, companion planting, crop tiering, climate considerations, drought strategies, annual crop inventories, and livestock species and management. General interview questions included myth and story associated with food crops, varietal histories, specific relations between individual crops and the region, religious significance, food preparation techniques and traditions, holiday, ceremonial, or ritual food preparations, family relations with particular agricultural crops, crop names and origins of names, and the meanings of food crops to individuals and to communities.

I first selected participants based on experience with crops and length of time living/working in the oasis. I included both women and men to learn planting, harvest, and preparation knowledge. I chose one to ten families at each oasis and one to four people per family, individuals and groups, to conduct one- to two-hour oral histories. These involved both younger and older generations (ages 20–40 and ages 40–95) to document the changing relations to historic crops, and understand methods and effectiveness of knowledge transmission through generations. These also provided information on the cultural reserves of knowledge and how knowledge is divided among generations and genders. In all, I conducted seventy-nine individual and group farmer interviews and ninety individual and group oral histories at the twelve oases.

To develop specific crop inventories and document symbolic meanings, I interviewed the same respondents about five to ten particular crops, including mission figs, olives, grapes, pomegranates and dates. I recorded personal and group interviews by hand and typed them into the field computer under individual codes. I coded and evaluated emerging themes of symbols, significance, story, historic crop memories and experiences. I analyzed these data in terms of number of ceremonies or recipes associated with the crop, historical prevalence, and crop persistence. I draw from these histories shared meanings, shared methods of cultivation, harvesting, processing, and cooking, and the role of the crops in the lives of the oasis residents.

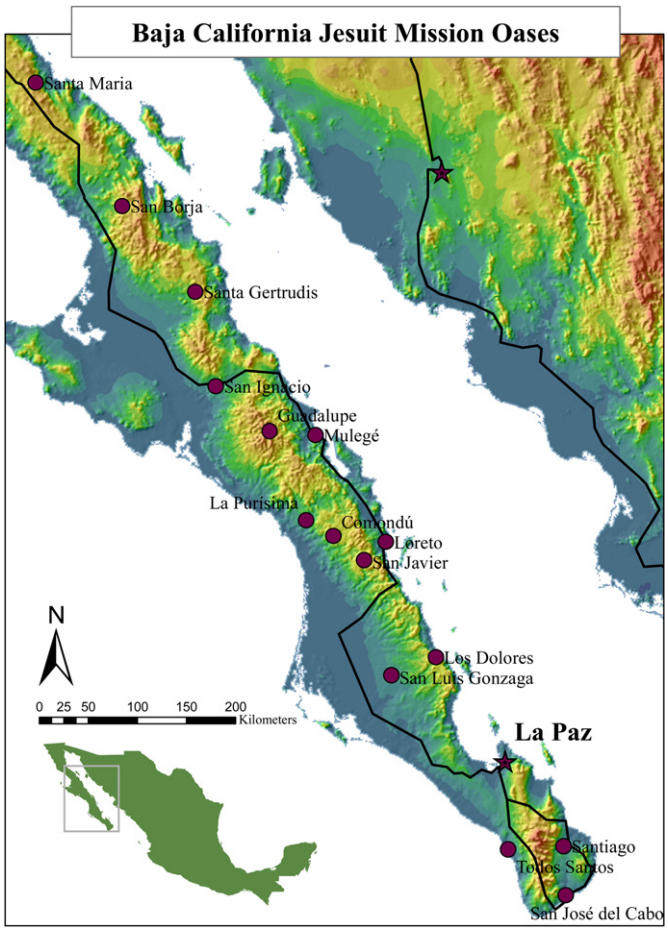

Fig. 2. Jesuit Mission oases of the Baja California peninsula.

3.3. Agro-biodiversity surveys

In association with the oral histories and interviews, I attempted to survey every field garden, or *huerta*, within the original irrigation systems in each of the mission-oases and document species of perennial and annual crops as well as wild and weedy species. I utilized a guide at some of the missions who introduced me to farmers, pointed out the boundaries of the huertas, clarified questions on some varieties and species, and served as a connection to the community. In other missions, I visited the gardens, located the farmers through word-of-mouth, and conducted the garden surveys with the farmers or alone. I recorded scientific names, local names and species abundances for all cultivated perennial species. I recorded GPS points and drew diagrams of the springs, canals, and huerta boundaries in the oasis valleys to understand the structure and dynamics of oasis agro-ecosystems.

4. Results and discussion

4.1. Date palm as a cultural keystone species

Date palms are emblematic in Old World oasis cultures. The palms, which can only flourish and ripen fruit in hot, arid

environments where water is at or close to the surface, figure prominently in the food and belief systems of oasis peoples as well as being a major religious icon for Islamic, Christian, and Jewish peoples far from oasis habitats (Popenoe, 1973). The oasis agro-ecosystems represent identities and tie cultures back to historic roots, in memory, and in ways that have been transformed and no longer are held in the memories of the people. These cultural practices play a role in the way individuals and communities create an identity, perceive land or space, and act in their everyday lives (Abufarha, 2008). Garibaldi and Turner (2004) describe a cultural keystone species as plants and animals that form the contextual underpinnings of a cultural and figure prominently in language, ceremonies and narratives of the people. These species may have roles in the medicine, nutrition, materials, or cosmologies of the culture. Christancho and Vining (2004) call a Culturally Defined Keystone Species as one whose existence and symbolic value are essential to the stability of the culture over time.

In the central oases of the Baja California peninsula, residents identify the date palm as emblematic of their culture and their homeland. For some, the dates are a living biblical reference to their Christian heritage. Other testimonies describe date palms as a locally symbolic species, representing Baja California peninsula oases and oasis culture. Most members of the older generations can describe in detail techniques of pruning and harvesting the date palms, and drying the fruit. Many families have woven cane drying racks to process dates for personal use, especially older residents who are accustomed to utilizing the dates as part of the traditional diet. Many households have beds made of rawhide strips woven over frames of palm wood, and use palm wood as support posts and rafters in the houses, benches, tables, and fence poles. Women have individual recipes for using dates in date bread, date cakes, date candy and sweet preserves. Older residents in the oases remember transporting dried dates, figs and raisins by mule and cart to the nearby mining settlements and peninsula towns, and said that these fruits constituted a large part of oasis economy in the 19th and early to mid 20th centuries. Dates, more than every other heritage crop species, except in some cases the mission grapes used to make wine and sugarcane with its economic importance, emerged from the interviews and oral histories as the species most representing Baja California peninsula oasis culture. Date palms are also the most numerous of the heritage crop species because of their naturalization and the extent of the populations outside the oasis huertas.

Oasis residents in the central peninsula manage seedling date groves within the arroyos upstream and downstream of the oasis towns, as well as individual or groups of palms within their huertas. The farmers do propagate offshoots in a few cases, though this seems to be a more recent practice and these planted date orchards are few in number and small in extent within the mission-oases. In many valleys, the mature date palm offshoots form extensive and very dense stands, and these are cleared only occasionally by wild fire or by hurricane flooding.

Management of the palms in the oases is limited to minimal pruning of the dead leaves and harvesting. Oasis farmers said there was no need to actively pollinate the palms due to the high ratio of males in the orchards and the efficiency of wind and insect pollination. A few farmers risk climbing up in the palms to chop the dead branches at times of the year other than harvest, though most only scale the palms once, chopping away dead leaves and cutting the fruit bunches at the same time. Most hire *piscadores,* men with knowledge and equipment to prune the palms of dead fronds and harvest dates when they mature. Traditionally, these men climbed the palms barefoot, without protective gear, and many reportedly died in the occupation. These *piscadores* had a reputation for being acrobatic, brave and calloused local heroes. Now, younger harvesters use modern protective gear, including cramp-ons, harnesses and ropes to climb the palms and secure themselves to the palms. They still use machetes to cut the full fruit bunches, and they slide them down the ropes to tarps or waiting trucks. They transport the bunches to drying racks, locally called *petates*, and made of the introduced cane species, laid out on wooden palm tables called *soleadores*.

Most residents have individual techniques and practices for drying the fruit: some leave the dates on the raceme for the first few days while others remove the fruit from the stems immediately. Most people described gathering the dates into plastic sacks at night or covering them with tarps or palm leaves to keep heat concentrated and protect the dates from cold air. They spread the fruit in the sun each day, repeating this process for three to five days, depending on the maturity (Fig. 3). Damaged, small, or wrinkled fruits are discarded throughout the process. During the final curing stages, the dates are gathered into plastic sacks to begin

Fig. 3. Dates drying in Mulegé oasis.

the "honeying." The cured, dry dates are packaged in plastic bags for market or domestic use, though traditionally, residents noted that the dates were stored in hanging rawhide or woven containers called *zurrones*.

Date culinary practices include the baking of date bread, date empanadas and date-cheese pie, most famous in the oasis of San Ignacio. The date preserves, called *colache*, involve cooking dates and pressing them through a screen to remove the seeds, then mixing in orange peel, anis, and cinamon. Women wrap pieces of this thickened date candy in corn husks. In a few oases, men remember a liquor of fermented dates.

The date fruit of the different oases reveal the heterogeneity of the populations; different individuals might produce small fruits to very large, Medjool-sized fruits. Some of the dates have large fat seeds, while others have long narrow seeds. Fruit color varies from red, yellow, dark, black, to light caramel colored (Fig. 4). Flavor ranges from sweet to highly astringent. Oasis residents currently sell these dates commercially, though most of the seedling dates do not compare with the quality of commercial varieties. A few farmers identify different varieties of dates in the oases, while many identify only a single variety called "mission date." Most growers distinguish the newly imported commercial varieties called "*dátiles de Indio* or *dátiles de Bonfil*," referring to varieties imported from Indio, California and the *ejido* or communal land of Bonfil that imported and produces four date varieties, Kadrawi, Zahidi, Medjool and Deglet Noor from Indio, California. The Mexican government reportedly has a program to import varieties from Israel, however, these have not yet made it into the repertoire of variety names used by most farmers.

A decline in date palm management, harvesting, and use may be emblematic of the changes facing the Baja California peninsula oasis culture. Many residents attest to a shortage of *piscadores* because the sport is dangerous and few are willing to climb up the thousands of palms in each oasis. Others cite environmental regulations, which include the prohibition of burning to clean the branches pruned from the palms; this lack of management has left the palms full of dead leaves and more prone to large, devastating fires. Some residents say that the dates do not have a broad enough market to sustain the active management of the palm groves. Efforts to market locally produced mission dates have had the effect of preserving traditional oasis culture in some of these isolated yet rapidly changing landscapes such as Mulegé and San Ignacio, indicating that date palms are a cultural keystone species.

4.2. The date palm as an ecological keystone species

Date palms have also come to serve as ecological keystone species in the Baja California peninsula oasis agro-ecological systems. Keystone species are those in an ecosystem that determine the ability of many other species to persist in the community (Primack, 2008). They often have a role in an ecosystem greater than their biomass indicates and may strongly influence community structure and dynamics through direct and indirect interactions. When a keystone species falls into rapid decline, it affects many other species that rely on its structural, nutritive, or functional resources. Inversely, conservation of keystone species can save entire guilds within ecosystems and preserve ecosystem function (Sergio et al., 2006). Humans themselves can be, or can introduce, keystone species into ecosystems, and influence or determine ecosystem function.

Native keystone species are involved in dynamic networks of species relations. The species composition on the Baja California peninsula includes many endemic species—Over 754 endemic plant taxa (species and subspecies) have been identified (Riemann and Ezcurra, 2005). These were integrated in systems of similarly endemic seed dispersers, pollinators, soil fauna and flora, and relationship with the hunting-gathering tribes that occupied the peninsula for millennia prior to the Spanish arrival.

Historically and still in many peninsula oases where date palms are not the dominant species, native fan palms serve as ecological keystone species. Native palms host numerous insect visitors and pollinators and provide shade, food, and habitat for resident amphibians, reptiles, birds and mammal species as well as migratory or overwintering species (Cornett, 2008; Rodríguez et al., 1997). These palms and the fauna that utilize them for food and habitat provide a fertile understory of organic matter that supports other trees, shrubs and herbs in a patch-like microclimate and microhabitat. They also redistribute floodwaters in the arroyos that arrive during hurricane season and often reshape the oasis landscape. *Washingtonia* palms still occur in most of the peninsula oases; they are self-seeding and together with the date palms form the upper story of the gardens and dense stands through the valleys. Oasis

Fig. 4. Red dates of Santa Gertrudis Mission. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

residents actively harvest the native palms for wood and fiber resources. The fruits of the *Washingtonia* palms are small and have a tasty mesocarp, but are not typically harvested by oasis human residents. The rigor of the introduced date palm combined with social selection for them has led to the partial replacement of native palms in oasis ecosystems (Fig. 5).

Date palms now play a key role in the Baja California peninsula anthropogenic oases with new oasis guilds of wild, weedy, and domesticated species. Oasis huertas, which hold both native and introduced species of flora and fauna, are managed as diverse agroecosystems. These oasis gardens show structural diversity and an integrated native and domesticated animal and plant agricultural system. They are also, in most cases, small-scale farming systems that utilize crop rotation, livestock integration, mixed annuals and perennials, and crop tiering. In many of the gardens, perennial fruit plants grow along the irrigation ditches and form hedgerows between fields, providing shade, windbreaks, and attraction for predatory species and pollinators. Open areas between yield forage crops, grains, legumes, vegetable crops, or are planted in rows of perennial fruit crops or vineyards. Livestock, including cattle, burros, sheep and goats are grazed in the gardens during fallow periods, or tethered to tall trees and palms in the huertas and fed grass and herbaceous plants harvested by sickle. These mixed-method systems offer a defense against pest epidemics, drought, and floods and enable long-term viability of the farms and the farm families. In the areas surrounding the oases, residents manage or semi-manage palm groves and graze livestock on the desert vegetation. These peripheral areas do not receive the same anthropogenic attention, but are part of the oasis ecosystems and transition zones.

Fig. 5. A canyon of seedling date palms in Comondú oasis.

Date palms form the tallest component of the physical vegetation structure within the oasis *huertas*, where woody perennial crop species are categorized by relative height in the oasis guilds. Below the palm canopy, olive (*Olea europaea*), mango (*Mangifera indica*), avocado (*Persea americana*), citrus (*Citrus* spp.), loquat (*Eriobatrya japonica*), fig (*Ficus carica*), pomegranate (*Punica granatum*), guava (*Psidium guajava*) and grape (*Vitis vinifera*) are the primary structural components of mid to low canopy in the oases. On the periphery, date palms and *Washingtonia* palms may grow in dense stands with very little vegetation beneath them. In other areas, native trees, shrubs, cactus and herbs form a shorter structural canopy and understory; Arriaga et al. (1997) identify these desert scrub species as *Acacia brandegeana*, *Cercidium floridium*, *Jatropha cinerea*, *Leucaena microcarpa*, *Olneya tesota*, *Pithecellobium undulatum* and *Prosopis articulata*. León de la Luz and Domínguez (2006) identify other scrubland species growing opportunistically as an understory in the oasis riparian areas, including *Pachycereus pringlei*, *Cylindropuntia cholla*, *Vallesia glabra*, *Acacia farnesiana*, *Celosia floribunda*, *Bebbus juncea*, and *Ambrosia ambrosioides*. In the riparian corridor, Arriaga et al. (1997) identify *Phragmites communis, Cryptostegia grandiflora, Panicum purpurascens, Typha domingensis* and *Baccharis glutinosa* as the primary species forming the herb and shrub layers. León de la Luz and Domínguez (2006) document a total of fifty-seven obligate hydrophytes in their oasis research.

Functionally, the date palm canopy moderates the temperature and increases humidity for the strata beneath them, provides nesting and habitat sites for flora and fauna, attracts pollinators and seed and insect eaters, reduces some types of plant herbivory (through increased wild diversity), and provides nutrient-sharing environments that can increase overall diversity in a small area. Date palms provide a diverse and temporally varied food source, including pollen, sap and fruit to many insects, birds, and mammal species. These herbivores in turn attract reptiles, birds, and animals higher on the trophic level to eat them, and these in turn can be consumed by the higher predators such as raptors, coyotes, and mountain lions. Moist soils beneath the palms attract soil flora and fauna that can be beneficial to all plants within the guild. Birds and small mammals deposit manure, and the leaves of the deciduous canopy can provide a source of organic matter to the crops growing below. Often these crops are grown in waffle gardens or grids, structured around the irrigation canal system, with trees and shrubs grown at the perimeter, shade-loving crops beneath them, and sun-loving crops in the open centers. This creates a mosaic with many gradients of temperature, sunlight, salt, pH, and moisture to increase the niches available to cultivated, weedy, and wild species in the oasis agricultural environment.

Ecological influences of domesticated keystone species such date palms differ from those of wild keystone species, such as fan palms in their roles in desert oases in complex ways. The relatively recent introduction of agriculture with the Jesuits (1697–1768) does not allow sufficient time for speciation and co-evolution with native flora and fauna. This is different for older agricultural systems in the Middle East and North Africa, where wild and domesticated plants have millennial-length histories in the same oasis. However, even these oases are going through similar processes of change with agricultural industrialization and introduction of other cultivated and ornamental species from around the world. Introduced species provide a greater and more dependable food source (especially in those oases that have been continuously managed for the last three hundred years), which attracts more species that feed upon the fruit, nut, vegetable, and grain species. Active management of the water systems provides migratory species with a more reliable water and food source, and might alter migratory routes to take advantage of these, or timing of migration to correspond with

fruiting or flowering times of oasis species. Resident populations of oasis-crop feeders and associates and other anthropogenic species also increase, altering predator-prey and competition relationships among wild, weedy, and domesticated species. Weed species and other non-native invasive species can be found in higher concentrations in oases (Arriaga et al., 1997) providing food resources, opportunities for genetic out-crossing in some cases, and increasing competition with domesticated and wild species. New hosts of pollinators, insect predators, and seed dispersers are attracted to the fruit and vegetable crops.

5. Conclusions

Date palms are a recent introduction to the oases of the Baja California peninsula, with a history of cultivation barely three centuries old. As the palms became naturalized and seedling date groves filled the oasis canyons along the central Baja California peninsula, date palms developed the role of an ecological keystone species, in many cases growing along with or replacing the native *Washingtonia* fan palm. Equally, the palms, fruit, and symbolic status evolved to be a critical component of Baja California peninsula oasis culture. The presence of the palms symbolizes water in the desert, represents the mission heritage, and has come to be seen as part of the "natural" landscape. Date palms provide a series of resources, including food, fiber, and wood which are used within the households and bring revenues to oasis communities. The date palms, though many are seedling varieties with varying quality and minimal formal management, have become firmly established in the ecological and cultural systems of the oases. Despite the relatively recent introduction of date palms to the peninsula, this role is similar to many Old World Oases, in which the date palms have evolved with wild species guilds and dynamic oasis farming and pastoral communities for thousands of years.

Acknowledgments

This research would not have been possible without the academic guidance of Dr. Gary Paul Nabhan, Dr. Paul Robbins, Dr. Steve Yool, Dr. Micheline Cariño Olvera, Dr. Stuart Marsh, and Dr. Suzanne Fish at the University of Arizona. I wish to express my gratitude to Dr. Robert Krueger at the National Clonal Germplasm Repository for Citrus and Dates, Dr. Exequiel Ezcurra, David Karp and Ben Wilder at California State University Riverside, Dr. Marc Baker of Southwest Botanical Research, Dr. Robert Bye at the *Universidad Nacional Autónoma de México*, Dr. José Luis León de la Luz at *Centro de Investigaciones Biológicas del Noroeste* at La Paz, and Jaime Gil, agricultural engineer of the Canary Islands *RIDISOS* and *Cultura del Oasis* for collaboration, for research advice, information and technical support. Science Foundation Arizona, Fulbright-COMEXUS, the Philanthropic Education Organization, and the School of Geography and Development at the University of Arizona provided the institutional and financial support for this doctoral research. My deepest gratitude and love to Jaime and Zoraya de Grenade, Don, Rebecca, Kanin, and Cody Routson, Jack and Eileen Routson, Sally Bregar, Karen and Bill Pearson, Beth Horan, and those who provided the encouragement and support necessary for this extensive research project.

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