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The Ecological Importance of Mangroves in Baja California Sur: Conservation Implications for an Endangered Ecosystem

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Conservation was made up by politicians who drive big cars and have never experienced hunger.
—a retired fisherman from Laguna San Ignacio as quoted by Dedina (2000: 105)

Mangroves occur throughout the tropics, along shallow seashores protected from waves (Chapman 1976; Tomlinson 1986; Hogarth 1999). They grow in mud and other nonrocky substrates inundated during high tide. To cope with their environment (e.g., anoxic soil conditions and excess salt), they have developed a variety of morphological and physiological adaptations. For example, some mangroves have aerial roots for gas exchange, or they may actively secrete sodium chloride through salt glands in the leaves. Hydrological and edaphic conditions in mangrove ecosystems prevent all but a few other plant species from invading (Lugo 1998).

Mangroves do not constitute a discrete taxonomic group. Instead, the world's mangrove vegetation is the product of amazing convergence, probably due to biogeochemical and climatic factors and is hypothesized to have had at least 16 separate evolutionary origins (Duke 1995; Hogarth 1999). Based on mangrove species richness and composition, the world's tropics can be divided into 2 zones. The eastern zone (East Africa, India, southeastern Asia, Australia, and the western Pacific) shows a greater diversity of mangrove species than the western zone (West Africa, South, Central, and tropical North America; Tomlinson 1986).

In the tropics, characterized by an abundance of rainfall and fresh water, mangrove trees can reach a height of 30–40 m (Tomlinson 1986). They represent the dominant plant form in many coastal areas (e.g., Kunstadter et al. 1986) and often form forestlike communities several kilometers wide or more (Tomlinson 1986). Mangroves of the tropics are among the most productive ecosystems in the world (Farnsworth et al. 1996; Jennerjahn and Venugopalan 2002), providing not only habitat (Acosta and Butler 1997; Aliaume et al. 1997; Acosta 1999) but also nutrients—in the form of detritus—for a large number of organisms. Protozoa, diatoms, and phototrophic cyanobacteria, the latter forming dense mats up to 25 cm thick, all thrive in mangrove ecosystems (Lopez-Cortez 1991; Toledo et al. 1995; Sigueiros-Beltrones and Morzari 1999) and constitute the basis of highly complex food webs (Day and Yáñez-Arancibia 1985; Yáñez-Arancibia et al. 1993, 1994; Kaly and Jones 1998; Skilleter and Warren 2000; Holguin et al. 2001). Mangroves benefit human populations through their high productivity, and by also protecting coastal areas from storms and erosion (Menéndez et al. 1994).

In this chapter we discuss the ecological importance and conservation status of mangroves in Baja California Sur (hereafter BCS). In western North America, mangroves reach the northern edge of their distribution in coastal Sonora and along both sides of the Baja California peninsula (Turner et al. 1995). In this region, they grow under suboptimal conditions, and mangrove communities are far less extensive than in many parts of the tropics. They have been described for BCS or elsewhere in northwestern Mexico in a number of botanical works (e.g., Wiggins 1980; León de la Luz and Coria-Benet 1992; Turner et al. 1995; Felger et al. 2001). By comparison, however, little has been published on their associated fauna. Here, we place on record, as a basis for future research, lists of macroinvertebrate and vertebrate species inhabiting or regularly visiting BCS mangrove ecosystems. Despite being less extensive than in the tropics, BCS mangroves perform an important ecological role by sustaining a rich macrofauna, providing spawning/nursery habitat for many offshore species, and as a nutrient source for coastal ecosystems. Mangrove conservation is an important priority in Mexico. According to Herrera-Silveira and Ceballos-Cambranis (2000), Mexico lost 65% of its mangrove communities between 1972 and 1992 due to direct exploitation and agricultural and urban development.

Distribution of Mangroves in Baja California Sur

Based on 1994 estimates, Mexico has 488,367 ha of mangrove vegetation, 12,120 ha (2.5%) of which are on the Baja California peninsula (Loza 1994). Stands of mangroves, sometimes referred to as "mangals" (Tomlinson 1986), or in northwestern Mexico as "*manglares*," are found in isolated coves, lagoons, and *esteros* of both sides of the peninsula (figs. 15.1–15.6). As in northwestern mainland Mexico, they occur in protected, shallow-water habitats that drain and fill daily. They do not tolerate stagnant water and soon perish if cut off from tidal circulation (e.g., Felger et al. 2001). Along the eastern (Gulf of California) side of the peninsula, mangroves are distributed from the Cape Region north to small islands in Bahía de Los Angeles (e.g., Isla Smith) in the state of Baja California. On the western (Pacific) side, mangroves have a more limited range. The northern limit of their distribution is near Laguna San Ignacio in BCS (Brusca 1975; Roberts 1989; Danemann and Carmona 1993; León de la Luz et al. 1995; Turner et al. 1995; Peterson 1998; Williams and Williams 1998).

Mangroves of BCS occur mainly in 5 coastal areas, referred to here as zones (fig. 15.1). The 3 most extensive mangrove ecosystems of the state are found in the Laguna San Ignacio complex (Zone I) and at Bahía Magdalena and adjacent shores (Zone II) along the Pacific coast; and along Bahía de la Paz (Zone IV) on the Gulf side.

Zone I (fig. 15.2) is centered on Laguna San Ignacio, located between 26°43' and 26°58' N, and 113°08' and 113°16' W. In the vicinity of Laguna San Ignacio are 3 other important locations: Estero la Bocana (also known as Pond Lagoon), Estero el Coyote (or Laguna la Escondida), and Estero San Juan. Traditionally, these 3 additional areas are grouped with Laguna San Ignacio to form what is referred to as the "San Ignacio complex."

Zone II (fig. 15.3) is centered on Bahía Magdalena. Together with adjacent coastal areas (e.g., Bahía Almejas), Bahía Magdalena forms a 240 km-long complex of bays and lagoons. It is often described as the "Chesapeake of the Pacific," due to its extensive size, beauty, and ecosystem dynamics (Dedina 2000: 125).

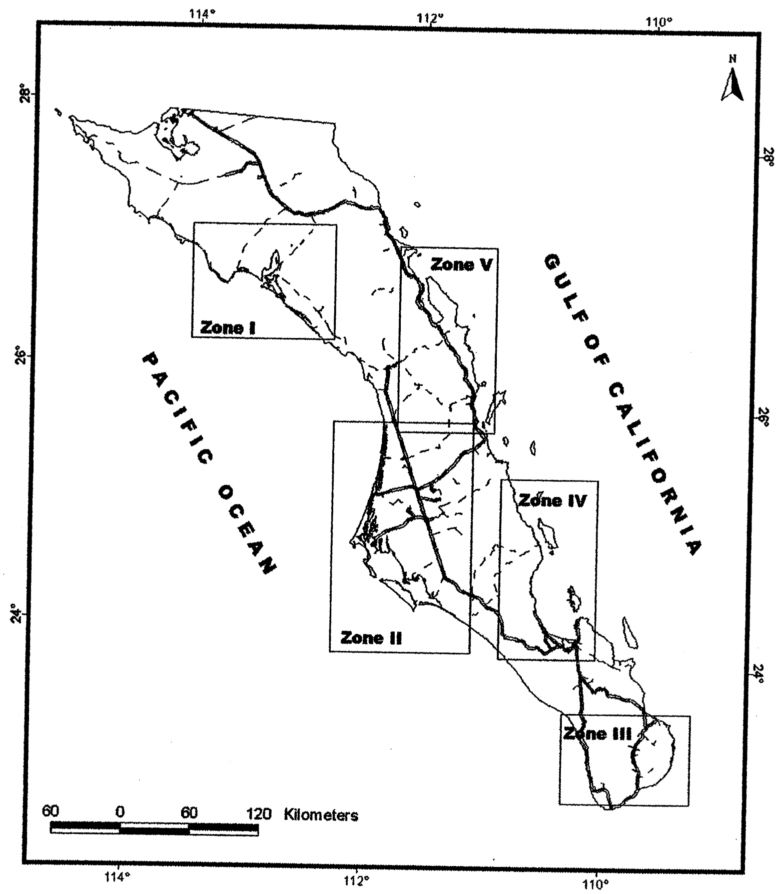

Figure 15.1. Baja California Sur, with the 5 coastal zones harboring notable mangrove stands.

The outer, ocean-facing shore is formed by 6 narrow islands, the largest of these being Isla Magdalena and Isla Margarita. Mangrove stands are spaced irregularly along almost 160 km of the coastline. Particularly important is the northern half of the Bahía Magdalena area (Boca Las Animas south to Boca La Soledad), where the stands occur almost continuously. Local natural resources support a fishing economy in the town of Puerto San Carlos (or San Carlos).

On the eastern coast of BCS, the largest mangrove areas are found in Zone IV (fig. 15.4), occupied by Bahía de la Paz. Mangroves are found along the southern end of the bay, including on the peninsula of El Mogote and along Ensenada de Aripes (also called Ensenada de La Paz). Some offshore islands have extensive and pristine mangrove stands, including at Bahía San Gabriel (24°27' N, 110°22' W) on Isla Espíritu Santo, and at Bahía Amortajada (24°53' N, 110°35' W) on Isla San José. Across Ensenada de Aripes from El Mogote is the capital city of BCS La Paz, with its nearly 200,000 residents (INEGI 2001).

The Cape Region (Zone III, fig. 15.5) has less extensive, more discontinuous mangrove vegetation. Several isolated mangrove stands can be found between Todos Santos (23°26' N, 110°14' W) and Estero Migriño (23°00' N, 110°06' W) on the Pacific coast, and at Punta Colorada (23°30' N, 109°30' W).

Zone V (fig. 15.6) along the Gulf side of BCS, has only isolated mangrove pockets, most notably at Bahía Concepción and along Bahía de Loreto. Bahía Concepción (between 26°33' and 26°53' N and 111°42' and 111°56' W) has at least 8 small coves (e.g., Ensenada Morgán) with mangrove stands, none of which covers more than a few hectares. These mangrove stands are separated from one another

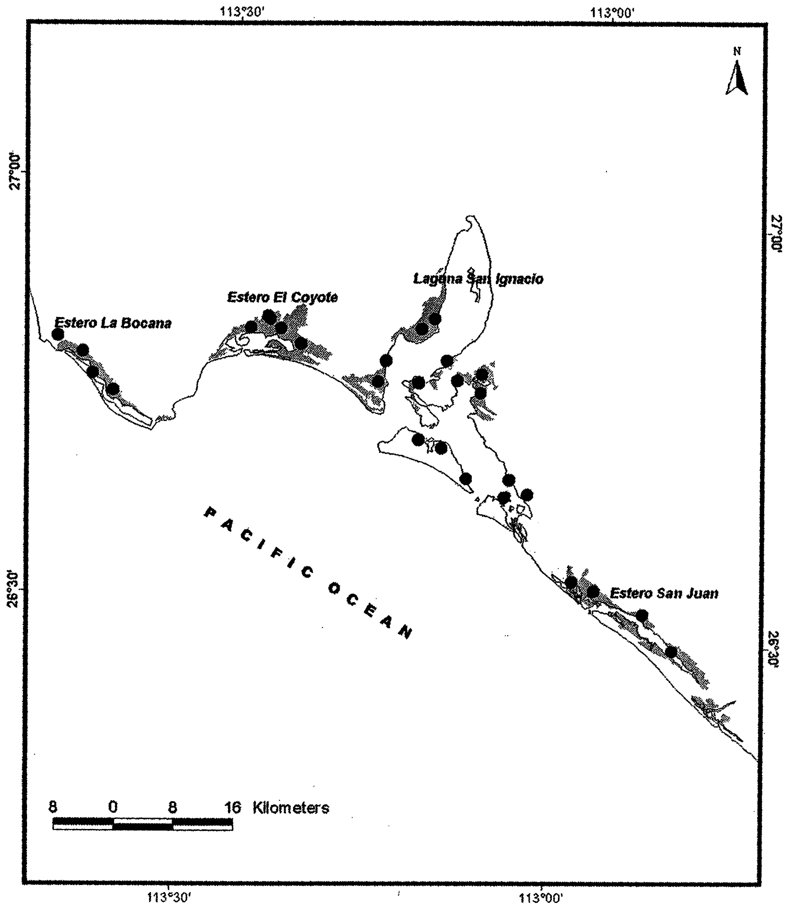

Figure 15.2. Mangrove distribution in Baja California Sur: Zone I, San Ignacio complex. Dots represent verified mangrove stands based either on on-site verification, photographic interpretation, or herbarium specimens. The shaded areas represent potential mangrove areas based on cartographic interpretation. Map generated using the Lambert Conformal Conic Projection. Cartographic source: INEGI 1:250,000 and 1:50,000; photographic source: INEGI 1:75,000. Map prepared by P. González and G. Arredondo, September 2002.

by a mean distance of 14 km, with 44 km representing the maximum distance between 2 stands (Whitmore et al. 2000). Several mangrove stands occur along Bahía de Loreto, including on Isla Danzante (25°47' N, 111°15' W) and Isla Monserrat (25°40' N, 111°03' W).

Vascular Plants

Worldwide, the northern distributional limit of mangroves is determined by reduced air and sea temperatures (Tomlinson 1986). In northwestern mainland Mexico, for example, this distributional limit coincides with occasional freezing weather (Felger and Moser 1985; Turner et al. 1995; Felger et al. 2001). Aridity is also believed to play an important role in limiting the establishment of mangroves, albeit only indirectly. Many mangroves are chiefly estuarine species growing in brackish waters. However, along arid coastal areas, freshwater runoff and river flow are minimal. The salt content of tidal waters is higher in arid regions than in wetter climates, and soils are typically poor and offer fewer

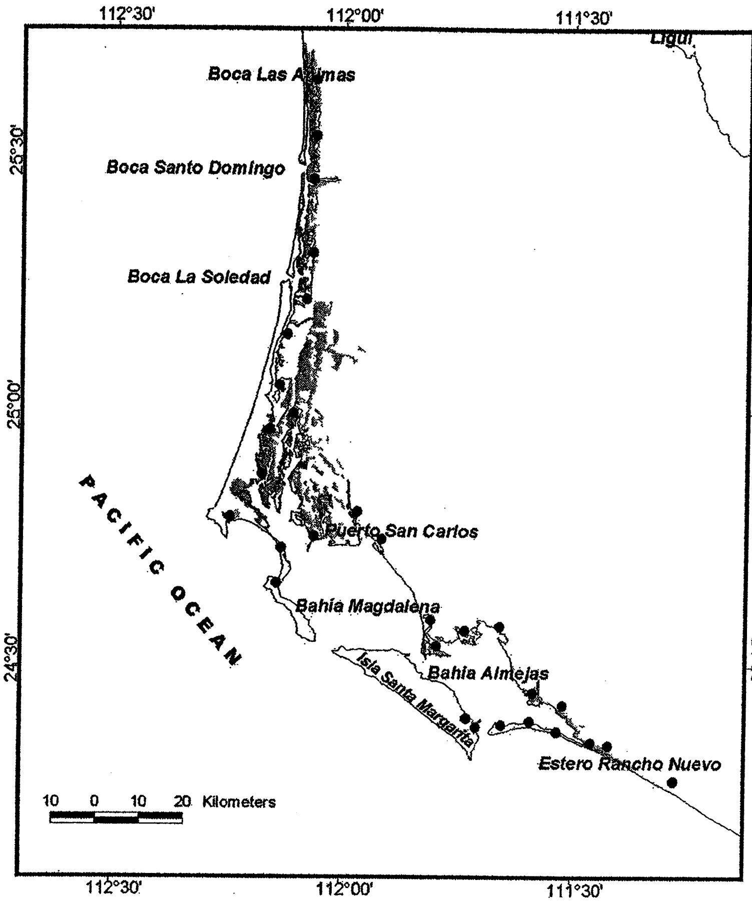

Figure 15.3. Mangrove distribution in Baja California Sur: Zone II, Bahía Magdalena area. Dots represent verified mangrove stands based either on on-site verification, photographic interpretation, or herbarium specimens. The shaded areas represent potential mangrove areas based on cartographic interpretation. Map generated using the Lambert Conformal Conic Projection. Cartographic source: INEGI 1:250,000 and 1:50,000; photographic source: INEGI 1:75,000. Map prepared by P. González and G. Arredondo, September 2002.

mineral nutrients for the growth of mangroves (Chapman 1976; Tomlinson 1986). In sum, mangroves grow under suboptimal conditions in areas with dry climates. As a result of the arid regional climate, mangroves in northwestern Mexico occur in strictly tidal saltwater, with the exception of 2 locations (Mulegé and Loreto) in BCS. Along *esteros* and some shallow bays (e.g., the inner coast of El Mogote in Bahía de la Paz), tidal waters are hypersaline.

At the landscape level, BCS mangrove communities constitute a relatively narrow and discontinuous band of desert-fringe vegetation. Individual plants consist typically of arborescent shrubs or small trees (León de la Luz and Coria-Benet 1992). Species diversity of mangroves in northwestern Mexico is low, as is the case for mangroves in arid regions elsewhere in the world. Three species dominate the mangrove vegetation nearly everywhere in BCS: red mangrove (*Rhizophora mangle*, Rhizophoraceae), black mangrove (*Avicennia germinans*, Avicenniaceae), and white mangrove (*Laguncularia racemosa*, Combretaceae). Overlapping zonation within the mangroves is pronounced and similar to that in Sonora (e.g., Felger et al. 2001): red mangrove extends into deep-

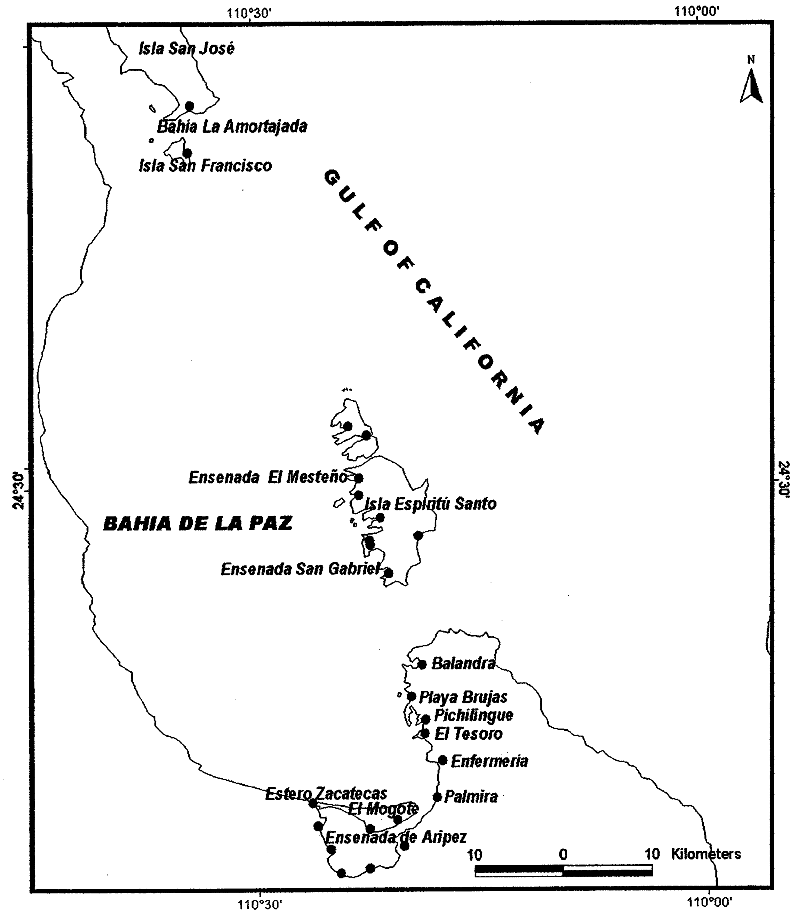

Figure 15.4. Mangrove distribution in Baja California Sur: Zone IV, Bahía de La Paz area. Dots represent verified mangrove stands based either on on-site verification, photographic interpretation, or herbarium specimens. Map generated using the Lambert Conformal Conic Projection. Cartographic source: INEGI 1:250,000 and 1:50,000; photographic source: INEGI 1:75,000. Map prepared by P. González and G. Arredondo, September 2002.

est water (the seaward zone), and black mangrove reaches maximum density in the shallowest water (landward zone); white mangrove reaches maximum density between the peak zones of the other 2. On the Pacific coast, the black mangrove extends its distribution north only to the Bahía Magdalena area. Farther north, such as at Laguna San Ignacio, stands of mangrove vegetation consists only of red and white mangrove (Centro de Investigaciónes Biologicas de Baja California Sur 1994).

A fourth mangrove species, buttonwood mangrove or *mangle botoncillo* (*Conocarpus erecta*; Combretaceae), occurs chiefly in the form of individual plants distributed sparsely at several locations of BCS. In the tropics, this species may grow as a tree, often reaching 15 m in height and forming thick stands. At Ensenada El Mezteño (24°31' N, 110°19' W) on Isla Espíritu Santo, buttonwood mangrove occurs as the only pure stand of this species on the peninsula. The buttonwood mangrove stand in this cove consists of 50–60 shrubby plants 2.5–3 m tall at the edge of a salt flat (J. León de la Luz, pers. obs.).

Red mangroves are characterized in part by arching "prop roots" descending from branches and stems, leathery leaves that are nearly opposite and decussate, wind-pollinated flowers, and viviparous

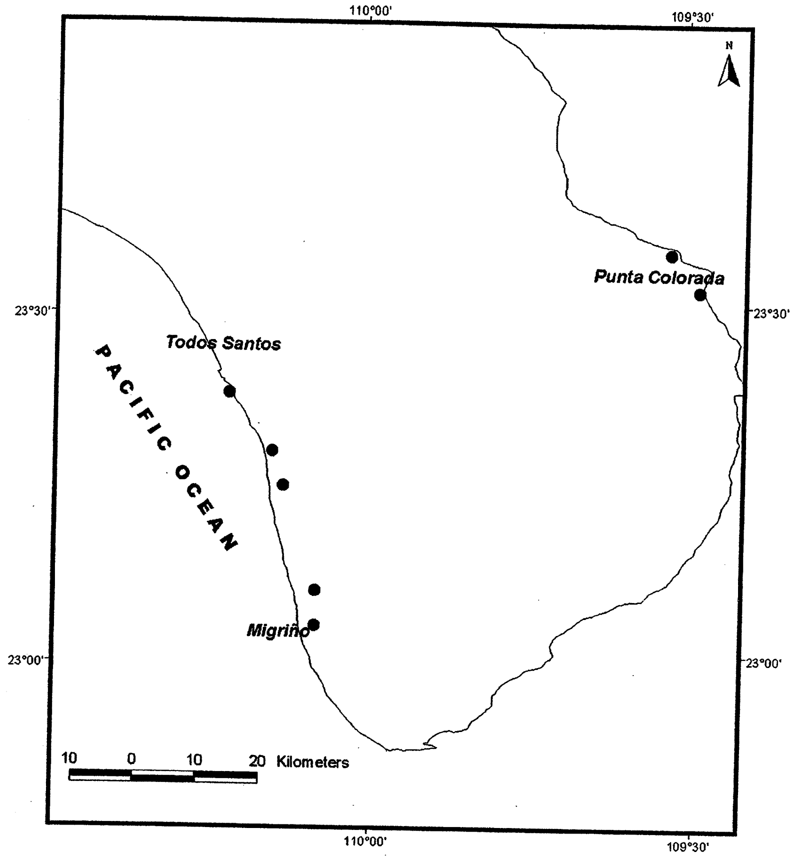

Figure 15.5. Mangrove distribution in Baja California Sur: Zone III, Cape Region. Dots represent verified mangrove stands based either on on-site verification, photographic interpretation, or herbarium specimens. Map generated using the Lambert Conformal Conic Projection. Cartographic source: INEGI 1:250,000 and 1:50,000; photographic source: INEGI 1:75,000. Map prepared by P. González and G. Arredondo, September 2002.

fruits (e.g., León de la Luz and Coria-Benet 1992; Felger et al. 2001). The bark, and to a lesser extent, the leaves, have a high tannin content. Red mangrove is used traditionally for tanning hides, but also as fuel wood and construction material for *covachas* (shelters). It is used to treat a number of ailments, including leprosy, fever, and sore throat (León de la Luz and Coria-Benet 1992). The Seri people, who live along the central Sonora coast, collected the driftwood as firewood and the roots to make a black dye. They also have used the fruits (enlarged embryos) in a variety of ways, for example to make a tea as a remedy for dysentery or, once roasted, to consume as food (Felger and Moser 1985).

Black mangrove is widespread in the western mangrove zone of the tropics, where it may reach a height of 25 m (Felger et al. 2001). In BCS—and elsewhere in northwestern Mexico—it reaches 6 m in height (León de la Luz and Coria-Benet 1992). Its root system includes subterranean cable roots, from which both anchoring roots and pneumatophores arise. The flowers produce nectar that is highly fragrant, especially at night (Felger et al. 2001). The fruits are viviparous. Black mangrove is used traditionally for tanning hides (León de la Luz and Coria-Benet 1992), and the Seris prized the wood for the curved ribs of their boats and used the driftwood for building fires (Felger and Moser 1985).

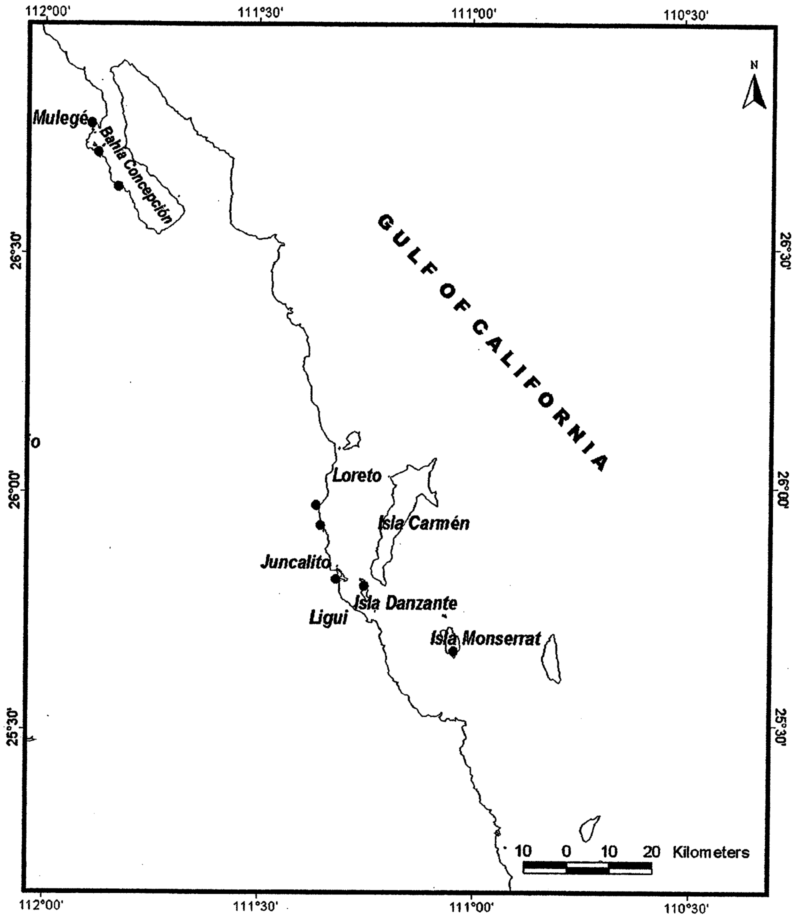

Figure 15.6. Mangrove distribution in Baja California Sur: Zone V, Bahía Concepción/ Bahía de Loreto area. Dots represent verified mangrove stands based either on on-site verification, photographic interpretation, or herbarium specimens. Map generated using the Lambert Conformal Conic Projection. Cartographic source: INEGI 1:250,000 and 1:50,000; photographic source: INEGI 1:75,000. Map prepared by P. González and G. Arredondo, September 2002.

White mangrove has shallow, horizontal roots and pneumatophores. The flowers, which appear from July to October in BCS (León de la Luz and Coria-Benet 1992), are visited by bees in the tropics (Felger et al. 2001). The Seris made use of the wood for boat paddles, harpoon shafts, and house posts and beams and used the leafy branches for roofing (Felger and Moser 1985).

A halophytic or salt-scrub vegetation is associated with mangroves, usually on the landward side. It is made up of highly predictable species of perennial saltgrasses (*Jouvea pilosa*, *Monanthochloe littoralis*, *Sporobolus virginicus*), perennial halophytic shrubs (e.g., *Allenrolfea occidentalis*, *Maytenus phyllanthoides*, *Salicornia subterminalis*, *Suaeda nigra*), and other halophytes (e.g., *Atriplex barclayana*, *Batis maritima*, *Heliotropium curassavicum*, *Salicornia bigelovii*, *S. virginicus*, *Sesuvium portulacastrum*). Extensive undersea meadows of *Zostera marina* occur near the mangrove stands in Bahía Magdalena (Ramírez-García and Lot 1994), and substantial quantities of this seagrass may seasonally wash into the mangroves. Stranded pieces of the seagrass often become entangled in the mangrove branches. Another seagrass, *Ruppia* *maritima* (Ruppiaceae), sometimes occurs in shallow water adjacent to mangrove stands—for example, at El Mogote (Bahía de La Paz) and Bahía Concepción (Ramírez-García and Lot 1994).

Macrofauna of Baja California Sur Mangroves

Baja California Sur mangroves and adjacent intertidal and subtidal waters provide habitat and nutrients for a large number of organisms, both terrestrial and marine. Habitats provided or strongly influenced by mangroves include their canopy and roots, soil surface, and tidal waters. Use of mangroves by birds and sea turtles has been fairly well documented. The inventory of macroinvertebrates, fish, and mammals remains incomplete. With the exception of some dipterans (biting midges and mangrove flies; Cheng and Hogue 1974), we are not aware of any published information on terrestrial or flying arthropods of BCS mangroves. Some of these are important, such as the insects pollinating black mangrove.

Biting Midges and Mangrove Flies (Order: Diptera)

Cheng and Hogue (1974) documented the presence of several dipterans associated with mangroves and adjacent mudflats in BCS. The mosquito *Deinocerites mcdonaldi* Belkin & Hogue (family Culicidae) breeds in the burrows of 2 land crab species, *Cardisoma crassum* and *Sesarma sulcatum* (see table 15.1). The infamous *jejene Culicoides furens* (Poey) is a common biting midge in the family Ceratopogonidae. It breeds around the aerial roots of black mangrove, in mud and burrows of *S. sulcatum.* Three other species, *Megaselia minutior* Borgmeier (Phoridae), *Dasyhelea* sp. (Ceratopogonidae), and *Smittia* sp. (Chironomidae), have been collected in emergence traps set on muddy flats around the aerial roots of black mangrove (Cheng and Hogue 1974).

Intertidal and Subtidal Macroinvertebrates

We present a list of all the (named) macroinvertebrates recorded from mangrove-lined lagoons, *esteros*, and coves on the Gulf side of BCS, including offshore islands (table 15.1). We are not aware of any other published compilation of mangrove-associated macroinvertebrates for any part of the Baja California peninsula. In addition to the described (named) invertebrate fauna of the Gulf of California, there is a large undescribed fauna (Brusca et al. [chapter 9] estimate that less than half of the Gulf macroinvertebrates have been described). In particular, there are easily a dozen or more species of sponges (Porifera) and of tunicates (Urochordata) that are common in mangrove-lined waters of BCS. Of these, however, most are undescribed species.

The intertidal and subtidal macroinvertebrate fauna associated with BCS mangroves is diverse. Most species are intertidal, but some live in the permanent, subtidal channels of the mangrove lagoons. Our compilation lists 214 taxa, 15 of which occur only in association with rocky substrate near mangroves. Among the 214 taxa are 71 crustaceans, 63 bivalves (class Pelecypoda), 38 gastropods, 14 polychaete annelids, 6 echinoderms, 5 cnidarians (sea anemones), 5 sponges, 4 chordates (3 tunicates and 1 cephalochordate/amphioxus), 3 polyplacophorans (chitons), 3 ectoprocts (bryozoans), 1 nemertean, and 1 sipunculan (peanut worm). Tunicates and sponges dominate communities living on the roots of mangroves (i.e., the mangrove root microhabitat), whereas crustaceans and molluscs dominate the remaining habitats. Crustaceans and bivalves are not only diverse in these communities, but they also dominate the biomass. Virtually all of the bivalves are suspension feeders, attesting to the high productivity that characterizes these detritus-based ecosystems. Crustaceans are a mix of algal grazers, scavengers, and predators, as are the gastropods. The annelids are a mix of suspension-feeders and predators. Included in the list are 3 frequently seen visitors to coastal lagoons, species that live offshore in subtidal waters but occasionally break free in storm surge to be carried into mangrove embayments, where they can live for many weeks, rolling about with tides: *Zoobotryon verticillatum* (the gelatinous "spaghetti bryozoan," which may also grow on pier pilings in coastal lagoons), *Cliona* cf. *chilensis* (the "barrel sponge," also known as *Pseudosuberites pseudos*), and the bright orange *Aplidium* sp. (the colonial "ball ascidian").

The mangrove embayments of BCS also provide important refugia for young of the commercially valuable penaeid shrimps of the southern portion of the Gulf of California. Penaeid shrimps use these habitats as nursery grounds, migrating into them subsequent to their offshore planktonic larval phase. When they reach the juvenile or subadult stage, they migrate offshore once again. Loss of mangrove and other coastal lagoon habitats thus reduces the area

Table 15.1. Intertidal and subtidal invertebrate species documented from mangrove lagoons and *esteros* along the eastern (Gulf of California) coast of Baja California Sur.

Phylum	Subphylum	Class	Family	Scientific Name	Species Author
Porifera		Calcarea	Leucosoleniidae	*Leucosolenia cf. irregularis*	Jenkin, 1908
			Leucettidae	*Leucetta losangelensis*	(de Laubenfels, 1930)
		Demospongiae	Clionidae	*Cliona celata*	Grant, 1826
				Cliona cf. chilensis	Thiele, 1905
			Tetillidae	*Craniella crania*	(Müller, 1776)
Ectoprocta (Bryozoa)		Gymnolaemata	Bugulidae	*Bugula californica*	Robertson, 1905
			Thalamoporellidae	**Thalamoporella californica*	(Levinsen, 1909)
			Vesiculariidae	*Zoobotryon verticillatum*	(della Chiaje, 1828)
Cnidaria		Anthozoa	Cerianthidae	*Andvakia insignis*	(Carlgren, 1951)
			Hormathiidae	*Calliactis polypus*	(Verrill, 1869)
			Phyllactidae	*Phyllactis californica*	(McMurrich, 1893)
			Caryophylliidae	*Phyllangia consagensis*	(Durham & Barnard, 1952)
			Renillidae	*Renilla amethystina*	Verrill, 1866
Nemertea		Anopla	Lineidae	*Cerebratulus californiensis*	Coe, 1905
Annelida		Polychaeta	Capitellidae	*Capitella capitata*	(Fabricius, 1780)
				Notomastus magnus	Hartman, 1947
			Pilargidae	*Synelmis albini*	(Langerhans, 1881)
			Syllidae	*Branchiosyllis exilis*	(Gravier, 1900)
				Ehlersia cornuta	(Rathke, 1843)
				Typosyllis okadai	(Fauvel, 1934)
				Typosyllis regulata	Imajima, 1966
			Nereidae	*Perinereis bajacalifornica*	de León González & Solís-Weiss, 1998
			Amphinomidae	*Linopherus tripunctata*	(Kudenov, 1975)
			Onuphidae	*Diopatra farallonensis*	Fauchald, 1968
			Terebellidae	*Neoleprea spiralis*	(Johnson, 1901)
			Sabellidae	*Branchiomma cingulata*	(Grube, 1870)
				Branchiomma nigromaculata	(Baird, 1865)
				Sabella melanostigma	Schmarda, 1861
Sipuncula		Sipunculidea	Sipunculidae	*Sipunculus nudus*	Linnaeus, 1766
Arthropoda	Crustacea	Maxillopoda	Pollicipedidae	*Arcoscalpellum californicum*	(Pilsbry, 1907)
			Balanidae	*Balanus amphitrite*	Darwin, 1854
				Balanus eburneus	Gould, 1841
				Balanus improvisus	Darwin, 1854
				Balanus inexpectatus	Pilsbry, 1916
				Balanus trigonus	Darwin, 1854
				Chthamalus anisopoma	Pilsbry, 1916

(*continued*)

Table 15.1. Continued

Phylum	Subphylum	Class	Family	Scientific Name	Species Author
		Malacostraca	Amphilochidae	**Gitanopsis pusilloides*	Shoemaker, 1942
			Ampithoidae	*Amphitoe ramondi*	Audouin, 1826
			Corophiidae	*Gammaropsis thompsoni*	(Walker, 1898)
				Photis brevipes	Shoemaker, 1942
			Ischyroceridae	*Microjassa macrocoxa*	Shoemaker, 1942
			Lysianassidae	*Orchomene magdalenensis*	(Shoemaker, 1942)
			Cirolanidae	*Cirolana harfordi*	Lockington, 1877
			Corallanidae	*Excorallana tricornis*	(Hansen)
			Cymothoidae	*Ceratothoa gaudichaudii*	(Milne-Edwards, 1840)
				Ceratothoa gilberti	(Richardson, 1904)
				Cymothoa exigua	Schioedte & Meinert, 1884
				Elthusa menziesi	(Brusca, 1981)
				Elthusa vulgaris	(Stimpson, 1857)
				Enispa convexa	(Richardson, 1905)
				Livoneca bowmani	Brusca, 1981
				Mothocya gilli	Bruce, 1986
				Nerocila acuminata	Schioedte & Meinert, 1881
				Rocinela murilloi	Brusca & Iverson, 1985
			Sphaeromatidae	*Paracerceis sculpta*	(Holmes, 1904)
				Paracerceis richardsoni	Lombardo, 1988
			Ligiidae	**Ligia occidentalis*	Dana, 1853
			Leucosiidae	*Randallia ornate*	(Randall, 1839)
			Inachidae	**Stenorhynchus debilis*	(Smith, 1871)
			Xanthidae	*Cataleptodius occidentalis*	(Stimpson, 1871)
				Eurytium affine	(Streets & Kingsley, 1879)
				Eurytium albidigitum	Rathbun, 1933
				Hexapanopeus sinaloensis	Rathbun, 1930
				Panopeus purpureus	Lockington, 1877
				**Pilumnus spinohirsutus*	(Lockington, 1877)
				**Pilumnus townsendi*	Rathbun, 1923
			Pinnotheridae	*Pinnixa occidentalis*	Rathbun, 1893
				Raymondia clavapedata	(Glassell, 1935)
			Ocypodidae	*Ocypode occidentalis*	Stimpson, 1860
				Uca brevifrons	(Stimpson, 1860)
				Uca crenulata	(Lockington, 1877)
				Uca latimanus	(Rathbun, 1893)
				Uca musica	Rathbun, 1914

			Uca princeps	(Smith, 1870)
			Uca vocator	(Herbst, 1904)
			Uca zacae	Crane, 1941
			Ucides occidentalis	(Ortmann, 1897)
		Gecarcinidae	*Cardisoma crassum*	Smith, 1870
			Gecarcinus quadratus	de Saussure, 1853
		Grapsidae	*Aratus pisonii*	(H. Milne Edwards, 1837)
			Goniopsis pulchra	(Lockington, 1877)
			Grapsus grapsus	(Linnaeus, 1758)
			Pachygrapsus crassipes	Randall, 1839
			Pachygrapsus transversus	(Gibbes, 1850)
			Armases magdalenense	(Rathbun, 1918)
			Sesarma sulcatum	Smith, 1870
			**Tetragrapsus jouyi*	(Rathbun, 1893)
		Alphaeidae	*Alpheus normanni*	Kingsley, 1878
		Palaemonidae	**Periclimenes infraspinis*	(Rathbun, 1902)
		Penaeidae	*Farfantepenaeus brevirostris*	(Kingsley, 1878)
			Farfantepenaeus californiensis	(Holmes, 1900)
			Litopenaeus stylirostris	(Stimpson, 1874)
			Litopenaeus vannamei	(Boone, 1931)
			Trachysalambria brevisuturae	(Burkenroad, 1934)
		Diogenidae	*Clibanarius albidigitus*	Nobili, 1901
			Clibanarius digueti	Bouvier, 1898
			Clibanarius panamensis	Stimpson, 1859
			Petrochirus californiensis	Bouvier, 1895
		Galatheidae	*Munida hispida*	Benedict, 1902
		Porcellanidae	*Petrolisthes armatus*	(Gibbes, 1850)
Mollusca	Polyplacophora	Ischnochitonidae	**Lepidozona pectinulata*	(Pilsbry, 1893, ex Carpenter)
		Lepidopleuridae	**Leptochiton rugatus*	(Pilsbry, 1892)
		Mopaliidae	**Placiphorella velata*	Dall, 1879
	Gastropoda	Lottiidae	**Lottia atrata*	(Carpenter, 1864)
			**Colisella strongiana*	Hertlein, 1958
		Fissurellidae	*Diodora saturnalis*	(Carpenter, 1864)
		Columbellidae	*Parvanchis pygmaea*	(Sowerby, 1832)
		Neritidae	*Theodoxus luteofasciatus*	(Miller, 1879)
			**Nerita funiculate*	Menke, 1851
		Littorinidae	*Littoraria rosewateri*	Reid, 1999
			Littoraria variegata	(Souleyet, in Eydoux & Souleyet, 1852)
		Turritellidae	*Turitella gonostoma*	Valenciennes, 1832
		Modulidae	*Modiolus catenulatus*	(Philippi, 1849)

(continued)

Table 15.1. Continued

Phylum	Subphylum	Class	Family	Scientific Name	Species Author
			Cerithiidae	*Cerithium stercusmuscarum*	Valenciennes, 1833
			Potamididae	*Cerithidea californica californica*	Haldeman, 1840
				Cerithidea californica mazatlanica	Haldeman, 1840
				Cerithidea montagnei	(d'Orbigny, 1839)
				Cerithidea valida	(Adams, 1852)
			Strombidae	*Strombus gracilior*	Sowerby, 1825
			Calyptraeidae	*Calyptraea mamillaris*	Broderip, 1834
				Crepidula incurva	(Broderip, 1834)
				Crepidula striolata	Menke, 1851
				Crucibulum spinosum	(Sowerby, 1824)
			Triviidae	**Trivia californica*	(Sowerby, 1832 ex Gray, MS)
			Trochidae	*Tegula rugosa*	(A. Adams, 1853)
			Muricidae	*Hexaplex nigritus*	(Philippi, 1845)
				Hexaplex erythrostomus	(Swainson, 1831)
				Muricopsis zeteki	Hertlein & Strong, 1951
				Ceratostoma unicorne	(Reeve, 1849)
				Thais kiosquiformis	(Duclos, 1832)
				Acanthina lugubris	(Sowerby, 1822)
			Buccinidae	*Cantharus gatesi*	(Berry, 1963)
				Melongena patula	(Broderip & Sowerby, 1829)
				Nassarius luteostomus	(Broderip & Sowerby, 1829)
			Olividae	*Oliva incrassata*	(Lightfoot, 1786)
			Turridae	*Pyrgocythara scammoni*	(Dall, 1919)
			Pyramidellidae	*Turbonilla baegerti*	Bartsch, 1917
			Melampidae	*Melampus olivaceus*	Carpenter, 1857
			Bullidae	*Bulla gouldiana*	Pilsbry, 1895
			Haminoeidae	*Haminoea vesicula*	(Gould, 1855)
			Aplysiidae	*Stylocheilus longicauda*	(Quoy & Gaimard, 1824)
		Pelecypoda	Arcidae	*Arca pacifica*	(Sowerby, 1833)
				Barbatia gradata	(Broderip & Sowerby, 1829)
				Barbatia reeveana	(d'Orbigny, 1846)
				Anadara adamsi	Olsson, 1961
				Anadara obesa	(Sowerby, 1833)
				Anadara tuberculosa	(Sowerby, 1833)
				Anadara nux	(Sowerby, 1833)
				Anadara emarginata	(Sowerby, 1833)
			Noetiidae	*Noetia reversa*	(Sowerby, 1833)

Glycymerididae	*Glycymeris gigantea*	(Reeve, 1843)
	Glycymeris maculata	(Broderip, 1832)
	Glycymeris inaequalis	(Sowerby, 1833)
Mytilidae	*Lithophaga calyculata*	(Carpenter, 1857)
	Modiolus capax	(Conrad, 1837)
Pinnidae	*Pinna rugosa*	Sowerby, 1835
	Atrina maura	(Sowerby, 1835)
Pteriidae	*Pinctada mazatlanica*	(Hanley, 1856)
Ostreidae	*Saccostrea palmula*	(Carpenter, 1857)
Plicatulidae	*Plicatula penicillata*	Carpenter, 1857
Pectinidae	*Leptopecten velero*	(Hertlein, 1935)
Anomiidae	*Anomia peruviana*	d'Orbigny, 1846
Crassatellidae	*Crassinella varians*	(Carpenter, 1857)
Carditidae	*Carditamera affinis*	(Sowerby, 1833)
Ungulinidae	*Diplodonta subquadrata*	Carpenter, 1856
	Felaniella cornea	(Reeve, 1850)
Sportellidae	*Fabella stearnsii*	(Dall, 1899)
Chamidae	*Chama sordida*	Broderip, 1835
	Pseudochama saavedrai	Hertlein & Strong, 1946
Cardiidae	*Trachycardium consors*	(Sowerby, 1833)
	Trachycardium obovalis	(Sowerby, 1833)
	Trachycardium panamense	(Sowerby, 1833)
	Trachycardium procerum	(Sowerby, 1833)
	Papyridea aspersa	(Sowerby, 1833)
	Trigoniocardia granifera	(Broderip & Sowerby, 1829)
	Laevicardium elenense	(Sowerby, 1840)
Veneridae	*Globivenus isocardia*	(Verrill, 1870)
	Pitar lupanaria	(Lesson, 1830)
	Pitar concinnus	(Sowerby, 1835)
	Megapitaria squalida	(Sowerby, 1835)
	Dosinia dunkeri	(Philippi, 1844)
	Dosinia ponderosa	(Gray, 1838)
	Cyclinella singleyi	Dall, 1902
	Chione californiensis	(Broderip, 1835)
	Chione undatella	(Sowerby, 1835)
	Chione subrugosa	(Wood, 1828)
	Protothaca asperrima	(Sowerby, 1835)
	Protothaca grata	(Say, 1831)
Mactridae	*Mulinia pallida*	(Broderip & Sowerby, 1829)
	Rangia mendica	(Gould, 1851)

(*continued*)

Table 15.1. Continued

Phylum	Subphylum	Class	Family	Scientific Name	Species Author
			Tellinidae	*Tellina mcneilii*	Dall, 1900
				Tellina simulans	C.B. Adams, 1852
				Tellina reclusa	Dall, 1900
				Tellina virgo	Hanley, 1844
				Macoma secta	(Conrad, 1837)
			Donacidae	*Donax carinatus*	Hanley, 1843
				Donax gracilis	Hanley, 1845
				Donax punctatostriatus	Hanley, 1843
				Donax transversus	Sowerby, 1825
			Psammobiidae	*Tagelus affinis*	(C.B. Adams, 1852)
				Tagelus politus	(Carpenter, 1857)
			Pholadidae	*Pholadidae melanura*	(Sowerby, 1834)
			Thraciidae	*Asthenothaerus diegensis*	(Dall, 1915)
			Corbiculidae	*Polymesoda mexicana*	(Broderip & Sowerby, 1829)
Echinodermata	Asterozoa	Asteroidea	Echinasteridae	*Echinaster parvispinus*	A.H. Clark, 1916
		Ophiuroidea	Ophiactidae	*Ophiactis savignyi*	(Muller & Troschel, 1842)
				Ophiactis simplex	(Le Conte, 1851)
			Ophiotrichidae	*Ophiothrix spiculata*	Le Conte, 1851
	Echinozoa	Echinoidea	Loveniidae	*Lovenia cordiformis*	A. Agassiz, 1872
		Holothuroidea	Stichopodidae	*Isostichopus fuscus*	(Ludwig, 1875)
Chordata	Urochordata	Ascidiacea	Molgulidae	*Molgula occidentalis*	Traustedt, 1883
			Polyclinidae	*Aplidium sp. ?*	
			Botryllidae	*Botrylloides diegensis*	Ritter & Forsyth, 1917
	Cephalochordata			*Branchiostoma californiense*	Andrews, 1893

Data are from the Macrofauna Golfo Database (Findley et al. in press), Holguin-Quiñones and García-Domínguez (1997), and the personal field notes of R. C. Brusca. *Occurrence restricted to rocks in mangrove waters.

that is critical to the life history of this commercially important invertebrate (Brusca 1980).

The grapsid crab *Goniopsis pulchra* has a wide distribution that includes both coasts of BCS and the eastern side of the Gulf (Brusca 1980). This bright-red semiterrestrial crab is distributed throughout the intertidal zone, and it is abundant in mangrove swamps of the middle and southern Gulf of California. At least in Sonora, *G. pulchra* is the primary herbivore of mangrove propagules that reach the swamp floor. In a study in 3 mangrove communities in Sonora, C. McIvor and A. I. Robertson (Charles Sturt University, Wagga Wagga, New South Wales, Australia, unpubl. data) determined that this crab fed preferentially on the propagules of black mangrove (*Avicennia*) when offered those in equal abundance to red mangrove (*Rhizophora*) propagules. Nevertheless, when only red mangrove propagules were seasonally available, 8–40% of those propagules tethered were rendered nonviable for germination (growing tip removed, more than 50% of propagule consumed, or propagule pulled down a burrow) in less than 20 days. Preferential consumption of some as opposed to other species of mangrove propagules is believed to have ramifications for mangrove structure and zonation (e.g., Smith et al. 1989; Smith 1992).

In Sonora, *G. pulchra* took tethered propagules down their burrows for consumption when possible; otherwise they grazed on this food source during ebb tides on the swamp floor. Mangrove herbivory by grapsid crabs of this and other genera has been repeatedly identified, especially in the Indo-West Pacific biogeographic realm, as an alternative pathway of carbon and organic matter processing to detritivory in mangrove ecosystems (e.g., Robertson 1991). In the infrequently flooded high intertidal zone (Robertson and Daniel 1989) and in poorly flushed basin forests (Twilley 1985), crab herbivory probably results in increased retention of mangrove organic matter within the swamp and thus lowered export. In lower intertidal zones subject to frequent tidal flooding, however, herbivorous crabs (or other invertebrates) are consumed by fish and turtles, and mangrove production is directly transferred out of the swamp to the adjacent coastal ecosystem.

Fish

Fishes are important inhabitants of mangrove waters around the world. Members of several groups such as gobies (Gobiidae) and mojarras (Gerreidae) occur in these areas for most or all of their lives, while others are temporary inhabitants as adults, juveniles, or both. Mangrove ecosystems are thus important for many tropical fishes (Blaber 1997), and this is true in particular with respect to the mangroves of BCS.

A detailed compilation of the fish fauna associated with BCS mangrove waters has not been published, although the fishes of several of the larger bays of the state that include mangroves have been extensively surveyed and recently summarized by Galván-Magaña et al. (2000). The most extensively studied systems are Bahía de La Paz (Abitia-Cárdenas et al. 1994; Castro-Aguirre and Balart 1997; González-Acosta et al. 1999; Galván-Piña et al. 2003) and Bahía Concepción (Rodríguez-Romero et al. 1992, 1994, 1998), on the east coast of BCS, and Bahía Magdalena (de la Cruz-Agüero et al. 1994) and Laguna San Ignacio (Danemann and de la Cruz-Agüero 1993; de la Cruz-Agüero and Cota-Gómez 1998) on the Pacific side. These published surveys include all species of fishes recorded in these large and diverse lagoon systems and generally do not indicate which species are associated with mangroves. Only 2 of these studies report on species from relatively restricted lagoons lined with mangroves within Bahía de La Paz. Castro-Aguirre and Balart (1997) report fishes recorded from Ensenada de Aripes, and González-Acosta et al. (1999) report fishes taken from a mangrove-lined swamp near the mouth of Ensenada de Aripes. Table 15.2 presents a list of fish species recorded in these 2 studies, as well as additional, unpublished records of fishes from that same area (Galván-Magaña, unpubl. data) and unpublished records of fishes collected adjacent to BCS mangrove stands and archived at the Scripps Institution of Oceanography Marine Vertebrates Collection. The latter collections are primarily from the lagoon systems along the Pacific coast of BCS, from Bahía Magdalena northward to near Punta Abreojos (26°49' N).

A total of 160 species of fishes have been recorded from mangrove systems of BCS (table 15.2). This list includes a number of species that normally occur in mangrove waters as both juveniles and adults, as well as a number of others that also occur in other habitats both inside and outside of the larger lagoon systems. Dominant members include grunts (Haemulidae, 17 species), gobies and sleepers (Gobiidae and Eleotridae, 15 species), drums (Sciaenidae, 11 species), jacks (Carangidae, 10 species), mojarras (Gerreidae, 9 species), anchovies (Engraulidae, 9 species), and seabasses (Serranidae, 8 species). Fishes

Table 15.2. Fish species recorded from mangrove waters of Baja California Sur.

Order	Family	Scientific Name
Carcharhiniformes	Triakidae	*Mustelus henlei* (Gill, 1863)
		Mustelus lunulatus Jordan & Gilbert, 1882
		Triakis semifasciata Girard, 1855
Rajiformes	Dasyatidae	*Dasyatis dipterura* (Jordan & Gilbert, 1880)
	Urolophidae	*Urobatis halleri* (Cooper, 1863)
		Urotrygon chilensis (Günther, 1871)
	Gymnuridae	*Gymnura marmorata* (Cooper, 1864)
	Rhinobatidae	*Rhinobatos productus* Ayers, 1854
Elopiformes	Elopidae	*Elops affinis* Regan, 1909
Albuliformes	Albulidae	*Albula nemoptera* (Fowler, 1911)
		Albula sp.
	Ophichthidae	*Myrichthys tigrinus* Girard, 1859
		Myrophis vafer Jordan & Gilbert, 1883
		Ophichthus zophochir Jordan & Gilbert, 1882
	Congridae	*Heteroconger digueti* (Pellegrin, 1923)
	Clupeidae	*Harengula thrissina* (Jordan & Gilbert, 1882)
		Lile stolifera (Jordan & Gilbert, 1882)
		Opisthonema libertate (Günther, 1867)
		Sardinops caeruleus (Girard, 1854)
	Engraulidae	*Anchoa argentivittata* (Regan, 1904)
		Anchoa exigua (Jordan & Gilbert, 1882)
		Anchoa ischana (Jordan & Gilbert, 1882)
		Anchoa lucida (Jordan & Gilbert, 1882)
		Anchoa mundeola (Gilbert & Pierson, 1898)
		Anchoa mundeoloides (Breder, 1928)
		Anchovia macrolepidota (Kner, 1863)
		Cetengraulis mysticetus (Günther, 1867)
		Engraulis mordax Girard, 1854
Gonorynchiformes	Chanidae	*Chanos chanos* (Forsskål, 1775)
Siluriformes	Ariidae	*Ariopsis planiceps* (Steindachner, 1877)
		Ariopsis seemanni (Günther, 1864)
		Bagre panamensis (Gill, 1863)
		Bagre pinnimaculatus (Steindachner, 1877)
		Galeichthys peruvianus Lütken, 1874
	Synodontidae	*Synodus scituliceps* Jordan & Gilbert, 1882
	Ophidiidae	*Ophidion galeoides* (Gilbert, 1890)
Batrachoidiformes	Batrachoididae	*Porichthys myriaster* Hubbs & Schultz, 1939
Mugliformes	Mugilidae	*Mugil cephalus* Linnaeus, 1758
		Mugil curema Valenciennes, 1836
		Mugil hospes Jordan & Culver, 1895
Atheriniformes	Atherinopsidae	*Atherinops affinis* (Ayers, 1860)
		Atherinopsis californiensis Girard, 1854
	Hemiramphidae	*Hyporhamphus naos* Banford & Collette, 2001
		Hyporhamphus rosae (Jordan & Gilbert, 1880)
Cyprinodontiformes	Fundulidae	*Fundulus parvipinnis* Girard, 1854
Gasterosteiformes	Fistulariidae	*Fistularia commersonii* Ruppell, 1838
	Syngnathidae	*Pseudophallus starksi* (Jordan & Culver, 1895)
		Syngnathus auliscus (Swain, 1882)
		Syngnathus euchrous Fritzsche, 1980
	Triglidae	*Prionotus stephanophrys* Lockington, 1881
Perciformes	Centropomidae	*Centropomus armatus* Gill, 1863
		Centropomus medius Günther, 1864
		Centropomus nigrescens Günther, 1864
		Centropomus robalito Jordan & Gilbert, 1882
		Centropomus viridis Lockington, 1877
	Serranidae	*Diplectrum euryplectrum* Jordan & Bollman, 1890

Table 15.2. Continued

Order	Family	Scientific Name
		Diplectrum pacificum Meek & Hildebrand, 1925
		Epinephelus analogus Gill, 1863
		Epinephelus itajara (Lichtenstein, 1822)
		Epinephelus niphobles Gilbert & Starks, 1897
		Mycteroperca xenarcha Jordan, 1888
		Paralabrax maculatofasciatus (Steindachner, 1868)
		Paralabrax nebulifer (Girard, 1854)
	Carangidae	*Caranx caninus* Günther, 1867
		Caranx sexfasciatus Quoy & Gaimard, 1825
		Caranx vinctus Jordan & Gilbert, 1882
		Chloroscombrus orqueta Jordan & Gilbert, 1883
		Gnathanodon speciosus (Forsskål, 1775)
		Hemicaranx leucurus (Günther, 1864)
		Oligoplites altus (Günther, 1868)
		Selene brevoortii (Gill, 1863)
		Selene peruviana (Guichenot, 1866)
		Trachinotus paitensis Cuvier, 1832
	Lutjanidae	*Lutjanus aratus* (Günther, 1864)
		Lutjanus argentiventris (Peters, 1869)
		Lutjanus colorado Jordan & Gilbert, 1882
		Lutjanus novemfasciatus Gill, 1862
	Gerreidae	*Diapterus aureolus* (Jordan & Gilbert, 1882)
		Diapterus peruvianus (Cuvier, 1830)
		Eucinostomus currani Zahuranec, 1980
		Eucinostomus dowii (Gill, 1863)
		Eucinostomus entomelas Zahuranec, 1980
		Eucinostomus gracilis (Gill, 1862)
		Eugerres axillaris (Günther, 1864)
		Eugerres lineatus (Humboldt, 1821)
		Gerres cinereus (Walbaum, 1792)
	Haemulidae	*Conodon serrifer* Jordan & Gilbert, 1882
		Haemulon flaviguttatum Gill, 1862
		Haemulon maculicauda (Gill, 1862)
		Haemulon scudderii Gill, 1862
		Haemulon sexfasciatum Gill, 1862
		Haemulon steindachneri (Jordan & Gilbert, 1882)
		Haemulopsis axillaris (Steindachner, 1869)
		Haemulopsis elongatus (Steindachner, 1879)
		Haemulopsis leuciscus (Günther, 1864)
		Haemulopsis nitidus (Steindachner, 1869)
		Orthopristis chalceus (Günther, 1864)
		Orthopristis reddingi Jordan & Richardson, 1895
		Pomadasys bayanus Jordan & Evermann, 1898
		Pomadasys branicki (Steindachner, 1879)
		Pomadasys macracanthus (Günther, 1864)
		Pomadasys panamensis (Steindachner, 1876)
		Xenistius californiensis (Steindachner, 1876)
	Sparidae	*Calamus brachysomus* (Lockington, 1880)
	Polynemidae	*Polydactylus approximans* (Lay & Bennett, 1839)
	Sciaenidae	*Atractoscion nobilis* (Ayers, 1860)
		Bairdiella icistia (Jordan & Gilbert, 1882)
		Cynoscion parvipinnis Ayers, 1861
		Cynoscion xanthulus Jordan & Gilbert, 1882
		Menticirrhus nasus (Günther, 1868)
		Menticirrhus undulatus (Girard, 1854)

(*continued*)

Table 15.2. Continued

Order	Family	Scientific Name
		Micropogonias altipinnis (Günther, 1864)
		Ophioscion strabo Gilbert, 1897
		Umbrina roncador Jordan & Gilbert, 1882
		Umbrina wintersteeni Walker & Radford, 1992
		Umbrina xanti Gill, 1862
	Mullidae	*Pseudupeneus grandisquamis* (Gill, 1863)
	Chaetodontidae	*Chaetodon humeralis* Günther, 1860
	Pomacanthidae	*Pomacanthus zonipectus* (Gill, 1862)
	Kyphosidae	*Girella nigricans* (Ayers, 1860)
	Pomacentridae	*Abudefduf troschelii* (Gill, 1862)
	Labridae	*Halichoeres aestuaricola* Bussing, 1972
	Scaridae	*Nicholsina denticulata* (Evermann & Radcliffe, 1917)
	Labrisomidae	*Exerpes asper* (Jenkins & Evermann, 1889)
		Paraclinus sini Hubbs, 1952
	Blenniidae	*Hypsoblennius gentilis* (Girard, 1854)
	Eleotridae	*Dormitator latifrons* (Richardson, 1844)
		Gobiomorus maculatus (Günther, 1859)
	Gobiidae	*Bathygobius ramosus* Ginsburg, 1947
		Clevelandia ios (Jordan & Gilbert, 1882)
		Ctenogobius manglicola (Jordan & Starks, 1895)
		Ctenogobius sagittula (Günther, 1861)
		Evorthodus minutus Meek & Hildebr&, 1928
		Gillichthys mirabilis Cooper, 1864
		Gobionellus microdon (Gilbert, 1892)
		Gobiosoma chiquita (Jenkins & Evermann, 1889)
		Ilypnus gilberti (Eigenmann & Eigenmann, 1889)
		Microgobius brevispinis Ginsburg, 1939
		Microgobius cyclolepis Gilbert, 1890
		Microgobius tabogensis Meek & Hildebrand, 1928
		Quietula y-cauda (Jenkins & Evermann, 1889)
	Microdesmidae	*Microdesmus dorsipunctatus* Dawson, 1968
	Ephippididae	*Chaetodipterus zonatus* (Girard, 1858)
	Scombridae	*Auxis thazard* (Lacepède, 1800)
	Paralichthyidae	*Citharichthys gilberti* Jenkins & Evermann, 1889
		Cyclopsetta panamensis (Steindachner, 1876)
		Etropus crossotus Jordan & Gilbert, 1882
		Paralichthys californicus (Ayers, 1859)
		Paralichthys woolmani Jordan & Williams, 1897
		Syacium ovale (Günther, 1864)
	Pleuronectidae	*Hypsopsetta guttulata* (Girard, 1856)
	Achiridae	*Achirus mazatlanus* (Steindachner, 1869)
		Trinectes fonsecensis (Günther, 1862)
	Cynoglossidae	*Symphurus chabanaudi* Mahadeva & Munroe, 1990
Tetraodontiformes	Balistidae	*Balistes polylepis* Steindachner, 1876
		Pseudobalistes naufragium (Jordan & Starks, 1895)
	Tetraodontidae	*Sphoeroides annulatus* (Jenyns, 1842)
		Sphoeroides lobatus (Steindachner, 1870)
	Diodontidae	*Diodon holocanthus* Linnaeus, 1758
		Diodon hystrix Linnaeus, 1758

Data are from Castro-Aguirre and Balart 1997 (Ensenada de La Paz, Bahía de La Paz); González-Acosta et al. 1999 (a mangrove-lined swamp near the mouth of Ensenada de La Paz, Bahía de La Paz); the personal field notes of F. Galván-Magaña (Ensenada de Aripes, Bahía de La Paz); and unpublished records of fishes collected adjacent to mangrove stands in BCS and archived at the Scripps Institution of Oceanography Marine Vertebrates Collection. The latter collections are primarily from the lagoon systems along the Pacific coast of BCS, from Bahía Magdalena northward to near Punta Abreojos (26° 49' N). Taxonomy of species follows Eschmeyer (1998) and Findley et al. (in press).

from these families are common inhabitants of mangrove systems around the world (Blaber 1997).

Like the entire fish fauna of the Gulf of California (Walker 1960), the fishes of mangrove waters in BCS are dominated by tropical species. However, the lagoons along the Pacific coast of BCS also have several warm-temperate species, such as the barred sandbass (*Paralabrax nebulifer*), the white seabass (*Atractoscion nobilis*), and California killifish (*Fundulus parvipinnis*), all of them found along the Pacific coast from BCS northward to California. These complex lagoon systems are thus especially rich systems that lie in a zone of overlap between the tropical regions of the eastern Pacific and the more temperate areas to the north (Hubbs 1960; Galván-Magaña et al. 2000). There is no doubt that many other fishes, especially juveniles of species inhabiting other habitats as adults, will be recorded from BCS mangrove lagoon systems as their fish fauna is more thoroughly studied.

Sea Turtles

The coastal waters of Baja California Sur host 4 of the world's 7 species of sea turtles: the green turtle (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), and olive ridley (*Lepidochelys olivacea*) (Cliffton et al. 1982; Nichols 2003; see also chapter 20). Within coastal mangrove systems the most common sea turtle species are the green turtle, and, to a lesser extent, the hawksbill (López-Mendilaharsu 2002; Seminoff et al. 2003; Brooks et al. 2003). Loggerhead turtles and olive ridleys typically prefer more offshore waters and are thus less common near mangroves (Nichols 2003).

The most important mangrove habitats for sea turtles in BCS include the Pacific Coast sites of Bahía Magdalena, Laguna San Ignacio, and Estero Coyote (Nichols 2003; J. Nichols, pers. comm.). Although a wide size-range of green turtles is typically seen, these areas appear to be most important as nursery grounds for small juveniles (Nichols 2003; Seminoff 2003). Seminoff (2003) has demonstrated that green turtles in mangrove systems of the Baja California peninsula are significantly smaller than turtles found in adjacent exposed, high-energy coastal areas and suggests the shallow and protected nature of these mangrove systems provides important predator-free habitat with abundant food for growing turtles.

Green turtles are primarily herbivorous throughout most of their global range, but in northwestern Mexico the species has been shown to consume a wide variety of both plants and invertebrates (Lopez-Mendilaharsu 2002; Seminoff et al. 2002a). Many potential food species are present near mangroves and, like elsewhere in the region (Seminoff et al. 2002b), green turtles likely maintain residency to these areas for extended periods while benefiting from the abundant local resources. In other parts of the world, it is the mangroves themselves that are consumed by green turtles. For example, the leaves of *Avicennia marina* make up a substantial portion of Australian green turtle diets (Pendoley and Fitzpatrick 1999; Limpus and Limpus 2000). The same can be said for green turtles foraging on red mangrove in the Galapagos (Pritchard 1971). However, although leaves and fruit of *A. germinans* are eaten on occasion in mangrove systems of BCS (Lopez-Mendilaharsu 2002), the primary value of these areas for sea turtles is the vast abundance of seagrass, marine algae, and invertebrate prey. Marine algae such as *Codium amplivesiculatum* and *Gracilaria textorii* are common near Pacific coast mangroves, and together with seagrasses they are the most important dietary components of local green turtles (Lopez-Mendilaharsu 2002). In addition, invertebrates such as molluscs and sponges have been found in the green turtle diet samples, the latter group being of primary importance also in the diet of local hawksbill turtles (Meylan 1988).

The hawksbill occurs on both coasts of the peninsula (Seminoff et al. 2003). Sightings of this now rare species are often in shallow, mangrove-lined bays, lagoons, and *esteros*. The hawksbill is seen occasionally in the mangrove *estero* at the mouth of the Río Santa Rosalía de Mulegé near the town of Mulegé (see below). Although it is principally a spongivore, it is known to eat the fruits, leaves, and bark of mangroves (Grismer 2002).

All sea turtles are threatened or endangered. Despite countrywide legal protection since 1990, illegal capture of sea turtles is still common, especially with green turtles in mangrove systems of the Baja California peninsula (Gardner and Nichols 2001; Nichols et al. 2002; chapter 20). Although some mangrove systems in BCS, particularly at Estero Coyote, continue to host a large number of turtles (Nichols 2003; J. Nichols, pers. comm.), it is clear that without stronger and immediate conservation action, sea turtle populations in and around these fragile ecosystems will continue to decline. For a discussion of sea turtle ecology and conservation in the Gulf of California, see chapter 20.

Birds

Much research has been conducted on birds inhabiting mangrove ecosystems in BCS. We present a list of species documented in mangrove stands and adjacent habitat (e.g., sand dunes, mudflats, and rocky outcroppings) of Bahía de La Paz, Bahía Magdalena, and the Laguna San Ignacio Complex (table 15.3). Our list is based on the published literature and the personal field notes (of E. S. A.-S., R. M.-S., and R. C. W.), plus those of Roberto Carmona and his students. The most detailed work was conducted in Bahía de La Paz. The list of winter migrants and transients, particularly songbirds (order Passeriformes) is likely incomplete. Elsewhere (e.g., the Caribbean; Sherry and Holmes 1996, Warkentin and Morton 2000, Reitsma et al. 2002), mangroves provide critical habitat for wintering species. Future research efforts in BCS should incorporate mist netting and banding outside the breeding season.

One hundred thirty-one species (representing 15 orders and 35 families) occur in association with the mangrove ecosystems of Bahía de La Paz, Bahía Magdalena, and the Laguna San Ignacio Complex. Sixty-six species have been documented at all 3 locations. The numbers of species documented at each of the 3 locations are not much different (Bahía de La Paz: 90 species; Bahía Magdalena: 104 species; Laguna San Ignacio Complex: 89 species). The list is dominated by the Scolopacidae (19 species), Anatidae (19 species), Laridae (16 species), and Ardeidae (12 species). Many of the species recorded also occur away from mangroves.

Of the 22 species using mangrove plants as nesting substrate, 10 are herons or egrets (family Ardeidae; see further on). With respect to ardeids, one location in particular stands out: Estero El Conchalito in Ensenada de Aripes, Bahía de La Paz (Carmona et al. 1994). During 1986–1991, 10 different species were documented nesting in the local black, red, and white mangroves. Yellow-crowned night-herons (*Nyctanassa violacea*), snowy egrets (*Egretta thula*), and cattle egrets (*Bubulcus ibis*) all nested colonially in black mangrove, while small colonies of black-crowned night-herons (*Nycticorax nycticorax*) and great blue herons (*Ardea herodias*) nested in red mangrove. Of all these species, only the great blue heron uses other nesting substrates besides mangroves (Carmona et al. 1994).

Other species recorded nesting in mangroves of BCS consist of the double-crested cormorant (*Phalacrocorax auritus*), magnificent frigatebird (*Fregata magnificens*), white ibis (*Eudocimus albus*), bald eagle (*Haliaeetus leucocephalus*), clapper rail (*Rallus longirostris*), Virginia rail (*Rallus limicola*), white-winged dove (*Zenaida asiatica*), Xantus's hummingbird (*Hylocharis xantusii*), western scrub-jay (*Aphelocoma californica*), verdin (*Auriparus flaviceps*), mangrove warbler (*Dendroica petechia castaneiceps*), and house finch (*Carpodacus mexicanus*). The Xantus's hummingbird is largely endemic to BCS. The bald eagle, recorded nesting on mangroves at Bahía Magdalena, is federally listed as Endangered (*En Peligro de Extinción*) by the Mexican government (DOF 2002). The clapper rail and the Virginia rail are federally listed as Subject to Special Protection (DOF 2002). The clapper rail nests in moderate numbers in red mangroves at El Mogote and along Ensenada Aripes (Massey and Palacios 1994; R. Carmona, pers. comm.). One Virginia rail nest was recorded in 1988 in a red mangrove in Bahía de La Paz. The mangrove warbler, a subspecies of the yellow warbler (*D. petechia*), is the only bird in the Baja California peninsula that is restricted to mangroves.

Several reasons have been postulated for the lack of a distinct mangrove avifauna worldwide, and they center on habitat structure considerations. Compared to terrestrial forests, such as those in the tropics, mangrove stands have low structural diversity, but they are extremely dense, consisting of "canopies of glossy, tough green leaves covering numerous gnarled to erect stems emerging from an inter-connected tangle of above-ground roots bedded in soft wet mud" (Duke 2001: 258). There is no understory vegetation, a principal component of terrestrial ecosystems to which many bird species are adapted (Maurer et al. 1980; Bell and Whitmore 1997). Although the world's mangroves do not have their own distinct avifauna, many birds use mangrove habitats for foraging on insects, as safe roosts, and for avoiding extreme temperatures during the day (e.g., Strong and Johnson 2001). Mangroves provide critical nesting habitat for many avian species (e.g., Hilton et al. 2000), most notably in BCS for the mangrove warbler, but also for most herons and egrets.

Mammals

The bottlenose dolphin (*Tursiops truncatus*) uses mangrove waters as feeding areas (Acevedo 1991; Ballance 1992; Felix 1994; J. Urbán-Ramírez, pers. comm.). North of Bahía Magdalena, in the Santo Domingo Channel (Puerto Lopez Mateos), bottle-

Table 15.3. Avian species documented in mangrove ecosystems of Baja California Sur.

Order	Family	Scientific Name	Common Name[a]	Area[b]
Gaviiformes	Gaviidae	*Gavia pacifica*	Pacific loon +	BM
		Gavia immer	Common loon +	BM
Podicipediformes	Podicipedidae	*Podilymbus podiceps*	Pied-billed grebe	BLP
		Podiceps nigricollis	Eared grebe +	BLP
		Aechmophorus clarkii	Clark's grebe +	BM
		Aechmophorus occidentalis	Western grebe +	BLP, BM, SI
Pelicaniformes	Sulidae	*Sula dactylatra*	Masked booby	BLP, BM
		Sula nebouxii	Blue-footed booby	BLP, BM
		Sula leucogaster	Brown booby	BLP
	Pelicanidae	*Pelacanus erythrorhynchos*	White pelican +	BLP, BM, SI
		Pelacanus occidentalis	Brown pelican	BLP, BM, SI
	Phalocrocoracidae	*Phalacrocorax auritus*	Double-crested cormorant	BLP, BM, SI*
		Phalacrocorax penicillatus	Brandt's cormorant	BLP, BM, SI
		Phalocrocorax pelagicus	Neotropic cormorant	BM
	Fregatidae	*Fregata magnificens*	Magnificent frigatebird	BLP, BM, SI*
Ciconiiformes	Ardeidae	*Botaurus lentiginosus*	American bittern	SI
		Ixobrychus exilis	Least bittern +	SI
		Ardea herodias	Great blue heron +, Pr	BLP*, BM*, SI*
		Ardea alba	Great egret	BLP*, BM*, SI*
		Egretta thula	Snowy egret	BLP*, BM*, SI*
		Egretta caerulea	Little Blue heron	BLP*, BM*, SI*
		Egretta tricolor	Tricolored heron	BLP*, BM*, SI*
		Egretta rufescens	Reddish egret Pr	BLP*, BM*, SI*
		Bubulcus ibis	Cattle egret	BLP*, BM
		Butorides virescens	Green heron	BLP*, BM*, SI*
		Nycticorax nycticorax	Black-crowned night-heron	BLP*, BM*, SI*
		Nyctanassa violacea	Yellow-crowned night-heron +	BLP*, BM*, SI*
	Threskiornithidae	*Eudocimus albus*	White ibis	BLP*, BM*, SI*
		Plegadis chihi	White-faced ibis +	BLP
		Ajaia ajaja	Roseate spoonbill +	BM
	Ciconiidae	*Mycteria americana*	Wood stork +, Pr	BLP
	Cathartidae	*Cathartes aura*	Turkey vulture	BLP, BM, SI
Anseriformes	Anatidae	*Anser albifrons*	Greater white-fronted goose +	SI
		Branta bernicula	Brant +	BM, SI
		Anas platyrhynchos	Mallard +	BLP
		Anas acuta	Northern pintail +	BLP, BM, SI

(*continued*)

Table 15.3. Continued

Order	Family	Scientific Name	Common Name[a]	Area[b]
		Anas cyanoptera	Cinnamon teal +	BLP, BM
		Anas clypeata	Northern shoveler +	BLP, BM
		Anas strepera	Gadwall +	BM
		Anas americana	American wigeon +	SI
		Aythya valisineria	Canvasback +	SI
		Aythya americana	Redhead +	BM, SI
		Aythya collaris	Ring-necked duck +	SI
		Aythya marila	Greater scaup +	BLP, SI
		Aythya affinis	Lesser scaup +	BLP, BM, SI
		Melanitta perspicillata	Surf scoter +	BM, SI
		Melanitta fusca	White-winged scoter +	BM
		Bucephala albeola	Bufflehead +	BLP, BM, SI
		Mergus merganser	Common merganser +	BM, SI
		Mergus serrator	Red-breasted merganser +	BLP, BM, SI
		Oxyura jamaicensis	Ruddy duck +	BLP, BM, SI
Falconiformes	Accipitridae	*Pandion haliaetus*	Osprey	BLP, BM, SI
		Elanus leucurus	White-tailed kite +	BM
		Haliaeetus leucocephalus	Bald eagle P	BM*
		Circus cyaneus	Northern harrier +	BM, SI
	Falconidae	*Falco sparverius*	American kestrel	BLP, BM
		Falco columbarius	Merlin +	BLP
		Falco peregrinus	Peregrine falcon Pr	BLP, BM, SI
Gruiformes	Rallidae	*Rallus longirostris*	Clapper rail Pr	BLP*, BM, SI
		Rallus limicola	Virginia rail Pr	BLP*, BM
		Porzana carolina	Sora +	BM
		Fulica americana	American coot	BLP
Charadriiformes	Charadriidae	*Pluvialis squatarola*	Black-bellied plover +	BLP, BM, SI
		Charadrius vociferus	Killdeer	BLP^, BM, SI
		Charadrius wilsonia	Wilson's plover	BLP^, BM^, SI^
		Charadrius semipalmatus	Semipalmated plover +	BLP, BM, SI
		Charadrius alexandrinus	Snowy plover	BLP^, BM, SI^
	Haematopodidae	*Haematopus bachmani*	Black oystercatcher	BM, SI
		Haematopus palliatus	American oystercatcher	BLP^, BM^, SI^
	Recurvostridae	*Himantopus mexicanus*	Black-necked stilt +	BLP, BM, SI
		Recurvirostra americana	American avocet +	BLP, BM, SI
	Scolopacidae	*Tringa melanoleuca*	Greater yellowlegs +	BLP, BM, SI
		Tringa flavipes	Lesser yellowlegs +	BLP, BM, SI

		Tringa solitaria	Solitary yellowlegs	BM
		Catoptrophorus semipalmatus	Willet +	BLP, BM, SI
		Heteroscelus incanus	Wandering tattler +	BLP, BM, SI
		Actitis macularia	Spotted sandpiper +	BLP, BM, SI
		Numenius phaeopus	Whimbrel +	BLP, BM, SI
		Numenius americanus	Long-billed curlew +	BLP, BM, SI
		Limosa fedoa	Marbled godwit +	BLP, BM, SI
		Arenaria interpres	Ruddy turnstone +	BLP, BM, SI
		Arenaria melanocephala	Black turnstone +	BLP, BM, SI
		Calidris alba	Sanderling +	BLP, BM, SI
		Calidris minutilla	Least sandpiper +	BLP, BM, SI
		Calidris mauri	Western sandpiper +	BLP, BM, SI
		Calidris canutus	Red knot +	BM
		Calidris alpina	Dunlin +	BLP, BM, SI
		Limnodromus griseus	Short-billed dowitcher +	BLP, BM, SI
		Limnodromus scolopaceus	Long-billed dowitcher +	BLP, BM, SI
		Phalaropus fulicaria	Red phalarope +	BLP, BM, SI
	Laridae	*Larus atricilla*	Laughing gull +	BLP, BM
		Larus philadelphia	Bonaparte's gull +	BLP, BM, SI
		Larus heermani	Heermann's gull Pr	BLP, BM, SI
		Larus delawarensis	Ring-billed gull +	BLP, BM, SI
		Larus californicus	California gull +	BLP, BM, SI
		Larus argentatus	Herring gull +	BM
		Larus livens	Yellow-footed gull Pr	BLP, BM, SI
		Larus occidentalis	Western gull	BM, SI
		Larus hyperboreus	Glaucous gull +	BM
		Xema sabini	Sabine's gull +	SI
		Sterna maxima	Royal tern	BLP, BM, SI
		Sterna elegans	Elegant tern Pr	BLP, BM, SI
		Sterna caspia	Caspian tern +	BLP, BM, SI
		Sterna forsteri	Forster's tern +	BLP, BM, SI
		Sterna antillarum	Least tern +, P	BLP^, BM, SI
		Rynchops niger	Black skimmer +	BLP, SI
Columbiformes	Columbidae	*Zenaida asiatica*	White-winged dove	BLP*
		Zenaida macroura	Mourning dove	BLP
Strigiformes	Strigidae	*Bubo virginianus*	Great-horned owl	SI
		Athene cunicularia	Burrowing owl	BLP, BM, SI
Caprimulgiformes	Caprimulgidae	*Chordeiles acutipennis*	Lesser nighthawk	BLP

(continued)

Table 15.3. Continued

Order	Family	Scientific Name	Common Name[a]	Area[b]
Apodiformes	Trochilidae	*Hylocharis xantusii*	Xantus' hummingbird	BLP*
		Archilocus alexandri	Black-chinned hummingbird +	SI
		Calypte costae	Costa´s hummingbird	BM
Coraciiformes	Alcedinidae	*Ceryle alcyon*	Belted kingfisher +	BLP, BM, SI
Piciformes	Picidae	*Melanerpes uropygialis*	Gila woodpecker	SI
Passeriformes	Laniidae	*Lanius ludovicianus*	Loggerhead shrike	BLP, BM, SI
	Corvidae	*Corvus corax*	Common raven	BM, SI
		Aphelocoma californica	Western scrub jay	BM*
	Alaudidae	*Eremophila alpestris*	Horned lark	BM, SI
	Remizidae	*Auriparus flaviceps*	Verdin	BLP*
	Mimidae	*Mimus polyglottos*	Northern mockingbird	BM, SI
	Motacillidae	*Anthus rubescens*	American pipit +	SI
	Parulidae	*Vermivora celata*	Orange-crowned warbler +	BM
		Dendroica petechia	Mangrove warbler	BLP*, BM*, SI*
		Seiurus aurocapillus	Ovenbird +	BM
		Seiurus novaboracensis	Northern waterthrush	BLP, BM, SI
	Emberizidae	*Amphispiza bilineata*	Black-throated sparrow	BM
		Passerculus sandwichensis	Savannah sparrow +	BLP, BM, SI
	Cardinalidae	*Passerina ciris*	Painted bunting +	BM
	Fringillidae	*Carpodacus mexicanus*	House finch	BLP*

Nomenclature follows the A.O.U. Checklist of North American Birds (American Ornithologists' Union 2000). Data are from Mendoza-Salgado (1983), Amador-Silva (1985), Wilbur (1987), Gutiérrez et al. (1989), Danemann and Guzmán-Poo (1992), Danemann and Carmona (1993), Carmona et al. (1994), Massey and Palacios (1994), Becerril and Carmona (1997), Page et al. (1997), and Howell et al. (2001), and the personal field notes of R. Carmona, R. Whitmore, R. Mendoza-Salgado, and E. Amador-Silva.

[a]+ migratory birds; P = species federally listed as in Danger of Extinction by the Mexican government (DOF 2002); Pr = species federally listed by the Mexican government as requiring Special Protection (DOF 2002).

[b]BLP = Bahía de La Paz; BM = Bahía Magdalena; SI = Laguna San Ignacio/Estero El Coyote/Estero La Bocana area; *species using mangroves as nesting substrate; ^ ground-nesting species.

nose dolphins are frequently seen in narrow channels among the mangroves. According to local fishermen, they search for mullets (*Mugil* spp.), moving in and out of mangrove waters with the tides. Bottlenose dolphins are also common near mangroves in Laguna San Ignacio (J. Urbán-Ramírez, pers. comm.). Numerous other marine mammal species are found in deeper waters that are energetically linked, but not adjacent to mangrove ecosystems, such as Bahía de La Paz or Laguna San Ignacio (Ballance 1992; Urbán-Ramírez et al. 1997).

On the terrestrial side, mangrove margins are visited by raccoons (*Procyon lotor*), coyotes (*Canis latrans*), badgers (*Taxidea taxus*), bobcats (*Lynx rufus*), and gray foxes (*Urocyon cinereoargenteus*) (Dedina 2000; R. Carmona, pers. comm.; R. Rodríguez-Estrella, pers. comm.). All of these species likely feed on mangrove-associated fauna, including crabs and birds, and perhaps also on the fruits of mangroves. Although their presence near mangroves has not been documented in BCS, the ring-tailed cat (*Bassariscus astutus*) and the spotted skunk (*Spilogale putorius*) might also visit these areas (R. Rodríguez-Estrella, pers. comm.).

Loss of Mangrove Vegetation in Baja California Sur

To date, the loss of mangroves on both coasts of BCS has been pronounced, but not as severe as that in other regions of the world, such as southeastern Asia or the Caribbean (Strong and Bancroft 1994; Colonnello and Medino 1998; Allen et al. 2001; Aube and Caron 2001; Mazda et al. 2002). As already mentioned, mangroves were used traditionally for tanning hides and for preparing remedies, and as fuelwood, charcoal, and construction material. Although not documented, the impact of some of these traditional uses was likely important in some areas (see Herrera-Silveira and Ceballos-Cambranis 2000). However, it pales in comparison with the wholesale clearing and destruction witnessed in recent decades and likely to continue in the future.

One probable cause of habitat loss, of historical interest, was the use of Bahía Magdalena as a gunnery range by the U.S. Navy during 1904–1910. The peak activity occurred when Theodore Roosevelt's "White Fleet," consisting of 28 coal-burning ships that included 16 of the largest battleships in the U.S. Navy, arrived in March 1908. "The fleet bombed the bay day and night" (Dedina 2000: 24–25). To this date, unexploded ordinance can still be found in the bay and its surrounding habitats. However, it is difficult to assess the level of mangrove destruction incurred at the time.

Before the completion of a paved Transpeninsular Highway linking Ensenada to the Cape Region, the Baja California peninsula remained fairly cut off from the U.S. and mainland Mexico. During parts of the year the gravel and dirt portions of the existing road were impassable due to flash flooding and lack of maintenance. The opening of the Transpeninsular Highway in 1973 transformed the situation of the peninsula. Immigration from other parts of Mexico and tourism both increased greatly, leading to the growth of cities such as La Paz, with associated clearing of mangrove stands (Carmona et al. 1994; see further on). Beach camping, once limited primarily to travelers arriving by air or sea, became very popular with American and Mexican tourists, and small recreational vehicle parks were created, among other places, within existing mangrove stands.

To a large extent, human impacts on BCS mangroves have been related to commercial and sport fishery and to tourism. In two towns, Puerto Aldofo López Mateos and Puerto San Carlos, several canneries with accompanying piers, and a large oil-fired power plant required taking out large portions of the original mangrove habitat in the Bahía Magdalena area. Although the local fishery is in decline (due to overfishing and probable reduced production from the mangrove stands; Holguín et al. 2001), human impacts are still seasonally important. Tourists descend on both Laguna San Ignacio and Bahía Magdalena each season (usually January through March) to watch chiefly gray whales (*Eschrichtius robustus*). As many as 10,000 people visit the area every year, spending an estimated 30 million dollars (Dedina 2000). Most people charter small pangas (flat-bottomed boats) to get an up-close look at adult whales and newborn calves. The result of this activity is localized fragmentation of mangrove stands to allow panga skippers access to the lagoon waters. Entryways, often 5–10 m wide, linking either dune or gravel areas to the bay, are cut into the fringe stands (the Puerto San Carlos area is notable in this regard). In addition, as part of a typical whale-watching tour, panga skippers take visitors on guided tours up the narrow inlets into the mangrove habitat for the purpose of bird and other wildlife observation. On occasion, new "inlets" are created by simply cutting away entire mangrove plants or harshly trimming overhanging branches.

An additional threat to mangrove habitat has begun to materialize. At the southeastern end of the Bahía Magdalena complex, a so-called experimental shrimp farm has been carved into the mangroves near Puerto Chale (24°25' N, 111°34' W), using the mouth of the Estero Grande Santa Rita. The declining native shrimp catch has, in other parts of the world, led to extensive shrimp aquaculture. Coastal mainland Mexico already has a large number of small to moderately sized shrimp farms, mostly in mangrove habitats (e.g., Cruz-Torres 2000; DeWalt et al. 2002). Some farms have been placed in mangrove habitats on the east coast of the Baja California peninsula and on the mainland across the Gulf from La Paz.

There is growing opposition to shrimp farming in coastal areas of Mexico. At the same time, shrimp farms are considered the country's "pink gold" and a key focus of Mexico's export-oriented fishing activity (World Rainforest Movement 2001). Shrimp aquaculture is a real threat to the mangrove ecosystems of the Baja California peninsula (Búrquez and Martínez-Yrízar 1997; Paez-Osuna 2001; chapter 3), especially since recent changes in land statutes have made it easier for foreign nationals to purchase property on the Baja California peninsula. *Ejidos* (see chapter 3) have recently been privatized, giving land title to the *ejido* leadership, allowing them to sell the land as needed (Dedina 2002). Recently, the Ejido Matancitas, which owns approximately 120 km of coastline in Bahía Magdalena, has offered to sell its land for the establishment of large shrimp farms (Dedina 2002). In addition to shrimp aquaculture, 2000 ha at Bahía Magdalena have been sold for construction of a planned resort (Dedina and Young 1995). The privatization of the *ejidos* has opened up BCS to unprecedented land grabs, placing coastal areas in jeopardy. Without strict conservation guidelines, mangrove fragmentation is likely to occur at an alarming rate in the coming years.

The growth of La Paz has already led to population declines of aquatic birds, in part due to the extensive loss of mangroves (Carmona et al. 1994; Becerril and Carmona 1997). Such development is likely to occur in other areas of BCS. In particular, the 1.6 billion dollar *Escalera Náutica* project will result in the construction of at least 22 new marinas and resort developments in coastal areas of northwestern Mexico (see also chapters 9, 11, and 16). To date, targeted areas on the peninsula include Punta Abreojos near the entrance to Laguna San Ignacio, Bahía San Juanico (Scorpion Bay) near the town of San Juanico (26°15' N, 112°29' W) between Laguna San Ignacio and Bahía Magdalena, and Punta Canoas, north of Guerrero Negro (27°58' N, 114°05' W). Construction has already begun on a new marina at Santa Rosalillita also north of Guerrero Negro (Wildcoast 2002). The main plan behind this project is to connect the Pacific and Gulf of California coasts via a series of new marinas and improved roads. Santa Rosalillita is to be connected to Bahía Los Angeles, where a dredge permit has been awarded and plans drawn up for a new 175-m long marina (S. Dedina, pers. comm.).

Loss of mangroves has been better quantified in some areas of mainland Mexico (e.g., Ruíz-Luna and Berlanga-Robles 1999) than in BCS. One exception is the long-term study in Ensenada de Aripes just west of La Paz (table 15.4). Between 1973 and 1981 there was an overall 21% loss in mangrove area cover. El Mogote lost 18% and El Zacatal lost 28% due to tourism development and the construction of a marina, respectively. El Conchalito (the site supporting 10 nesting ardeid species) lost more than 37% due to the construction of two schools, a radio station, a highway, and a sewage conduit (Mendoza et al. 1984). More recently, Estero de Enfermería (adjacent to El Conchalito) was completely destroyed (loss of 5 ha) due to the construction of a highway that blocked seawater access to the mangrove system. Another notable loss was the construction of the Pichilingue port expansion, along the eastern side of Bahía de La Paz (north of La Paz), which destroyed several mangroves in the 1970s. And losses potentially occur anywhere urban sewage waste contamination is present (Machiwa 1999).

Mulegé

An example of step-by-step deterioration of mangrove habitat is that of Mulegé. This small town (26°53' N, 111°58' W) is located just north of Bahía Concepción. It sits at the mouth of the Río Santa Rosalía de Mulegé (or Río Mulegé), along an *estero*. The Río Santa Rosalía de Mulegé is fed by natural springs. It represents one of the few year-round large sources of fresh water on the peninsula. It also forms a beautiful oasis, with stagnant waters and lush vegetation along the banks. Associated with the fresh water marsh are introduced date palms (*Phoenix dactylifera*), native plants such as a Mexican fan palm (*Washingtonia robusta*), 2 rushes (*Juncus mexi-*

Table 15.4. Change in area coverage of mangrove stands at Ensenada de Aripes, Bahía de la Paz, between 1973 and 1981.

Location, with Plants Represented	Area Coverage in 1973 (ha)	Area Coverage in 1981 (ha)	Area Loss (ha)	% Area Loss
El Mogote *Avicennia germinans* *Rhizophora mangle* *Laguncularia racemosa*	149.62	122.42	27.22	18.18
Zacatecas *Avicennia germinans* *Rhizophora mangle* *Laguncularia racemosa*	15.93	15.93	0.00	0.00
El Comitán *Avicennia germinans* *Rhizophora mangle* *Laguncularia racemosa* *Maytenus phyllanthoides*	6.88	1.23	5.65	82.12
El Zacatal *Avicennia germinans* *Rhizophora mangle* *Laguncularia racemosa* *Maytenus phyllanthoides*	16.48	11.84	4.64	28.15
El Conchalito *Avicennia germinans* *Rhizophora mangle* *Laguncularia racemosa*	18.13	11.38	6.75	37.23
Total mangrove area	207.03	162.78	44.26	21.38

Of the plants represented, *Avicennia germinans*, *Rhizophora mangle*, and *Laguncularia racemosa* are true mangroves; *Maytenus phyllanthoides* is a mangrove-like shrub on the landward side of the stands. Data are from Mendoza et al. (1984).

cana and *J. acutus*.), a mesquite (*Prosopis articulata*), and Goodding's willow (*Salix gooddingii*), and limited cultivars including citrus and mango (Grismer and McGuire 1993). The marsh area upriver from the dam is highly impacted by domestic cattle and pigs, which run freely and have trampled significant portions of the edge habitat (Whitmore and Whitmore 1997). The river has also been dammed, not to regulate the flow of fresh water, but to prevent saltwater inundation of the oasis during high tides and storms.

Formerly, both sides of the *estero*, as well as numerous small islands within the waterway, were heavily vegetated with mangroves from the coast to the cement dam. Early disturbance was limited to access channels cut for local fishermen. Later, backfilled gravel and dirt roads were built on both sides of the *estero*, removing a large percentage of the mangroves vegetation.

The heaviest impacts did not occur until after the completion of the paved Transpeninsular Highway, when Mulegé began to blossom as a tourist destination. An abundance of mangroves on the south side were removed, and the terrain was backfilled to about 3 feet above the high-tide zone in order to construct recreational vehicle (RV) parks (fig. 15.7). In addition, boat docks, used by residents of the RV parks, were installed and a cement boat ramp constructed. At the eastern end of the *estero* a hotel with a small aircraft landing strip was built and today receives extensive use. The construction of houses along the *estero* has led to mangrove loss. Secluded portions of mangrove areas have been cut out for use as latrines by construction workers. One island

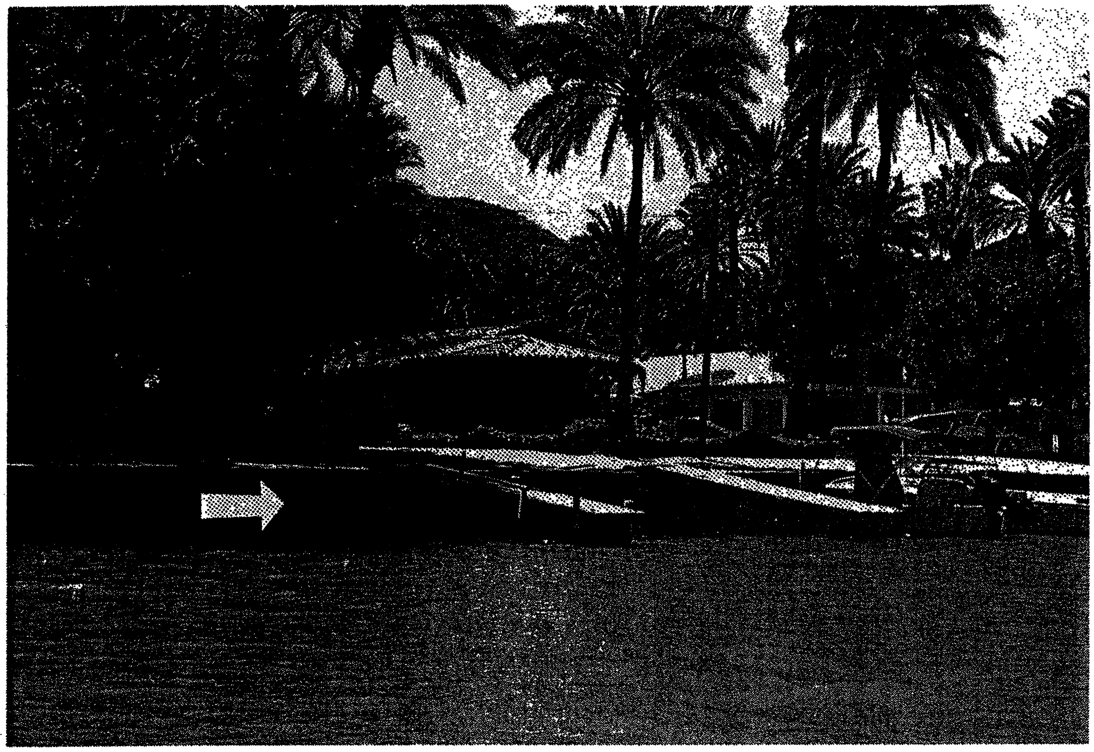

Figure 15.7. The south side of the *estero* at Mulegé, Baja California Sur, showing what was once a dense mangrove stand. The arrow points to a sea wall built during the construction of the original main north/south Transpeninsular Highway. The area has been backfilled and now that the paved version of highway has been completed and bypasses the area to the south, this location has been converted to a mobile home park with attendant permanent structures. Note that no mangroves appear in this photograph. (Photograph by Robert Whitmore, spring 2000.)

in the *estero* was clear-cut for the purpose of building a restaurant. Fortunately, the operation failed in the planning stages, and the island has partially revegetated (see below). Another island was similarly cut over to provide an area for pig grazing. Toward the western end of the *estero*, mangroves were severely pruned to allow residents of newly constructed homes to have a view of the water and boat access to it. These "single-trunk" red mangroves are destined to die since all prop roots have been removed. On the north side of the waterway similar removal has occurred. A small dirt road passes through the mangroves and leads to a restaurant on the sand beach at the eastern end of the *estero*. In addition, charter panga captains have cut passageways from the road to the water through the remaining fringe of mangroves. In sum, the remaining mangroves at Mulegé are only a small fraction of the original stands, and they are highly fragmented. Nonetheless, wildlife species, principally birds, use these fragments extensively. A small breeding population of mangrove warblers is present, and numerous species of wading birds nest or roost in the more isolated portions of the mangrove vegetation (Whitmore and Whitmore 1997; Whitmore et al. 1999). However, if development of the area is allowed to continue at its present rate, the future of the remaining mangroves is questionable.

Habitat Restoration

Historical data and recent studies suggest not only that mangrove fragmentation can be reversed, but also that new mangrove areas can be created where there were none before. In fact, it has been said that, "mangroves may be one of the easiest marine systems to reconstruct" (Kaly and Jones 1998: 656).

"Saline silviculture" has become the topic of an ever-widening body of literature (e.g., Teas 1982). Practiced since the eighteenth century, the planting, management, and harvesting of mangrove trees have become widespread, especially in some countries of the tropics such as Malaysia (Teas 1982). In Myanmar the planting of mangroves on previously clear-cut areas has been shown to be an economically feasible alternative to natural regeneration (Webb and Than 2000). A successful mangrove replanting program was initiated in Cuba in 1980, and by 1994 approximately 30,000 ha of mangroves had been restored (Menéndez et al. 1994). Mangrove areas were also established successfully in Hawaii (Cox and Allen 1999). Replanted mangrove habitat in the Philippines contained the highest shrimp densities of 4 microhabitats examined (Ronnback et al. 1999). And near La Paz in BCS, field-collected propagules of black mangrove have been successfully transplanted into a clear-cut zone at Laguna de Balandra, with 74% seedling survival after 2 years (Toledo et al. 2001).

Although mangrove stands may be easy to rehabilitate (Lugo 1998), they still require some attention, with a need also to actively manage the entire ecosystem (Christensen et al. 1996; Field 1999a,b; Ellison 2000), including biogeochemical pathways (McKee and Faulkner 2000). On the other hand, a uniform stand of replanted mangroves, especially if heavily managed, may actually provide less structural diversity and, hence, less species diversity than an unmanaged stand (Kumar 1999; Hsiang 2000). Fortunately, several nonprofit groups (e.g., Grupo Ecológico Manglar, Mangrove Replenishment Initiative) have taken an active role in mangrove conservation and creation in the United States and Mexico, with an emphasis on developing and defining a methodology for establishing self-sustaining mangrove stands.

Conclusions and Outlook

It should be noted that in Mexico, all mangrove species are protected by a variety of statutes including provisions under the General Law on Ecological Balance and Environmental Protection (see chapter 4). In the Mexican norm NOM-059-ECOL-2001, *Rhizophora mangle*, *Avicennia germinans*, *Conocarpus erecta*, and *Laguncularia racemosa* are all listed as Subject to Special Protection (DOF 2002). An environmental impact statement must be prepared for any proposed action requiring removal or alteration of mangrove habitat, and any outright destruction of mangroves is forbidden by law (Loza 1994; DOF 1999, 2002). [In 2004 the Mexican federal government substantially changed and relaxed the legal protection of mangroves, allowing clearing of mangroves against a fee or monetary compensation.—Ed.]

Also important is the fact that mangrove stands occur in at least 3 of the newly created biological reserves in BCS, Reserva de la Biósfera El Vizcaíno, Parque Nacional Bahía de Loreto, and Islas del Golfo de California. However, Mexican biological reserves suffer from a lack of law implementation and enforcement (see Suman 1994).

With the hope that tourism and shrimp export will boost the national economy, the government of Mexico will likely continue to sanction and devise plans that result in the destruction of mangrove ecosystems (World Rainforest Movement 1999), especially in areas that have strong drawing power (e.g., whale-watching sites). The *Escalera Náutica* project poses an enormous threat to mangrove ecosystems in the Baja California peninsula, although, to date, actual construction under this program has not impacted the key mangrove areas of La Paz, Bahía Magdalena, and the Laguna San Ignacio Complex.

Greater support for local conservation organizations is important. So is public education, with an emphasis on the role of mangroves in erosion prevention, land accretion, and ecosystem function. Mangrove systems should receive management priority and complete protection from disturbance. There has been some work on the Baja California peninsula on "reclaiming" disturbed habitats with native vegetation (Espejel and Ojeda 1995). Because of the ease with which disturbed mangrove habitats may be restored, a massive mangrove management and restoration program should even be initiated. It should be noted that regeneration of swamps and other habitats at the land–water interface is generally slow unless there is human assistance (Farnsworth et al. 1997).

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