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NOTA

VERIFICATION AND VALIDATION OF MANGROVE PRESENCE IN THE CENTRAL PORTION OF THE EAST COAST OF THE BAJA CALIFORNIA PENINSULA, MÉXICO

Verificación y validación de la presencia de manglar en la porción central de la costa oriental de la Península de Baja California, México

RESUMEN. Para verificar y/o validar la existencia de manglar en cuatro localidades de la porción central de la costa oriental de Baja California Sur, se realizó un recorrido en lancha desde la laguna costera San Lucas (27^0 14.8′ N; 112^0 12′ O) hasta el estero San Carlos (27° 42′ 13″ N, 112° 38′ 24″ O). Se verificó la ausencia de manglar en Campo Camacho, Santa Ana y San Carlos. La laguna costera San Lucas fue la única con presencia de manglar y los parámetros estructurales de este manglar indican tipologías de manglares de borde y enanos, los cuales se encontraron formando franjas paralelas a la línea de costa de entre 5 y 25 m de ancho. La cobertura total estimada mediante la digitalización de imágenes satelitales fue de 50 ha, lo que representó el 11% de la extensión de la laguna. La especie dominante fue *Rhizophora mangle* con el 44% de cobertura y altura promedio de 2.08 m (DE ± 0.41) con un intervalo de altura de 1.60–2.80 m, seguida por *Avicennia germinans* con 36% de cobertura, altura promedio de 2.4 m (DE ± 0.94) y un intervalo de 0.20–3.5 m y por último, *Laguncularia racemosa* con el 20% de cobertura, altura promedio de 2.40 m (DE ± 0.41) y un intervalo de 1.90–3 m.

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Mexico is recognized as one of the countries with the broadest extensions of mangroves on the planet (FAO, 2007); however, there are marked discrepancies in the estimates that have been made to determine the real expanse of mangroves (Ruiz-Luna *et al*., 2008; CONABIO, 2014). The earliest estimate, from 1973 (but published almost a decade later by FAO-UNEP, 1981), calculated a surface area of 700,000 h (1,729,746 acres) in the country's 17 coastal states, while the most recent calculation registered 764,486 h (1,889,096 acres; Rodríguez-Zúñiga *et al*., 2013). These differences are due to advances in geographic information systems (GIS), global positioning systems (GPS), and remote sensors (Ruiz-Luna *et al*., 2008), complemented by verification processes conducted in the field that allow us to compile and validate more precise data on certain regions still shrouded in uncertainty with respect to the composition and extension of their mangroves.

Mangroves on the Baja California Peninsula have an especially high level of uncertainty regarding their composition and extension, principally because of the characteristic shrubbery growth (León de la Luz *et al*., 2011), marked discontinuity along their fringes, and the lack of well-defined limits in terms of zonation. The exclusive use of remote detecting devices is insufficient to determine the specific composition of these forests, which explains why today there are still sites on the Baja California Peninsula registered in the literature where the presence of mangroves has not been verified or validated. For these reasons, validations based on fieldwork are indispensable. In addition, studies of the arboreal make-up of mangroves on the peninsula are all relatively recent (Acosta-Velázquez & Ruíz-Luna, 2007; Domínguez-Cadena *et al*., 2011, González-Zamorano *et al*., 2011) and, as a result, quite scarce. In light of these circumstances, the objective of the present work was to verify and validate the presence of mangroves in four coastal environments in the central portion of the east coast of the Baja California Peninsula.

The climate of the study area corresponds to that of the Gulf of California region (Vidal-Zepeda *et al*., 2006) and the Very Dry climatic unit, with an average annual temperature of 22°C and mean annual precipitation of 200 mm (INEGI 2015). To verify the existence of mangrove species, in July 2014 a field expedition was undertaken to visit the San Lucas coastal lagoon by land and to visually inspect the fringes of the littoral in search of sites where mangroves are present on board a small boat (*panga*). Observations focused especially on two sites: Campo Camacho (27° 27′ 43″ N, 112° 14′ 13″ W; Félix-Pico *et al*., 2011) and the San Carlos estuary (27° 42′ 13″ N, 112° 38′ 24″ W; González-Zamorano *et al*., 2011), identified in the literature as mangroves; while a third area where environmental conditions are propitious for mangrove development, called Santa Ana (27° 39′ 48″ N 112° 35′ 56″ W), was also studied. All three sites are located north of the San Lucas Lagoon.

The mangrove that borders the coastal San Lucas Lagoon (27^0 15′ 10" and 27^0 12′ 06" N, and 112^0 12′ 59" and 112^0 11′41" W), the most northern mangrove recorded in Baja California Sur (BCS), was originally recorded by Turner *et al*. (1995), and later mentioned by González-Zamorano *et al.* (2011). In both cases, the only data provided reflect the specific composition of a mangrove. To obtain information on the arboreal structure, three sample sites were selected and some parameters of the arboreal structure determined; namely, physiognomic type, species coverage, tree height, and total coverage.

To identify mangrove species we used the field guide by Agraz-Hernández *et al*. (2006), while to determine specific coverages the Line Intercept Technique was applied (Kent & Coker, 1992) by conducting searches parallel to

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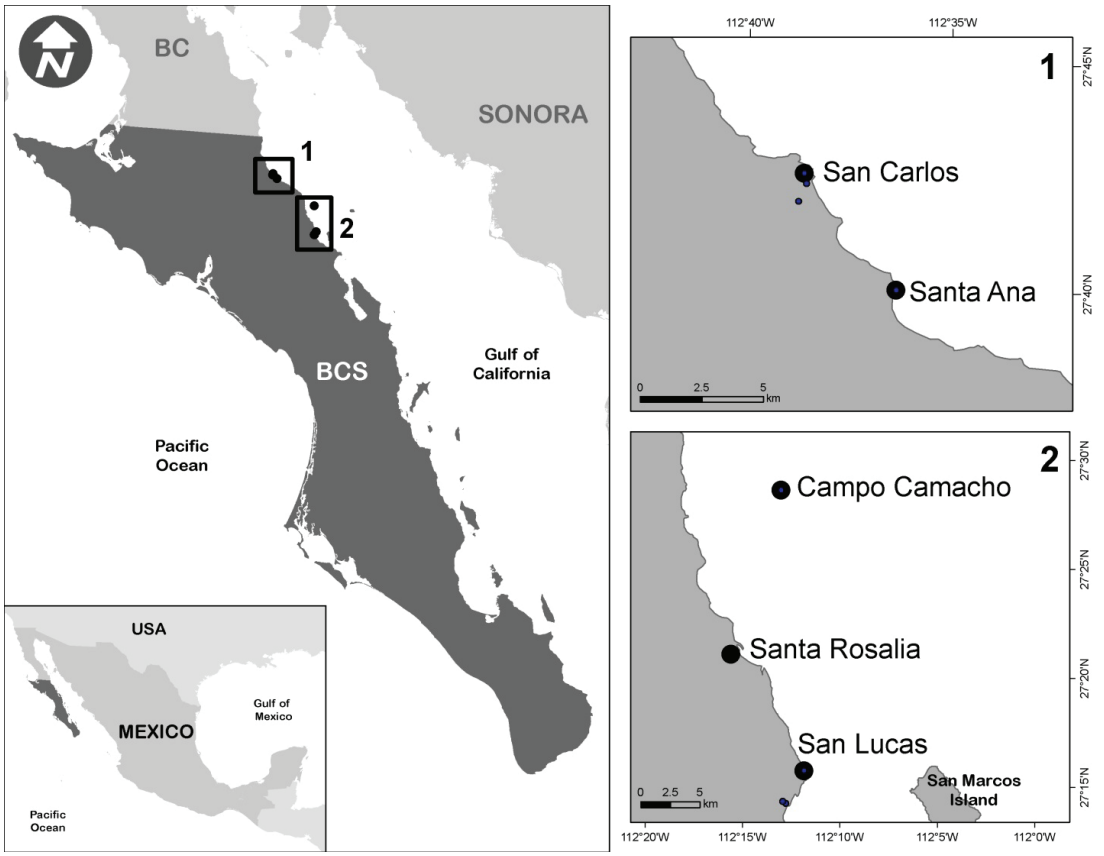

Figure 1. Study area. Verification sites (San Carlos, Santa Ana and Campo Camacho) and validation site (San Lucas).

the coast at each site. The characteristics of the environment were verified by measuring, *in situ*, the temperature and surface pH of water, as well as surface and interstitial salinity (3 cm) using a multi-parameter Horiba U10 and a refractometer, respectively.

The extension of the lagoon and mangrove coverage were determined by digitalizing Landsat-4 2014 satellite images (http://glovis.usgs.gov/) and aerial photographs taken in vector format at a scale of 1:75,000 (*Ortofoto Digital* G12A46B, G12A36D; INEGI 1993). ArcMap v.10.2 software was used to make estimates.

At San Carlos, researchers walked the margins of the entire estuary searching for *Avicennia germinans* (L.) L., because González-Zamorano *et al*. (2011) mentioned the possible existence of this species at that site. However, neither that species nor any other mangrove species was found. This confusion is probably due to the fact that the use of satellite images, like those upon which they based their study, does not allow a sufficiently detailed level of observation to identify types of vegetation or individual species.

At the Santa Ana site, meanwhile, we likewise found no mangrove species, but only observed a broad coverage of *Maytenus phyllanthoides* Benth known as sweet mangrove, a species that may sometimes grows in environments with high levels of desiccation and salinity but small flows of fresh water, similar to conditions at "true" mangroves.

With respect to the mangrove at the coastal San Lucas Lagoon, it was found to cover an estimated surface area of 11% of the total extension of the lagoon (58 ha). The predominant forest cover at this coastal system is of the border type, combined with patches of dwarf mangroves, according to the classification by Lugo & Snedaker (1974). In this system, mangrove trees form fringes that run parallel to the coastline and measure 5 to 25 m in width, though in some places their distribution is irregular and forms discontinuous patches with a mixture of *Rhizophora manlge* L., *A. germinans* and *Laguncularia racemosa* (L.) Gaertn. It is important to note that the delimitation of each species within the forest is not clearly defined. Also observed was the presence of areas with mono-specific growth of *R. mangle*, located on both the fringes of the littoral and along the borders of the lagoon's tidal canals. The predominant species was *R. mangle* with 44% of coverage, an average tree height of 2.08 m (7 ft; DE ± 0.41), and a height range of 1.60–2.80 m (5.4–7 ft), followed by *A. germinans* with 36% of coverage, average height of 2.4 m (7.8 ft; DE ± 0.94), and a range of 0.20–3.5 m (8 in–11.5 ft) and, finally, *L. racemosa* with 20% of coverage, average height of 2.40 m (7.8 ft; DE ± 0.41) and a range of 1.90–3 m (6.25–10 ft). This combination of mangrove shrubs and trees is likely due to the climatic

conditions, characterized by extreme temperatures and low precipitation, which produce high salinity, a limited inflow of fresh water and a low concentration of nutrients (Sánchez-Andrés *et al*., 2010). This causes variations in the forest structure and, as a result, distinct physiognomic types (Agraz-Hernández *et al*., 2006). However, the effects of this phenomenon were not evident at site 3, where the lowest values for surface and interstitial salinity were recorded (Table 1), probably due to a subterranean current of fresh water that permits the development of some more robust mangrove species. This condition has been observed as well at the Santispac mangrove in Bahía Concepción (approximately 100 km south of the coastal San Lucas Lagoon) and the mangroves at Bahía Magdalena on the west coast of the Baja California Peninsula (Mendoza-Salgado *et al*., 2011).

Table 1. Physico-chemical data in San Lucas coastal lagoon: surface and interstitial salinity (UPS), temperature (°C) and pH. Information Not Available (NA).

	Site 1	Site 2	Site 3
UPS surface	NA	34	20
UPS interstitial	40	39	27
pH	7.6	7.5	7.3
°C	30.1	33.6	32.5

The zoning seen in this study presents the typical pattern of sub-tropical mangroves (Agraz-Hernández *et al*., 2006); *i.e.*, *R. mangle* is located in the tidal flood (intertidal) zone, *A. germinans* above the minimal daily low-sea level where flooding is frequent, and finally *L. racemosa* is found where tidal flooding is limited most of the time. These patterns reveal the adaptive association of each species present in the mangrove ecosystem as a function of a climax possibly sustained due to tide levels, which may be the recurrent condition in the establishment and development of this vegetable community (Lugo, 1980).

At San Lucas, halophyte communities were also found in association with the mangrove, where they formed irregular fringes in the posterior area made up primarily of *Batis maritima* L., *Sporobolus virginicus* (L.) Kunthse and/or *Jouvea pilosa* (J. Presl) Scribn., and *M. phyllanthoides*.

While it is certain that one of the most representative -though not exclusive- characteristics of the mangroves in the Baja California Peninsula is their shrubby physiognomy that contrasts with the arboreal forms of the mangroves located in the rest of Mexico (León de la Luz *et al*., 2011), it is precisely this physiognomy that makes it difficult to obtain certain morphometric parameters (*e. g*. basal area, chest-height diameter) that are gathered quite easily in arboreal mangroves. This difficulty in measuring shrubs, added to the irregular distribution of the mangroves on the Baja Peninsula constitute significant limitations in terms of carrying out studies intended to determine forest structure, so in this region such studies are scarce.

At present, there is still great uncertainty regarding the total surface area covered by mangroves in México, such that the need for detailed field verifications and validations studies-like the one presented in this work-is clear, especially since this information is fundamental in planning management and conservation measures for México's mangroves.

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