Twenty-Six

Marine Fishes of the Upper Gulf Biosphere Reserve, Northern Gulf of California

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A book entitled *Dry Borders* does not immediately conjure up an image of fishes, let alone an image of hundreds of meter-long predatory ones churning the waters. One might not envision small, silvery fishes lining a wave-washed beach to bury their eggs in the sand either. Nonetheless, the northern Gulf of California counts among its inhabitants just such remarkable creatures, as well as a surprising array of other fishes. Fishes have played an important role in the economic development of the region and continue to fascinate and inspire those fortunate enough to visit the gulf and observe them firsthand. However, the marine region of the northern gulf has changed dramatically over the past several decades, and its fish communities are in danger of changing permanently; in fact, they have already begun to do so.

In June 1993 Mexico established the Reserva de la Biosfera del Alto Golfo de California y Delta del Río Colorado to protect the unique faunal assemblage of this region, with emphasis placed on two endemic and endangered species, the legendary totoaba and the vaquita, or Gulf of California harbor porpoise (Diario Oficial 1993). Total surface area of the reserve, including its marine portion and (greatly diminished) fresh- and brackish-water wetlands along with its adjacent desert lands, is 934,756 hectares, making it one of the largest biosphere reserves in Mexico. The reserve is divided into two areas (Figure 26.1). The nuclear, or core, zone *(zona nucleo)* includes the remaining wetlands of the lowermost Colorado River and the low mud islands and tidal channels of the river's now hypersaline estuary at the very head of the Gulf of California; its southern terminus is demarcated by a line connecting the fishing town of El Golfo de Santa Clara, Sonora, and the southern end of the Estero La Ramada, north of San Felipe, Baja California. Conservation of natural resources within the nuclear zone is purportedly complete, with no exploitative or extractive activities permitted. The second area, about 80 percent of the reserve and comprising mainly the marine waters and coastlines of the northernmost gulf, is a buffer zone *(zona de amortiguamiento)* extending southward of the nuclear zone to a line connecting Punta San Felipe (Punta Machorro), at the northern edge of the town of San Felipe, and Punta Pelícano (Punta Cholla, Roca del Toro), a few kilometers west-northwest of the town of Puerto Peñasco, Sonora. Certain kinds of regulated extractive activities (principally several types of fishing) are allowed within the buffer zone (INE 1995). Following an overview of the history of ichthyology in this extraordinary region, we present a summary of the marine fish fauna recorded from the biosphere reserve.

Ichthyology in the Northern Gulf of California

The study of fishes in the northern gulf had a relatively slow start. Though the deserts surrounding the gulf enjoyed a complex and storied history of scientific exploration, these same deserts effectively isolated the northern Gulf of California from early ichthyologists, most of whom apparently chose to forgo the rigors of the necessary overland expedition. Consequently, the early exploration of the northern gulf ichthyofauna was dominated by ship-based expeditions. Still, since the northern gulf was at the "end of the line," relatively few ships ventured as far north as the current biosphere reserve: there was no safe deepwater harbor or other major settlement in the region, and the conditions were often treacherous. Moreover, the southern and central portions of the gulf (e.g., Guaymas, Mazatlán, La Paz) were biologically fascinating and more accessible. Despite the deep regional knowledge of Native American peoples, such as

the Cucapás (Cocopahs), Quechans (Yumas), Hia C'ed O'odham (Sand Papagos), and Comcáac (Seris), the northern Gulf of California remained a frontier to the science of ichthyology until relatively recent times.

The first European explorers who ventured into the extreme northern gulf were usually in search of pearls, gold, or the Strait of Anián, a mythical seawater passage to the East Indies and (later) to Alta California (Bowen 2000; Flint & Flint 2005; Lindsey 1983; Ness 1993). Most published accounts of their expeditions rarely if ever mention fishes. Instead, the few early explorers who reached the delta of the Colorado River typically commented on the environmental extremes of the region, such as the summer heat, great tidal ranges (amplitudes), tidal bores, vast tidal flats, and shifting and treacherous channels, as well as the apparent paucity of life on the surrounding barren lands (Moriarty 1965; Sykes 1937). One of the earliest to mention fishes was Lt. Joseph C. Ives, commissioned by the U.S. secretary of war to survey the lower Colorado River for its potential for steamboat traffic, in the hope of opening up an aquatic supply line to mining and military camps upriver (e.g., Fort Yuma). In 1857 Ives reported that a retired ferryman had settled on the western side of the river's delta at "Robinson's Landing," just north of Isla Montague, to make oil from "black fish" that spawned there, possibly a reference to the dark-colored totoaba (Sykes 1937; Thurston 1973). If so, a settlement for harvesting the once abundant totoaba heralded the key role this species was to play in the region's economic development as the impetus for the establishment of fishing camps (later to become towns) at Punta Peñasco, El Golfo de Santa Clara, and San Felipe (Bahre et al. 2000; Munro-Palacio 1994).

The first scientific collection of fishes supported by a research vessel was a short excursion in 1881 into the northern gulf by the U.S. Coast and Geodetic steamer *Hassler,* captained by Lt. Henry E. Nichols. One 23-inch-long corvina (Sciaenidae) obtained at San Felipe was described as *Cynoscion othonopterus* by Charles Henry Gilbert, soon to figure prominently in North American ichthyology, and his mentor and colleague, David Starr Jordan, widely recognized as the father of American ichthyology. On opening the stomach of this single specimen, they found a recently ingested anchovy (Engraulidae) and also described it as a new species, *Stolephorus opercularis* Jordan & Gilbert, 1882, now considered a synonym of the common anchoveta, *Cetengraulis mysticetus* (Günther 1867).

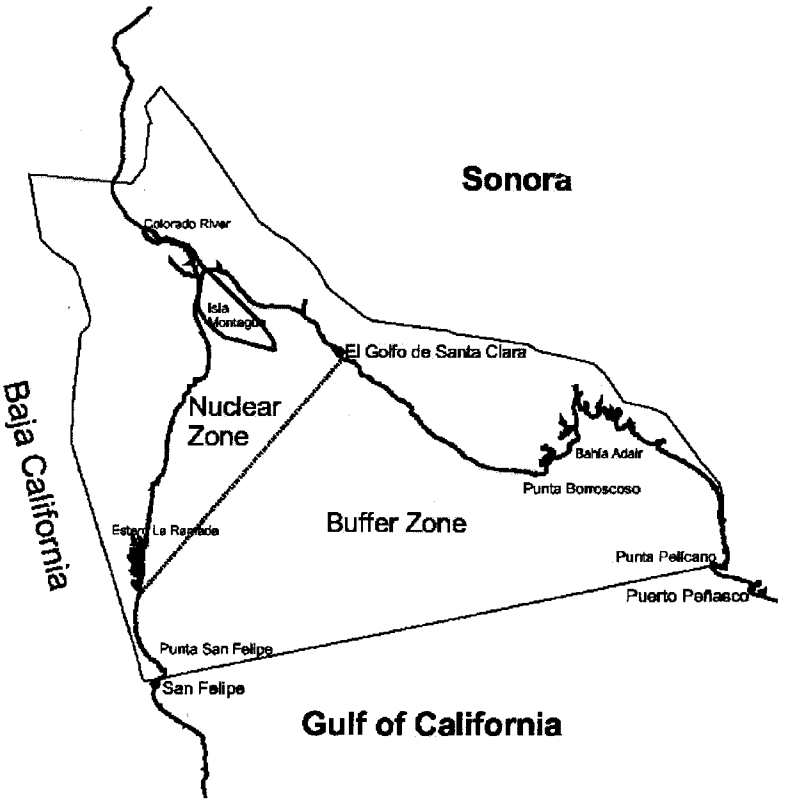

Figure 26.1. *The nuclear and buffer zones of the Reserva de la Biosfera del Alto Golfo de California y Delta del Río Colorado, northernmost Gulf of California. (Digitally prepared by N. Camacho)*

The first extensive collection of fishes in the extreme northern gulf was made by scientists and crew aboard the U.S. Fish Commission steamer *Albatross* (Figure 26.2). This legendary research ship was assigned to the Pacific coast in 1888 to study its environment and marine life. In the spring of 1889 the ship embarked from San Francisco to explore the coasts of southern California and western Mexico (Allard 1999). The *Albatross* first entered the Gulf of California on March 11, 1889, and reached the area now included in the biosphere reserve near the northeasternmost corner of the gulf on March 25. Unfortunately, the ship did not linger in the northern gulf, passing Rocas Consag on March 27 on its way southward. While at anchor, the crew of the *Albatross* typically fished from the ship with hand lines, and off "Shoal Point," near the mouth of the Colorado River, they caught large numbers of "squeteague" (corvinas, *Cynoscion* species, family Sciaenidae) and "sea bass" (probably *Totoaba macdonaldi,* also a corvina-like sciaenid). So many fish were caught, in fact, that

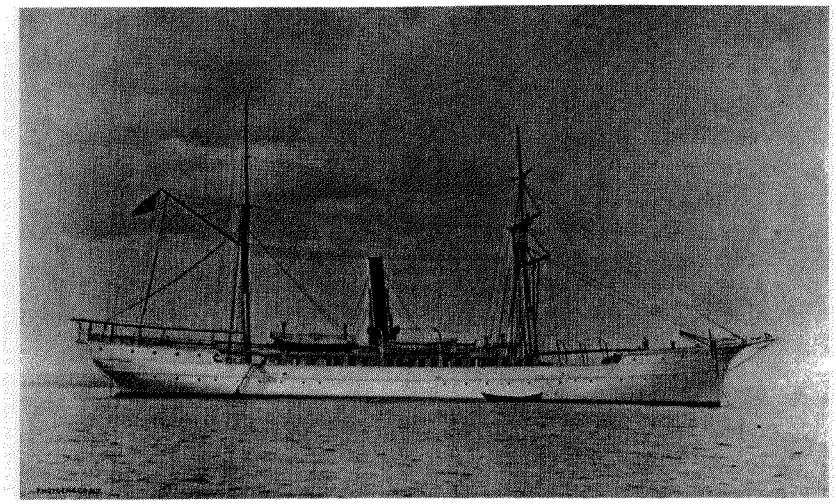

Figure 26.2. *The U.S. Fish Commission steamer* Albatross, *1896.*

the ship's commander felt "obliged to put a stop to the fishing" (Tanner 1892:440). The crew also collected using seines and gillnets, but Commander Tanner complained that "sharks and dogfish [likely smoothhounds of the genus *Mustelus* and the Pacific sharpnose shark, *Rhizoprionodon longurio*] were found throughout the gulf in sufficient numbers to make gill-net fishing impracticable" (Tanner 1892:440). During this cruise the *Albatross* made 22 dredge or trawl stations in the northern gulf (above 29° N latitude), although only 10 (stations 3023 to 3032) were above 31° N latitude (Tanner 1892) and thus in the current biosphere reserve.

The chief naturalist on board the *Albatross* at this time was the aforementioned great ichthyologist Charles Henry Gilbert (Figure 26.3), about whom the U.S. commissioner of fish and fisheries had written to Commander Tanner, "You will find Professor Gilbert an exceedingly agreeable man... one of the most accomplished ichthyologists of the present time... an experienced and enthusiastic collector" (Dunn 1997:270). Gilbert oversaw the field collections and later described the fishes collected from this and other *Albatross* cruises from this time period (e.g., Gilbert 1890, 1892; Gilbert & Scofield 1898). Species still considered valid that were described by Gilbert based on specimens collected from within the current biosphere reserve include a bewildering array of fishes: the corvina-like totoaba, *Totoaba macdonaldi* (Gilbert, 1890) (Sciaenidae); the spotfin cusk-eel, *Ophidion galeoides* (Gilbert, 1890) (Ophidiidae); the Cortez pipefish, *Syngnathus carinatus* (Gilbert, 1892) (Syngnathidae); the pennant goby, *Bollmania ocellata* (Gilbert, 1892) (Gobiidae); the squirrel sand perch, *Diplectrum sciurus* (Gilbert, 1892) (Serranidae); and the Cortez halibut, *Paralichthys aestuarius* (Gilbert & Scofield, 1898) (Paralichthyidae). In total, Gilbert described 20 new genera and 176 new species of fishes based on specimens collected during this gulf cruise and three other *Albatross* cruises off western North America (Dunn 1997), permanently establishing his place in the history of ichthyology of the eastern Pacific. In addition to the species described by Gilbert, the ocellated turbot, *Pleuronichthys ocellatus* (Starks & Thompson, 1910) (Pleuronectidae), and the Cortez stingray, *Urobatis maculatus* (Garman, 1913) (Urolophidae), were later described by others based on *Albatross* specimens collected in 1889 from the current biosphere reserve. The *Albatross* revisited the Gulf of California on other occasions, including an important cruise in 1911, but in this instance the ship turned back southward after passing Isla Ángel de La Guarda and thus did not enter the current biosphere reserve (Townsend 1916).

Relatively few other scientific vessels collected fishes in the extreme northern Gulf of California. One exception was the research yacht *Pawnee,* which visited the gulf in 1926 as part of a survey of fishes from Mexico to Panama for the private Bingham Oceanographic Collection of New York City (Moore & Boardman 1991). Charles Breder, of the New York Aquarium, reported on fishes from this cruise (Breder 1928a, b, c), describing as new *Urotrygon binghami* (Breder, 1928), now considered a synonym of the thorny stingray, *Urotrygon rogersi* (Jordan & Starks, 1895) (Urolophidae); the northern gulf anchovy, *Anchoa mundeoloides* (Breder, 1928) (Engraulidae); and a new genus of silversides in honor of Carl L. Hubbs, *Hubbsiella* (now considered a synonym of the grunion genus *Leuresthes,* Atherinopsidae), from specimens collected in the area of the current biosphere reserve. Subsequently, another anchovy, *Anchoviella parri* Hildebrand, 1943 (Engraulidae), was described from *Pawnee* specimens that had been collected at San Felipe in 1926. Interestingly, this mystery anchovy apparently has not since been collected, although Whitehead et al. (1988:324), based on the morphological characters provided by Hildebrand (1943), disputed its assignment to the genus *Anchoviella* and only briefly and rather enigmatically noted it as "an upper Gulf form of *A* [*nchoa*] *lucida,* perhaps a distinct species." Later Whitehead and Rodríguez-Sánchez (1995) evidently accepted it as a valid species, albeit again rather enigmatically,

in that "*Anchoa parri*" appears as such in their identification key to tropical eastern Pacific anchovies (pages 1068–71) and its accompanying table of morphological characters, but they failed to include it in their list of species present in the area (page 1072) and in their treatment of 23 regional anchovy species (pages 1073–87). Unfortunately, the untimely death of Peter J. P. Whitehead, the world's foremost authority on the systematics of anchovies, prevented his resolution of the taxonomic status of the mystery anchovy.

During the latter half of the twentieth century, most ship-based collection records for fishes from the biosphere reserve were from the bycatch associated with the shrimp trawling industry. One species, the Cortez butterfish, *Peprilus ovatus* Horn, 1970 (Stromateidae), was described based on specimens taken from shrimp trawls off El Golfo de Santa Clara and elsewhere in the northern gulf.

The offshore, trawl-based shrimp fishery in the gulf began under Japanese influence around 1921 and was centered at Guaymas (Hedgpeth & Ricketts 1978) until the 1940s and 1950s, when the fishery expanded to all exploitable areas of the gulf. The number of trawlers increased rapidly through the following decades to a peak of about 1,400 in 1983, declined to 1,144 in 1997, then increased again to 1,470 in 2000 (García-Caudillo & Gómez-Palafox in prep.). Collections of bycatch fishes from such bottom trawlers in the northern gulf were made in the 1940s and 1950s under the direction of Carl L. Hubbs (Scripps Institution of Oceanography [SIO]) and Boyd W. Walker (University of California Los Angeles [UCLA]) and in the late 1960s and early 1970s under the auspices of Donald A. Thomson and John R. Hendrickson (University of Arizona). Published accounts and theses documenting bycatch fishes of the northern gulf include Berdegué 1956, Castro-Aguirre et al. 1970, Guevara-Escamilla 1974, Romero 1978, Pérez-Mellado & Findley 1985, and Nava-Romo 1994. These studies are particularly important because they provide the only quantitative estimates of the offshore fish fauna of the northern gulf.

Land-based exploration of the marine waters of the extreme northern gulf was relatively difficult, owing to the lack of good roads into the region and difficulty in collecting along the soft and shifting shoreline. A few early collections, however, near the fishing camps of San Felipe and Punta Peñasco, included specimens of species new to science, such as the gulf anchovy, *Anchoa helleri* (Hubbs, 1921) (Engraulidae), collected at San Felipe by Edmund Heller in 1921. Other shore collections using mainly beach seines and gillnets were made during the 1940s to 1960s primarily in the San Felipe area by SIO and UCLA personnel under the guidance of Hubbs and Walker, in the early 1960s by students at California State University Long Beach (CSULB) under the tutelage of Arthur S. Lockley, and somewhat later by students in the Marine Science Program at the University of Arizona under the direction of Thomson.

Figure 26.3. *Charles Henry Gilbert (1891), legendary collector and describer of Pacific coast fishes. (Photo courtesy of Indiana University Archives)*

Thomson and his students began extensive studies of the biology of the northern gulf in 1964 (Thomson 1969). Their work, mainly on the Sonora side of the gulf, included a number of trips to El Golfo de Santa Clara, which led to a series of publications on the systematics, ecology, and behavior of the gulf grunion, *Leuresthes sardina*. Study of the rocky-shore fishes of the northern gulf by Thomson and his students was facilitated by establishment of field stations at Puerto Peñasco, first at a mostly open-air facility called Costa Azul and later at a more substantial installation located in the García House south of town, in the area known today as Las Conchas. A historically significant publication (Thomson & Lehner 1979), based on repeated quantitative samples from the extensive rocky tidepools near the field station (Figure 26.4), provides one of the earliest and indeed one of the only quantitative baselines for

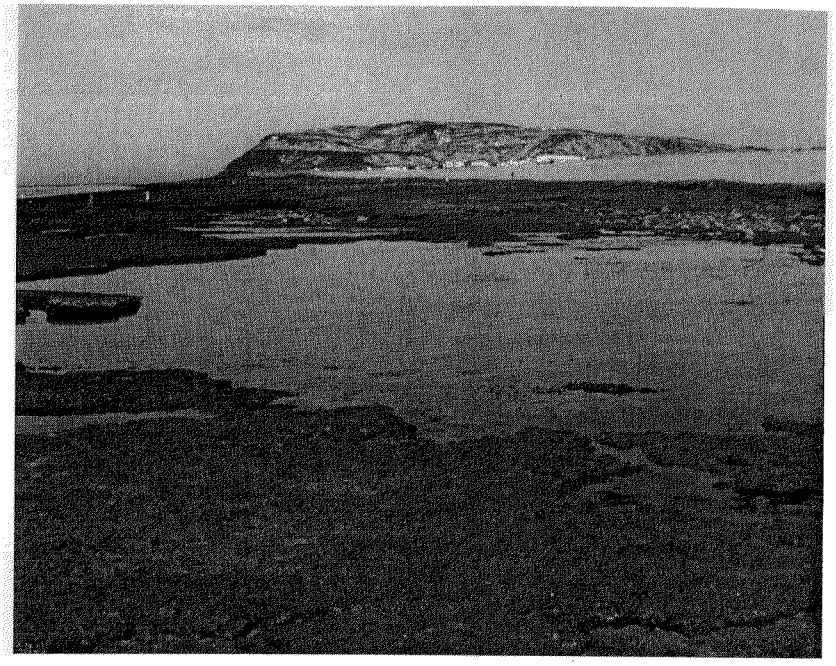

Figure 26.4. *Station Beach reef at Puerto Peñasco, 1966, the site of extensive samples of reef-associated fishes analyzed by Thomson and Lehner (1979). Punta Peñasco is seen in the background. (Photo by D. A. Thomson)*

species abundance of reef fishes in the northern gulf. These and other collections of fishes from throughout the gulf formed the basis of a popular guide to the common fishes of the gulf (Thomson & McKibbin 1976) and of the well-known *Reef Fishes of the Sea of Cortez* (Thomson et al. 1979, 2000). One of the most common intertidal species, the Sonora blenny, *Malacoctenus gigas* Springer, 1959, which is endemic to the gulf, was described based on specimens from the Puerto Peñasco area.

During the late 1960s and into the 1980s a colleague of Thomson's at the University of Arizona, John R. Hendrickson, was deeply involved in its Marine Science Program and, along with several students, carried out investigations on the biology of Gulf of California sea turtles and fishes. Hendrickson conducted pioneering work on the reproductive biology of the totoaba and was the first to attempt its aquaculture (Flanagan & Hendrickson 1976; Hendrickson 1979). The deep concern he and his American and Mexican colleagues had for the fate of this giant fish eventually led to the totoaba's official designation as an endangered species by both Mexico and the United States, the first marine fish accorded that status.

Apart from some additional research on the totoaba (e.g., see Cisneros-Mata et al. 1995 and references therein), including laboratory-based studies on captive individuals (Morales-Ortiz 1999; Ortiz-Viveros 1999), the most recent years have seen a general decline in ichthyological collecting and studies in the far northern gulf. However, observations on certain species continue to be made, principally by researchers at Mexican institutions such as the Ensenada campus of the Universidad Autónoma de Baja California (e.g., Gorgonio Ruiz-Campos and students) and, especially, the state of Sonora's Estación de Campo de El Golfo de Santa Clara of the Instituto del Medio Ambiente y del Desarrollo Sustentable del Estado de Sonora (IMADES). At the latter, important work on the northern-gulf endemic corvina, *Cynoscion othonopterus*, particularly its response to a relatively recently revived (but now apparently again declining) fishery, continues to be carried out by Martha Román-Rodríguez, assisted by her biologist husband, José Campoy-Favela, the administrative director of the biosphere reserve.

Fishes of the Alto Golfo Biosphere Reserve

We compiled a list of marine fish species recorded within the Alto Golfo Biosphere Reserve (see first checklist at end of this chapter) based on a database of all species of macrofauna known from the Gulf of California (Brusca et al. 2005; Findley et al. in press). Although the southern limit of the biosphere reserve's buffer zone extends from Punta San Felipe (Punta Machorro) to Punta Pelícano (Punta Cholla, Roca del Toro), just west-northwest of Punta Peñasco (Figure 26.1), we included all fishes taken in the vicinity of San Felipe, Baja California, and Puerto Peñasco, Sonora. This was deemed appropriate because older collection records commonly use the place-names *San Felipe* and *Puerto Peñasco* without precise details of locality. It also permitted us to take advantage of the extensive surveys of reef fishes done over several years at Station Beach (Figure 26.4), just east of Punta Peñasco (Thomson et al. 1979, 2000:Figure 3) by researchers from the University of Arizona (e.g., Thomson & Lehner 1979). Our species list is based on published systematic and other accounts of fishes from the region, unpublished records (e.g., Guevara-Escamilla 1974; Nava-Romo 1994), and surveys of holdings of natural history collections housing fishes from the region. Most important among these are the Scripps Institution of Oceanography (SIO) of the University of California San Diego, the University of California Los Angeles (UCLA), the University of Arizona (UAZ), and the Natural History Museum of Los Angeles

County (LACM), but collections at the Guaymas Campus of the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), the Mazatlán Unit of the Centro de Investigación en Alimentación y Desarrollo (CIAD-MAZ), and the Ensenada campus of the Universidad Autónoma de Baja California (UABC) were also surveyed. Records of the freshwater fish fauna in the lowermost Colorado River, recently reviewed by W. L. Minckley (1999, 2002) and Mueller and Marsh (2002), are not included here.

A total of 260 species of marine fishes have been recorded from within the waters of the biosphere reserve. This represents 29 percent of the approximately 908 species so far recorded from the Gulf of California (defined as extending from the delta region southward to Cabo San Lucas, Baja California Sur, on the peninsular side, and Cabo Corrientes, Jalisco, on the mainland side) (Findley et al. in press). One striking result of this compilation is the relatively high number of cartilaginous fishes recorded in the extreme northern gulf. The sharks, rays, and chimaeras (class Chondrichthys) of the gulf number 88 species, 46 of which (52 percent) have been recorded from the waters of the biosphere reserve. This finding may be attributed in part to the relative mobility of most cartilaginous fishes, coupled with the ample availability of suitable habitats in the northern gulf, which is dominated by the soft substrates occupied by most rays and many sharks. Also, reduction and eventual cessation of Colorado River flow into the northern gulf since the termination of construction of Hoover Dam in 1935 has almost certainly increased the likelihood of occurrence of strictly marine pelagic species (e.g., thresher and shortfin mako sharks), which might not be expected to occur in the relatively low-salinity, estuarine waters of the historical northern gulf. Because the sharks and rays of the gulf have come under intense fishing pressure in recent years (e.g., Applegate et al. 1993), the biosphere reserve has the potential to serve as an important refuge for these relatively long-lived and low-fecundity species, especially if commercial fishing for them can be better regulated or, preferably, eliminated from the reserve's buffer zone. However, an even larger protected area may be warranted, given the mobility of many of them.

The rich diversity of sharks and rays in the biosphere reserve stands in contrast to the relative paucity of marine ray-finned ("bony") fishes (class Actinopterygii). Although more species of ray-finned fishes have been recorded in the reserve (214), this number represents only 26 percent of the 817 ray-finned fish species known from the gulf (Findley et al. in press). This is partly the result of the relatively cold winter surface-water temperatures of the northern gulf, which, coupled with the relative scarcity of hard substrates, limit the number of tropical reef fish species in the region (Thomson & Lehner 1979; Walker 1960).

The fish fauna occupying the marine waters of the biosphere reserve is a particularly complex mixture of biogeographic elements (Walker 1960). It includes a number of eurythermal species widespread in the eastern Pacific; a number of tropical species also found farther south in the tropical eastern Pacific; several "northern disjuncts" (e.g., Figure 26.5), or species found both in the northern gulf and along the outer coast of the Baja California peninsula and in southern California but which are absent from the southern gulf (Bernardi et al. 2003; Huang & Bernardi 2001; Present 1987; Walker 1960); and several species endemic to the Gulf of California (Findley et al. 1999; Findley et al. in press; Walker 1960).

One gulf endemic, the delta silverside, *Colpichthys hubbsi,* has the distinction of being the only species of fish known solely from the biosphere reserve. Specimens of this species were first collected by Carl Hubbs, who recognized it as an undescribed species distinct from the related false grunion, *Colpichthys regis.* Hubbs intended to describe it with his graduate student and later long-time colleague from UCLA, Boyd Walker. Based on its unique morphology, they planned to place the new species in a new monotypic genus. However, as sometimes happens, they never completed their study, and the species was later formally described by Ben Crabtree (1989), then a student at UCLA, who placed it in the genus *Colpichthys,* based on both morphological and genetic data, and named it in honor of Hubbs in recognition of his discovery of the species. The delta silverside has been recorded only from the delta region of the Colorado River southward to San Felipe on the western side of the gulf and southward to El Golfo de Santa Clara on the eastern side. Its current status is unknown, but its restricted historical distribution implies that its life history was intimately tied to the former extensive estuary of the

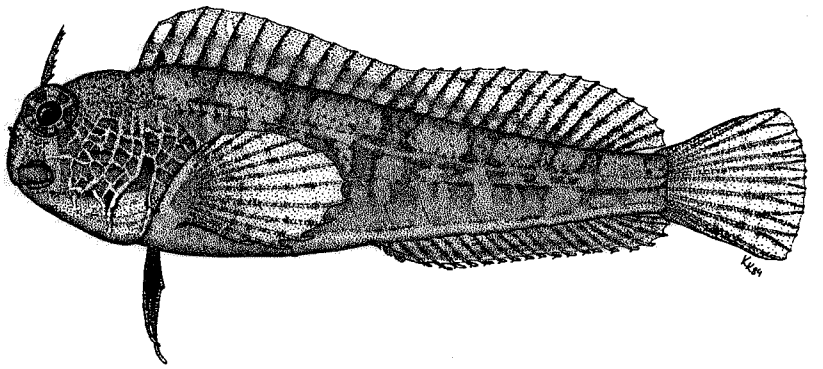

Figure 26.5. Hyposblennius gentilis, *the bay blenny, or* borracho de bahía, *family Blenniidae, a "northern disjunct" species, common on rocky reefs in the northern Gulf of California and in southern California. (Drawing by K. Kotrschal)*

Colorado River. Its numbers have undoubtedly declined since the cessation of flow from the river. Although we have been informed that Michael Horn and students at California State University Fullerton have recently collected and are studying a few specimens, the most recent published collections of *C. hubbsi* are from 1984 (Crabtree 1989), indicating that it persists in probably very low numbers in the biosphere reserve. Curiously, its presumed former abundance may have mirrored that of the delta clam, *Mulinia coloradoensis*, a species that was historically abundant in the delta's estuary but essentially absent just south of San Felipe; this clam was thought to be extinct until the recent discovery of a small remnant population at the mouth of the Colorado River channel (Rodriguez, Flessa, & Dettman 2001:Figure 4; Rodriguez, Flessa et al. 2001).

Ecological Components of the Fish Fauna of the Alto Golfo Biosphere Reserve

Soft-Bottom Fishes

The dominant ecological component of the Alto Golfo Biosphere Reserve ichthyofauna is associated with soft bottoms of sand and mud and includes representatives of several groups of fishes characteristic of both the continental shelf and shallow coastal bays and lagoons. Chief among them are the anchovies (Engraulidae), herrings (Clupeidae; Figure 26.6), New World silversides (Atherinopsidae), a variety of perciform fishes such as the corvinas and other croakers (Sciaenidae; Figure 26.7), the grunts (Haemulidae), and several groups of flatfishes or flounders (Pleuronectiformes). The dominance of soft-bottom fishes is not surprising given the fact that for millions of years the Colorado River deposited vast amounts of fine-grained sediments in the northern Gulf of California. Consequently, most of the marine area of the biosphere reserve is sand and mud, both along the coastal margins and along the gently sloping continental shelf on the northern margin of the relatively shallow Wagner Deep, the gulf's northernmost tectonic basin. Suspended sediment from the historical and unregulated Colorado River would have made the waters of the biosphere reserve extremely turbid much of the time. Even today they are usually turbid, but mainly as the consequence of resuspended sediment stirred from the bottom by powerful tidal currents (Baba et al. 1991; Carriquiry & Sánchez 1999).

Because the northern gulf, unlike the central and southern gulf, has a relatively extensive continental shelf habitat, many gulf fishes typical of this habitat have been reported from the biosphere reserve. The northern gulf also is ideal habitat for commercially targeted penaeid shrimps and has been extensively exploited by shrimp trawlers operating there for several decades (Galindo-Bect et al. 2000; Magallón-Barajas 1987). Many of our records of fishes from the biosphere reserve are from surveys of the shrimp bycatch, or *acompañante del camarón* (e.g., Guevara-Escamilla 1974; Nava-Romo 1994; Pérez-Mellado & Findley 1985;). The current status of most of these species is unknown, but the populations of most are probably greatly reduced from repeated and nearly unrelenting trawling in the region (Engel & Kvitek 1998; Nava-Romo 1994; Watling & Norse 1998).

Historically, the salinity regime of the northern gulf must have been extremely complicated. Springtime flows from the Colorado River would have turned the entire northern gulf into an estuarine system dominated by a large salt wedge (Lavín & Sánchez 1999). Salinity of northern gulf surface waters probably increased during periods of reduced river flow from summer to winter, but even then, portions of the relatively enclosed northern gulf, especially the delta region, must have been essentially estuarine in character most or all of the time. Consequently, it is not surprising that fishes able to tolerate wide ranges in salinity dominated the northern gulf ichthyofauna (Walker 1960) (Figure 26.8). Currently, the waters of the biosphere reserve are not estuarine in nature but are typically more salty (Bray & Robles 1991) than open ocean water (approximately 35 ppt). This is because the normally hot, dry deserts surround-

ing the northern gulf promote a rate of evaporation of seawater that is much higher than the rate of freshwater replenishment (Lavín et al. 1998). For example, at Puerto Peñasco, evaporation exceeds precipitation by as much as 3.15 meters per year, resulting in a net flow of water from the open ocean into the southern gulf and thence northward (Bray & Robles 1991). In essence, the gulf now acts as a huge straw, sucking water from the open Pacific and conveying it into the atmosphere over the surrounding deserts.

Estuaries are well-known spawning, nursery, and refuge areas for many fishes, but this key brackish-water habitat is now essentially missing from the upper gulf. Although the now hypersaline coastal lagoons *(esteros)* there still serve as important spawning and nursery sites for many fishes and other organisms, the effects of this change in habitat on estuarine-dependent fishes and other biota of the northern gulf certainly must have been great, but for the most part it can only be guessed at. This uncertainty exists because we have no quantitative estimates of the biotic communities of the northern gulf before the cessation of Colorado River input and generally no reliable way to recreate an appropriate baseline (see Rodríguez, Flessa, & Dettman 2001 and Rodriguez, Flessa et al. 2001 for an exception).

As noted by Walker (1960), typically intertidal (littoral) fishes are uncommon in the extreme northern gulf, especially along sandy and muddy coastal areas. This is not surprising since the region experiences some of the largest tidal ranges known on the planet, with maxima of more than seven meters near the mouth of the Colorado River (Lavin et al. 1998; Maluf 1983; Matthews 1968; Roden 1964). Because the bottom gradient is very slight in the extreme northern gulf, these enormous tidal changes expose vast mud and sand flats that stretch seaward for up to five kilometers (Maluf 1983), conditions that few fish species can tolerate. Notable exceptions include species adapted to environmental extremes such as the mudsucker gobies (*Gillichthys* spp.), which can survive in the shallow, poorly oxygenated tidal channels or burrow into the mud during low tides (Barlow 1961, 1963; Todd & Ebeling 1966).

Reef Fishes

With the exceptions of rocky headlands at the southern margins of Puerto Peñasco and San Felipe, the shoreline of the Alto Golfo Biosphere Reserve is almost exclusively sand or mud. Important rocky outcrops of volcanic and coquina (beachrock) origins include Punta Borrascoso at the northwestern corner of Bahía Adair (Figure 26.1), the northernmost rocky reef in the gulf (Thomson et al. 1979:Figure 2), and the areas around San Felipe and Puerto Peñasco (Figure 26.4). These areas harbor a relatively abundant, if not species-rich, reef-fish fauna (Thomson & Lehner 1979). However, another factor limiting reef-fish diversity in the northern gulf is the relatively cold winter temperatures of its surface waters, which can be lethal to tropical species (Heath 1967; Thomson & Lehner 1979; Walker 1960). Interestingly, a few hardy reef fishes reach their greatest abundance in the seemingly inhospitable northern gulf, including the aptly named Sonora goby, *Gobiosoma chiquita;* the Sonora blenny, *Malacoctenus gigas;* and the Sonora clingfish, *Tomicodon*

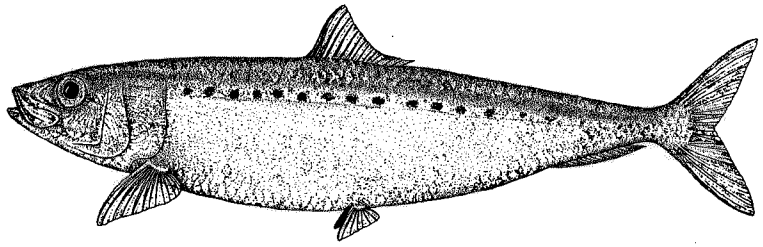

Figure 26.6. Sardinops caeruleus *(or* Sardinops sagax caeruleus*), the North Pacific sardine, or* sardina monterrey, *family Clupeidae, a commercially important pelagic herring common in the Alto Golfo Biosphere Reserve. (Drawing by T. Hansen)*

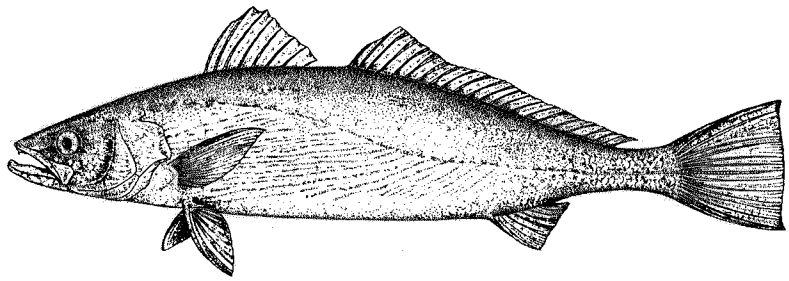

Figure 26.7. Cynoscion parvipinnis, *the shortfin corvina, or* corvina aleta corta, *family Sciaenidae, a popular foodfish common in the northern Gulf of California. (Drawing by T. Hansen)*

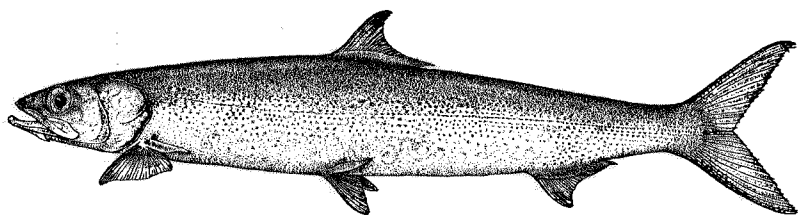

Figure 26.8. Elops affinis, *the* machete, *family Elopidae, one of the few marine fishes that historically frequented the lower Colorado River system, having been recorded far upriver in southwestern Arizona and in the Salton Sea of California. (Drawing by T. Hansen)*

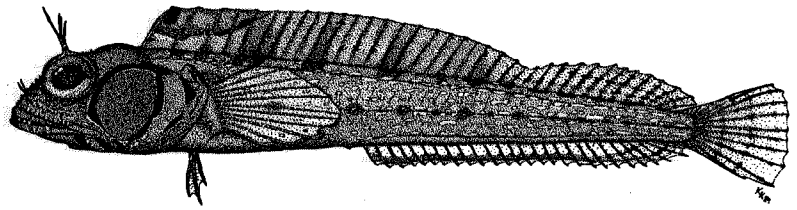

Figure 26.9. Acanthemblemaria crockeri, *the browncheek blenny, or* tubícola cachetón, *family Chaenopsidae, a Gulf of California endemic recorded from reefs at Isla San Jorge but not yet known to occur in the Alto Golfo Biosphere Reserve. (Drawing by K. Kotrschal)*

humeralis. Still, reef fishes make up a relatively small component here compared with more southerly regions of the gulf, where rocky reefs are dominant, winter temperatures are warmer, and reef fishes are significantly more diverse (Thomson et al. 1979, 2000).

A few species of reef fishes not known from the biosphere reserve have been recorded from the nearby Isla San Jorge, Sonora, and Rocas Consag, Baja California (see second checklist at end of chapter). Both of these rocky islands are outside the southern boundary of the current biosphere reserve but are under consideration for inclusion in an expanded reserve buffer zone. Although only 14 "new" species of fishes would be added to the fauna of the biosphere reserve (e.g., Figure 26.9), inclusion of these islands would protect more abundant and more diverse assemblages of reef-associated species than are present on the adjacent mainland reefs within the biosphere reserve (Thomson & Gilligan 1983).

Pelagic Fishes

A surprisingly large number of species of pelagic (open-water) fishes have been recorded from the Alto Golfo Biosphere Reserve. This diversity may be unnaturally high as a consequence of the reduced freshwater input to the northern gulf. Historically, species such as thresher sharks and sailfish were probably rarely if ever present in the low-salinity waters of the northern gulf. Because of the present-day relatively high salinity of the biosphere reserve's marine portion, virtually any pelagic fish species in the gulf may be an occasional visitor to the area.

A Comment on Freshwater Fishes

Nine species of native freshwater fishes are known from the main stream of the lower Colorado River, and eight have been recorded from the waters of the delta region (Minckley 1999, 2002; Mueller & Marsh 2002): four species of minnows (Cyprinidae), two species of suckers (Catostomidae), one species of pupfish (Cyprinodontidae) and one species of livebearer (Poeciliidae). As a consequence of extensive human-induced changes to the region's physical and biological environment, all these fishes are now absent or extremely rare in the lower Colorado. Two that are present (bonytail, *Gila elegans,* and razorback sucker, *Xyrauchen texanus*) owe their sparse occurrence to recent restocking efforts. A third species, the amazingly adaptable but nonetheless endangered desert pupfish, *Cyprinodon macularius macularius,* persists in a few small isolated spring-fed ponds and irrigation ditches marginal to the regionally important Ciénega de Santa Clara wetland (where it also occurs) and in shallow ponds of residual waters of the Cerro Prieto Geothermal Station near the greatly reduced headwater of the Río Hardy, once the major tributary of the Colorado River in the delta region (Minckley et al. 2001; Varela-Romero et al. 2002; see also Glenn & Nagler, this volume). None of these marginal habitats lies within the nuclear (core) zone of the biosphere reserve. Sadly, in place of the native fish fauna is a bewildering array of 38 introduced fish species (Minckley 1999, 2002; Mueller & Marsh 2002), for "the Lower Colorado River has the dubious distinction of being among the few major rivers of the world with an entirely introduced fish fauna" (Mueller & Marsh 2002:2). Even one of the limited success stories, the occurrence of the desert pupfish in the Ciénega de Santa Clara (Glenn et al. 1992, 1996; Zengel & Glenn 1996), is threatened by increased demands for the limited freshwater that supplies this fragile wetland (Glenn et al. 2001; see also Glenn & Nagler, this volume). Indeed, "the future is grim for native fish in the Lower Colorado River" (Mueller & Marsh 2002:65).

Two Remarkable Fishes from the Alto Golfo Reserve

Totoaba

The best-known fish in the northern Gulf of California, and deservedly so, is the totoaba, *Totoaba macdonaldi,* a giant member of a speciose family of sandy-shore fishes (Sciaenidae) that thrives in estuarine conditions. This gulf endemic was one of the first species described from the region (as *Cynoscion macdonaldi*) by Charles Henry Gilbert in 1890, based on specimens collected near the mouth of the Colorado River aboard the *Albatross.* It is one of the largest fishes in the gulf (Fig-

ure 26.10) and was at one time a dominant member of the northern gulf ichthyofauna. In the original description Gilbert wrote:

> This species is very abundant along the entire eastern shore of the gulf of California, and congregates in great numbers near the mouth of the Colorado River. It enters the rivers and is found in shallow water near the shore, where it is easily approached and speared. At the head of the Gulf it is known as the sea basse, while in the vicinity of Guaymas it... goes by the native name of "Totuava." It does not seem to be known at La Paz, and was not seen by us on the western side of the gulf. Many specimens were taken by hand-lines at the head of the Gulf, the largest weighing 172 pounds. Large specimens were also seen at Guaymas and at the mouth of the Rio del Fuerte. (Gilbert 1890:65)

Much has since been written about this impressive fish, the largest member of a diverse, worldwide group of fishes, the drums, croakers, and corvinas of the family Sciaenidae, which includes many important food fishes. Although the abundance of this species has declined markedly, the ecological and historical importance of the totoaba in the northern gulf should not be underestimated. In the past, adults and large juveniles *(machorros)* must have played a key role as top trophic-level predators (e.g., Román-Rodríguez 1990). Eggs, larvae, and small juveniles, generated in vast numbers from the totoaba's massive spawning aggregations, which historically may have occurred from January to June (Flanagan & Hendrickson 1976), must have also been key components in the food web of the northern gulf. The totoaba fishery, expanding northward from Guaymas, was largely responsible for the initial settlement of San Felipe, Puerto Peñasco (Bahre et al. 2000; Huey 1953; Munro-Palacio 1994), and, later, El Golfo de Santa Clara in the delta region. Ironically, these fishing villages were established before the development of the infrastructure (refrigeration and paved roads) ideally needed to get whole fishes or their fillets to market (Figure 26.11). Totoaba, like most other sciaenids, bear a large gas bladder used to regulate buoyancy and to generate sounds via special "drumming" muscles in males (Fish & Mowbray 1970). These bladders from sciaenids were (and are) highly sought after, especially in the Far East, where they are used as stock for special soups. Called *buche* in Sonora, these bladders were the "pearls" of these marvelous animals, attracting the attention of Asian traders and thus the attention of gulf fishermen. The early totoaba fishery exported only the *buches,* which, after removal from the fish, were dried and shipped to the Far East via the port of Guaymas. Some of the flesh was eaten locally, but most was simply discarded until mobile refrigeration made it possible to ship totoaba to markets in the southwestern United States, where demand grew quickly (Bahre et al. 2000; Chute 1928). The reported catches of totoaba peaked in 1938 and 1942 but then declined precipitously (Arvizu & Chávez 1972; Cisneros-Mata et al. 1995; Flanagan & Hendrickson 1976). This decline has been mainly at the hands of the intensive fishery, especially the effective gillnet fishery that operated during the totoaba reproductive season, as well as the high incidental mortality of juveniles in shrimp trawls (Barrera-Guevara 1990; Flanagan & Hendrickson 1976; Ortiz de Montellano 1987). In addition, the spawning

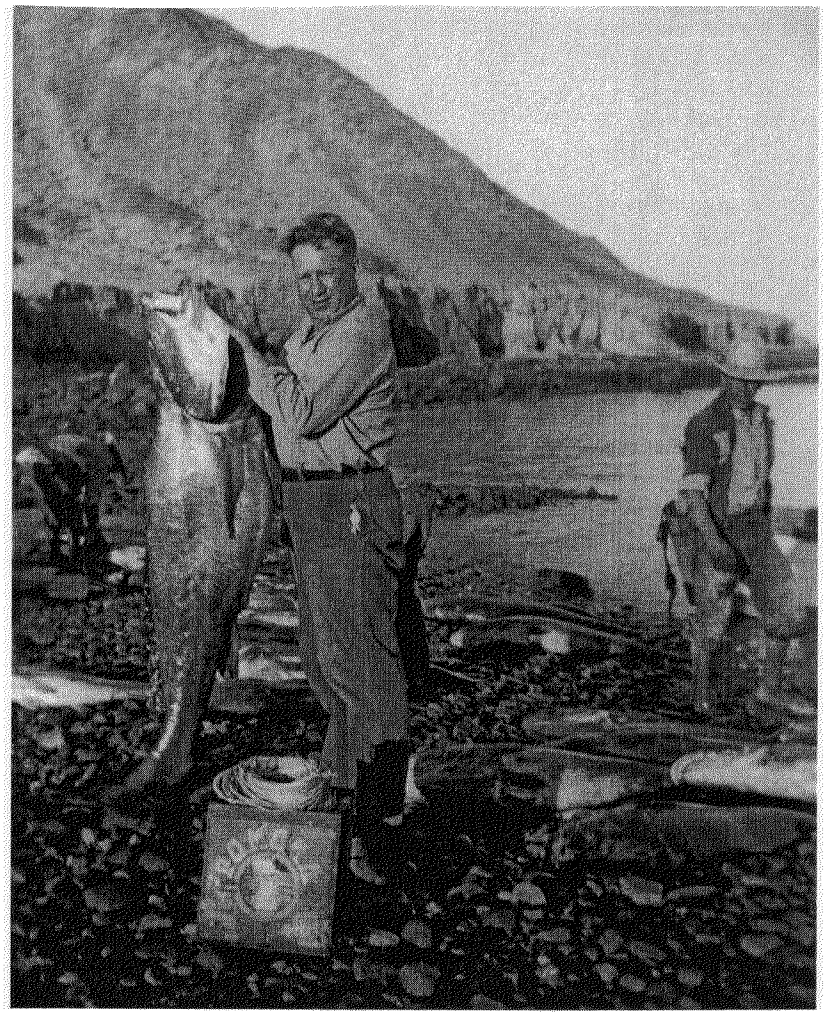

Figure 26.10. Totoaba macdonaldi *catch at San Felipe, 1938. (Photo provided by J. Seminoff)*

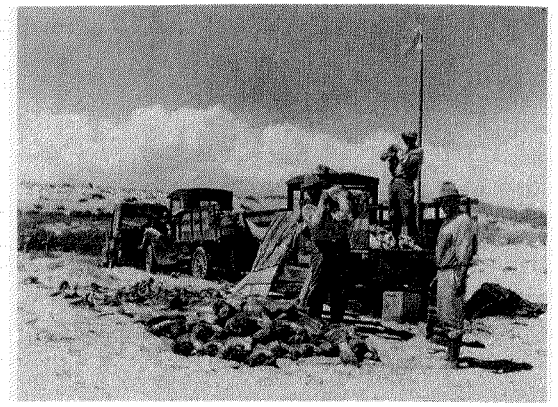

Figure 26.11. Trucks being loaded with totoaba carcasses for transport to southern California, near San Felipe, 1926. (Photo by L. M. Huey)

and nursery area of this species was radically altered by dam builders along the Colorado River. Even the brief flow from the Colorado River into the gulf during the relatively wet year of 1983 stimulated a significant recruitment pulse for the totoaba (Cisneros-Mata et al. 1995). All indications are that this long-lived and highly fecund species could recover if illegal fishing were to stop and if the environment of the northern gulf were returned, even sporadically, to its former "estuarine" conditions (Román-Rodríguez & Hammann 1997).

Because of the precipitous decline in the fishery, the Mexican government placed a total ban on the capture of totoaba in 1975. In 1976 it was placed on the endangered list of the Convention on International Trade in Endangered Species (CITES); in 1979 it was added to the U.S. Endangered Species list (Barrera-Guevara 1990; Lagomarsino 1991), where it remains (Musick et al. 2000). The marine portion of the Alto Golfo Biosphere Reserve was established in part to protect the totoaba and another gulf endemic species, the critically endangered vaquita, or Gulf of California harbor porpoise, *Phocoena sinus* (Flores-Skydancer & Turk Boyer 2002; Gallo-Reynoso 1998; Navarro, this volume; Rojas-Bracho & Taylor 1999; Vidal et al. 1999). The aquaculture work on totoaba begun by John Hendrickson has recently been brought to fruition with the successful laboratory rearing and spawning of this important fish by researchers led by Conal David True at the Ensenada campus of the Universidad Autónoma de Baja California, leading to restocking of small totoabas in the northern gulf. Enforcement of fishing restrictions within the biosphere reserve will remain a key feature in the recovery of this and other large species of sciaenids in the northern gulf ecosystem, such as the equally impressive Gulf corvina, *Cynoscion othonopterus*. This species, about which we know relatively little, also appears to be in renewed decline (Cudney-Bueno & Turk Boyer 1998; Román-Rodríguez et al. 1998).

Gulf Grunion

A particularly remarkable intertidal visitor to beaches of the Alto Golfo Biosphere Reserve is the gulf grunion, *Leuresthes sardina*, a member of the New World silverside family Atherinopsidae. This is an extraordinary fish, magnificently adapted to the extreme environmental conditions of the northern gulf. What happens to gulf grunion during most of their lives as "normal" subtidal fishes is completely unknown. But, unlike the case for most gulf fishes, we know a great deal about their reproductive behavior because spawning occurs in the intertidal zone. At very predictable intervals in the spring and early summer along sandy beaches of the northern gulf such as those near El Golfo de Santa Clara, gulf grunion gather to engage in a most unusual spawning behavior, called a "grunion run" (Moffatt & Thomson 1975; Reynolds & Thomson 1974; Thomson & Muench 1976). Unlike their close relative, the California grunion, *L. tenuis*, which runs only at night, gulf grunion can run either during daylight hours or at night, depending on tidal conditions. Predictions of gulf grunion runs were included in the tide calendar for the northern Gulf of California (Thomson 2002) for a single year (1977), but the practice was stopped because of concerns about overexploitation of this vulnerable fish during its runs (D. A. Thomson, personal communication 2002).

A grunion run begins when hundreds to thousands of these fish closely approach the shore's surf line, an event signaled by congregating pelicans and seagulls feeding near the shore. The first direct sign of a run occurs when a few isolated males begin riding small waves shoreward onto the beach. Slowly, almost imperceptibly, the number of fish in the wave wash on the beach grows and swells until a ribbon of writhing, mostly male fish marks the receding tide line (Figure 26.12). Then the females, heavy with eggs, begin their dash onto shore, quickly burying the posterior part of their bodies in the wet sand with rapid and vigorous tail beats and depositing a small clutch of eggs a few centimeters under the surface. These nearly vertical females are at once encircled by one or sometimes two or three males, which release

sperm that flows down the female's sides and fertilizes the eggs below (Figure 26.13). The females then dash back to the water while the males remain on the beach to spawn with other nearby females. This remarkable behavior, accomplished at the precise and propitious moment in the ebb and flow of northern gulf tides, ensures that the eggs will remain "safely" buried in moist sand for their developmental period of about two weeks. In the next tidal series, when the waves again reach that level of the beach, they moisten, expose, and agitate the eggs, stimulating them to hatch and launching the newborn larvae on the first stage of their otherwise unknown life in the gulf.

Grunion runs are still a common seasonal occurrence in the northern gulf, and small ones have been recorded even as far south as Bahía Bacochibampo at Guaymas. Unfortunately, we have little information on the historical distribution and abundance of this species and can only speculate that it, like other fishes characteristic of the northern gulf, may have suffered from the extreme changes in its environment. On the other hand, gulf grunion may be more abundant than they were historically, given the unfortunate population declines of such dominant piscivores of the northern gulf as the totoaba and related sciaenid fishes.

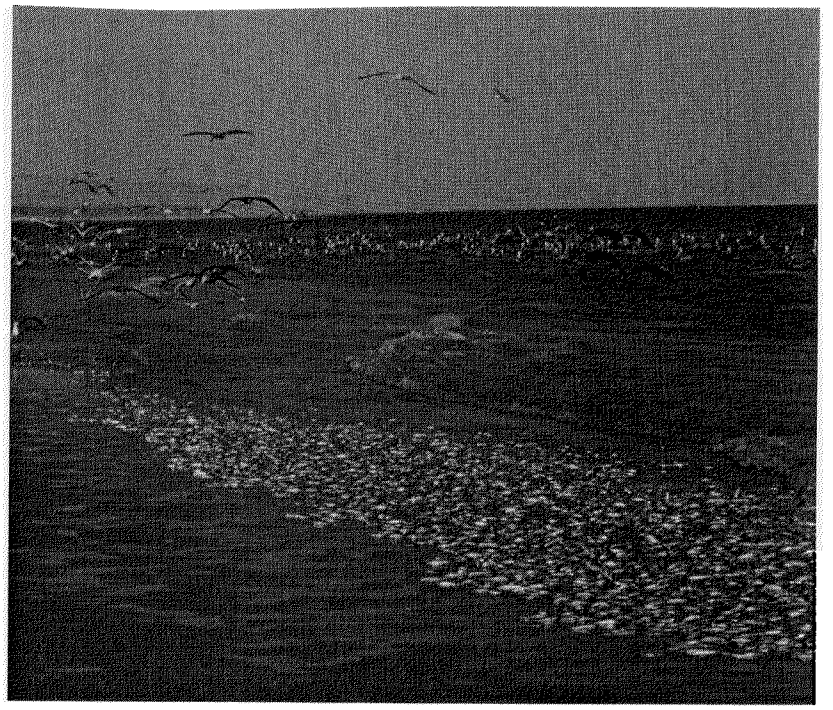

Figure 26.12. *A daytime grunion run, El Golfo de Santa Clara, 1998. (Photo by D. A. Thomson)*

Summary

Our survey of the literature and natural history collections for species of marine fishes recorded from the Alto Golfo Biosphere Reserve of the far-northern Gulf of California revealed a surprisingly large number of species. Although the reserve is relatively small and constitutes the most environmentally extreme part of the gulf, the 260 species recorded there represent approximately 29 percent of all fish species recorded from the entire Gulf of California. It should be noted that this list is necessarily inflated compared with the number of species that may be found in the reserve at any one time. Our list is based on the aggregate records for the entire history of scientific collecting in the gulf and includes many species not normally or only seasonally found there. Because the reserve is open to the remainder of the gulf, temporary occurrence there is possible for many other gulf fishes. Marine fishes are notoriously mobile, being able to disperse passively as eggs or larvae with ocean currents and in many cases actively as swimming juveniles or adults. Also, our list may not exactly reflect the species composition that occurs there today because the ecosystem of the northern gulf has been extensively altered via the cessation of flow from the Colorado River and the nearly relentless bottom trawling for shrimps over the past several decades. The impacts of these changes remain largely unknown, but it may be safely assumed that the fauna today is quite different from what it was even sixty years ago. Certainly the image of the commander of the *Albatross* putting an end to fishing at the mouth of the Colorado River because his crew had caught too many large fishes seems incredible today. The most hopeful signs for the future are the conservation measures already in place and those evolving as a consequence of the establishment of the Alto Golfo Biosphere Reserve, along with their strict enforcement. These measures are key components in the protection of the unique assemblage of fishes that characterizes the northern Gulf of California.

Acknowledgments

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Figure 26.13. *Spawning gulf grunion, or* pejerrey sardina, Leuresthes sardina, *during a night run, El Golfo de Santa Clara, 1985. Note erect female* (near center) *with encircling males. (Photo by D. A. Thomson)*

Donald Thomson provided illustrations and granted permission for their use. Nohemi Camacho digitally prepared Figure 26.1. We thank W. Linn Montgomery for reviewing and improving an earlier draft of this chapter. Funding for the Macrofauna Golfo database project was initially provided by the Mexican government's Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) and by several other organizations via Conservation International's Región Golfo de California Program in Guaymas. The latter continues to support the project, for which we especially thank María de los Ángeles Carvajal and Alejandro Robles. Over the years Donald A. Thomson and the late John R. Hendrickson provided encouragement and numerous opportunities for us and many other researchers to explore the biology of the Gulf of California.

Annotated Checklist of Marine Fishes recorded in or immediately adjacent to the Alto Golfo Biosphere Reserve

Higher classification and common names follow Nelson et al. 2004. Habitats: P = pelagic; R = reefs; S = soft bottoms.

Class Chondrichthys – cartilaginous fishes

Heterodontiformes

Heterodontidae – bullhead sharks; tiburones cornudos

Heterodontus francisci – horn shark; tiburón puerco S

Heterodontus mexicanus – Mexican horn shark; tiburón perro R,S

Orectolobiformes

Rhincodontidae – whale sharks; tiburones ballena

Rhincodon typus – whale shark; tiburón ballena P

Carcharhiniformes

Triakidae – hound sharks; cazones

Mustelus californicus – gray smooth-hound; cazón mamón S

Mustelus henlei – brown smoothhound; cazón hilacho S

Mustelus lunulatus – sicklefin smooth-hound; cazón segador S

Carcharhinidae – requiem sharks; tiburones gambusos

Carcharhinus altimus – bignose shark; tiburón narizón P

Carcharhinus brachyurus – narrowtooth shark; tiburón cobrizo P

Carcharhinus falciformis – silky shark; tiburón piloto P

Carcharhinus leucas – bull shark; tiburón toro P,S

Carcharhinus limbatus – blacktip shark; tiburón volador P

Carcharhinus obscurus – dusky shark; tiburón gambuso P

Carcharhinus porosus – smalltail shark; tiburón poroso P

Nasolamia velox – whitenose shark; tiburón coyotito P

Negaprion brevirostris – lemon shark; tiburón limón P,S

Rhizoprionodon longurio – Pacific sharpnose shark; cazón bironche P,S

Sphyrnidae – hammerhead sharks; tiburones martillo

Sphyrna lewini – scalloped hammerhead; cornuda común P

Sphyrna mokarran – great hammerhead; cornuda gigante P

Sphyrna tiburo – bonnethead; cornuda cabeza de pala P,S

Sphyrna zygaena – smooth hammerhead; cornuda prieta P

Lamniformes

Alopiidae – thresher sharks; tiburones zorro

Alopias pelagicus – pelagic thresher; zorro pelágico P

Alopias superciliosus – bigeye thresher; tiburón zorro ojón P

Alopias vulpinus – thresher shark; tiburón zorro común P
Cetorhinidae – basking sharks; tiburones peregrinos
Cetorhinus maximus (extirpated) – basking shark; tiburón peregrino P
Lamnidae – mackerel sharks; jaquetones
Carcharodon carcharias – white shark; tiburón blanco P
Isurus oxyrinchus – shortfin mako; mako P

Hexanchiformes
Hexanchidae – cow sharks; tiburones cañabotas
Notorynchus cepedianus – broadnose sevengill shark; tiburón pinto P,S

Squatiniformes
Squatinidae – angel sharks; angelotes
Squatina californica – Pacific angel shark; angelote del Pacífico S

Torpediniformes
Narcinidae – electric rays; rayas eléctricas
Diplobatis ommata – bullseye electric ray; raya eléctrica diana R,S
Narcine entemedor – giant electric ray; raya eléctrica gigante S

Rajiiformes
Rhinobatidae – guitarfishes; guitarras
Rhinobatos leucorhynchus – whitesnout guitarfish; guitarra trompa blanca S
Rhinobatos productus – shovelnose guitarfish; guitarra viola S
Zapteryx exasperata – banded guitarfish; guitarra rayada S
Rajidae – skates; rayas
Raja binoculata – big skate; raya bruja gigante S
Dasyatidae – whiptail stingrays; rayas látigo
Dasyatis dipterura – diamond stingray; raya látigo diamante S
Dasyatis longa – longtail stingray; raya látigo largo S
Urolophidae – round stingrays; rayas redondas
Urobatis concentricus – reef stingray; raya redonda de arrecife R,S
Urobatis halleri – round stingray; raya redonda común S
Urobatis maculatus – Cortez stingray; raya redonda de Cortés S
Urotrygon aspidura – Panamic stingray; raya redonda panámica S
Urotrygon chilensis – blotched stingray; raya redonda moteada S
Urotrygon rogersi – thorny stingray; raya redonda de púas S
Gymnuridae – butterfly rays; rayas mariposa
Gymnura marmorata – California butterfly ray; raya mariposa californiana S
Myliobatidae – eagle rays; águilas marinas
Myliobatis californica – bat ray; tecolote P,S
Rhinopteridae – cownose rays; rayas gavilán
Rhinoptera steindachneri – golden cownose ray; gavilán dorado P
Mobulidae – mantas; mantas
Mobula munkiana – pygmy devil ray; manta chica P

Class Actinopterygii – ray-finned fishes

Elopiformes
Elopidae – tenpounders; machetes
Elops affinis – machete; machete del Pacífico P

Albuliformes
Albulidae – bonefishes; macabíes
Albula sp. – Cortez bonefish; macabí de Cortés P,S

Anguilliformes
Muraenidae – morays; morenas
Gymnothorax castaneus – Panamic green moray; morena verde panámica R
Gymnothorax equatorialis – spottail moray; morena cola pintada S
Ophichthidae – snake eels; tiesos
Myrichthys tigrinus – tiger snake eel; tieso tigre S
Myrophis vafer – Pacific worm eel; tieso lombriz S
Ophichthus triserialis – Pacific snake eel; tieso del Pacífico S
Ophichthus zophochir – yellow snake eel; tieso amarillo S
Muraenesocidae – pike congers; congrios picudos
Cynoponticus coniceps – conehead eel; congrio espantoso S

Clupeiformes
Engraulidae – anchovies; anchoas
Anchoa helleri – gulf anchovy; anchoa del golfo P
Anchoa ischana – sharpnose anchovy; anchoa chicotera P
Anchoa lucida – bright anchovy; anchoa ojitos P
Anchoa mundeoloides – northern gulf anchovy; anchoa golfina P
Anchoa nasus – bignose anchovy; anchoa trompuda P
Anchoa parri – mystery anchovy; anchoa misteriosa P
Anchoa walkeri – persistent anchovy; anchoa persistente P

Anchovia macrolepidota – bigscale anchovy; anchoveta escamuda P
Cetengraulis mysticetus – anchoveta; anchoveta bocona P
Clupeidae – herrings; sardinas
Dorosoma petenense (intoduced) – threadfin shad; sardina maya P
Etrumeus teres – round herring; sardina japonesa P
Harengula thrissina – flatiron herring; sardinita plumilla P
Opisthonema libertate – deepbody thread herring; sardina crinuda P
Sardinops caeruleus – Pacific sardine; sardina monterrey P

Siluriformes
Ariidae – sea catfishes; bagres marinos
Ariopsis c.f. *guatemalensis* S
Bagre panamensis – chihuil; bagre chihuil S

Argentiformes
Argentinidae – argentines; argentinas
Argentina sialis – Pacific argentine; argentina del Pacífico P,S

Aulopiformes
Synodontidae – lizardfishes; chiles
Synodus lucioceps – California lizardfish; chile lucio S
Synodus scituliceps – lance lizardfish; chile arpón S

Ophidiiformes
Ophidiidae – cusk-eels; brótulas y congriperlas
Lepophidium prorates – prowspine cusk-eel; congriperla cornuda S
Ophidion galeoides – spotfin cusk-eel; congriperla adornada S
Bythitidae – viviparous brotulas; brótulas vivíparas
Ogilbia spp. – several undescribed species of viviparous brotulas R

Gadiformes
Moridae – codlings; moras y carboneros
Physiculus nematopus – charcoal codling; carbonero de fango S
Merlucciidae – merlucciid hakes; merluzas
Merluccius angustimanus – Panama hake; merluza panameña P,S
Merluccius hernandezi – Cortez hake; merluza de Cortés P,S
Merluccius productus – Pacific hake; merluza norteña P,S

Batrachoidiformes
Batrachoididae – toadfishes; peces sapos
Porichthys analis – darkedge midshipman; sapo de luto S
Porichthys mimeticus – mimetic midshipman; sapo mimético S

Lophiiformes
Antennariidae – frogfishes; ranisapos
Antennarius avalonis – roughjaw frogfish; ranisapo antenado R
Ogcocephalidae – batfishes; murciélagos
Zalieutes elater – roundel batfish; murciélago biocelado S

Mugiliformes
Mugilidae – mullets; lisas
Mugil cephalus – striped mullet; lisa rayada P,S
Mugil curema – white mullet; lisa blanca P,S

Atheriniformes
Atherinopsidae – New World silversides; charales y pejerreyes
Atherinops affinis – topsmelt; pejerrey pescadillo P,S
Colpichthys hubbsi – delta silverside; pejerrey delta P,S
Colpichthys regis – false grunion; pejerrey charal P,S
Leuresthes sardina – gulf grunion; pejerrey sardina P,S

Beloniformes
Belonidae – needlefishes; agujones
Ablennes hians – flat needlefish; agujón sable P
Strongylura exilis – California needlefish; agujón californiano P
Tylosurus crocodilus – houndfish; agujón lisero P
Tylosurus pacificus – Pacific agujon; agujón del Pacífico P
Exocoetidae – flyingfishes; voladores
Fodiator acutus – sharpchin flyingfish; volador picudo P
Hemiramphidae – halfbeaks; pajaritos
Hyporhamphus naos – Pacific silverstripe halfbeak; pajarito del Pacífico P
Hyporhamphus rosae – California halfbeak; pajarito californiano P

Gasterosteiformes
Syngnathidae – pipefishes and seahorses; peces pipa y caballitos de mar
Cosmocampus arctus – snubnose pipefish; pez pipa chato R,S
Hippocampus ingens – Pacific seahorse; caballito del Pacífico S
Syngnathus auliscus – barred pipefish; pez pipa anillado S
Syngnathus carinatus – Cortez pipefish; pez pipa de Cortés S

Scorpaeniformes

Scorpaenidae – scorpionfishes; escorpiones y rocotes

Scorpaena guttata – California scorpionfish; escorpión californiano S

Scorpaena mystes – stone scorpionfish; escorpión roquero R

Scorpaena sonorae – Sonora scorpionfish; escorpión de Sonora S

Triglidae – searobins; vacas y rubios

Prionotus ruscarius – rough searobin; vaca rasposa S

Prionotus stephanophrys – lumptail searobin; vaca voladora S

Perciformes: Percoidei

Serranidae – sea basses and groupers; cabrillas y meros

Cephalopholis panamensis – Panama graysby; cabrilla enjambre R

Diplectrum labarum – highfin sand perch; serrano espinudo S

Diplectrum macropoma – Mexican sand perch; serrano mexicano S

Diplectrum pacificum – Pacific sand perch; serrano cabaicucho S

Diplectrum sciurus – squirrel sand perch; serrano ardilla S

Epinephelus acanthistius – gulf coney; baqueta R,S

Epinephelus analogus – spotted cabrilla; cabrilla pinta R

Epinephelus niphobles – star-studded grouper; baqueta ploma R

Mycteroperca rosacea – leopard grouper; cabrilla sardinera R

Paralabrax maculatofasciatus – spotted sand bass; cabrilla de roca S,R

Rypticus nigripinnis – twice-spotted soapfish; jabonero doble punteado R

Polyprionidae – wreckfishes; náufragos

Stereolepis gigas – giant sea bass; pescara R,S

Opistognathidae – jawfishes; bocones

Opistognathus punctatus – finespotted jawfish; bocón punteado S

Apogonidae – cardinalfishes; cardenales

Apogon retrosella – barspot cardinalfish; cardenal de Cortés R

Malacanthidae – tilefishes; blanquillos

Caulolatilus affinis – Pacific golden-eyed tilefish; conejo S

Coryphaenidae – dolphinfishes; dorados

Coryphaena hippurus – dolphinfish; dorado P

Carangidae – jacks; jureles y pámpanos

Caranx caballus – green jack; jurel bonito P

Caranx caninus – Pacific crevalle jack; jurel toro P

Chloroscombrus orqueta – Pacific bumper; horqueta del Pacífico P

Oligoplites altus – longjaw leatherjack; piña bocona P

Oligoplites refulgens – shortjaw leatherjack; piña flaca P

Oligoplites saurus – leatherjack; piña sietecueros P

Selar crumenophthalmus – bigeye scad; charrito ojón P

Selene peruviana – Pacific moonfish; jorobado papelillo P

Trachinotus paitensis – paloma pompano; pámpano paloma P

Trachinotus rhodopus – gafftopsail pompano; pámpano fino P

Lutjanidae – snappers; pargos y huachinangos

Hoplopagrus guentherii – barred snapper; pargo coconaco R

Lutjanus argentiventris – amarillo snapper; pargo amarillo R

Lutjanus guttatus – spotted rose snapper; pargo lunarejo R,S

Lutjanus novemfasciatus – Pacific dog snapper; pargo prieto R

Lobotidae – tripletails; dormilonas

Lobotes pacificus – Pacific tripletail; dormilona del Pacífico P

Gerreidae – mojarras; mojarras

Eucinostomus currani – Pacific flagfin mojarra; mojarra tricolor S

Eucinostomus dowii – Pacific spotfin mojarra; mojarra manchita S

Eucinostomus entomelas – darkspot mojarra; mojarra mancha negra S

Eucinostomus gracilis – graceful mojarra; mojarra charrita S

Haemulidae – grunts; burros y roncos

Anisotremus davidsonii – sargo; sargo rayado R,S

Anisotremus interruptus – burrito grunt; burro bacoco R,S

Haemulon flaviguttatum – Cortez grunt; burro de Cortés R

Haemulon maculicauda – spottail grunt; burro rasposo R

Haemulon steindachneri – Latin grunt; burro latino R,S

Haemulopsis leuciscus – raucous grunt; ronco ruco S

Haemulopsis nitidus – shining grunt; ronco brillante S
Orthopristis reddingi – bronzestriped grunt; burrito rayado S
Pomadasys panamensis – Panamic grunt; roncacho mapache S
Xenistius californiensis – salema; salema R,S
Sparidae – porgies; plumas
Calamus brachysomus – Pacific porgy; pluma marotilla R,S
Polynemidae – threadfins; barbudos
Polydactylus approximans – blue bobo; barbudo seis barbas S
Sciaenidae – drums and croakers; corvinas y berrugatas
Atractoscion nobilis – white seabass; corvina cabaicucho S
Bairdiella icistia – bairdiella; ronco roncacho S
Chielotrema saturnum – black croaker; corvinata negra S
Cynoscion othonopterus – gulf covina; corvina golfina S
Cynoscion parvipinnis – shortfin corvina; corvina aleta corta S
Cynoscion reticulatus – striped corvina; corvina rayada S
Cynoscion xanthulus – orangemouth corvina; corvina boquinaranja S
Isopisthus remifer – bigeye corvina; corvina ojona S
Larimus pacificus – Pacific drum; boquinete del Pacífico S
Menticirrhus nasus – highfin kingfish; berrugato real S
Menticirrhus panamensis – Panama kingfish; berrugato panameño S
Menticirrhus undulatus – California corbina; berrugato californiano S
Micropogonias altipinnis – golden croaker; chano sureño S
Micropogonias megalops – gulf croaker; chano norteño S
Ophioscion strabo – squint-eyed croaker; corvineta bizca S
Pareques viola – rock croaker; payasito gungo R
Totoaba macdonaldi – totoaba; totoaba S
Umbrina roncador – yellowfin croaker; berrugata aleta amarilla S
Mullidae – goatfishes; chivos
Pseudupeneus grandisquamis – bigscale goatfish; chivo escamudo S
Pomacanthidae – angelfishes; ángeles
Pomacanthus zonipectus – Cortez angelfish; ángel de Cortés R
Kyphosidae – sea chubs; chopas
Girella simplicidens – gulf opaleye; chopa ojo azul R
Hermosilla azurea – zebraperch; chopa bonita R
Kyphosus analogus – blue-bronze chub; chopa rayada R
Kyphosus elegans – Cortez sea chub; chopa de Cortés R

Perciformes: Labroidei

Pomacentridae – damselfishes; castañetas y jaquetas
Abudefduf troschelii – Panamic sergeant major; petaca banderita R
Stegastes rectifraenum – Cortez damselfish; jaqueta de Cortés R
Labridae – wrasses; doncellas y señoritas
Halichoeres chierchiae – wounded wrasse; señorita herida R
Halichoeres dispilus – chameleon wrasse; señorita camaleón R
Halichoeres nicholsi – spinster wrasse; señorita solterona R
Halichoeres notospilus – banded wrasse; señorita listada R
Halichoeres semicinctus – rock wrasse; señorita piedrera R
Scaridae – parrotfishes; loros
Nicholsina denticulata – loosetooth parrotfish; pococho beriquete R

Perciformes: Trachinoidei

Uranoscopidae – stargazers; miracielos
Astroscopus zephyreus – Pacific stargazer; miracielo perro S

Perciformes: Blennioidei

Dactyloscopidae – sand stargazers; miraestrellas
Dactylagnus mundus – giant stargazer; miraestrellas gigante S
Dactyloscopus lunaticus – moonstruck stargazer; miraestrellas lunática S
Dactyloscopus pectoralis – whitesaddle stargazer; miraestrellas fisgona S
Myxodagnus opercularis – dart stargazer; miraestrellas virote S
Labrisomidae – labrisomid blennies; trambollos
Exerpes asper – sargassum blenny; trambollo sargacero R
Labrisomus xanti – largemouth blenny; chalapo R

Malacoctenus gigas – Sonora blenny; trambollo de Sonora R
Malacoctenus hubbsi – redside blenny; trambollo rojo R
Paraclinus sini – flapscale blenny; trambollito frondoso R
Chaenopsidae – tube blennies; trambollos tubícolas
Emblemaria hypacanthus – gulf signal blenny; tubícola flamante R
Emblemaria walkeri – elusive signal blenny; tubícola fugaz R
Blenniidae – combtooth blennies; borrachos
Hypsoblennius gentilis – bay blenny; borracho de bahía R,S
Hypsoblennius jenkinsi – mussel blenny; borracho mejillonero R,S

Perciformes: Gobiesocoidei

Gobiesocidae – clingfishes; chupapiedras
Gobiesox papillifer – bearded clingfish; chupapiedra barbona R
Gobiesox pinniger – tadpole clingfish; chupapiedra renacuajo R
Gobiesox schultzi – smoothlip clingfish; chupapiedra labioliso R
Pherallodiscus funebris – fraildisc clingfish; chupapiedra discofrágil R
Tomicodon boehlkei – Cortez clingfish; chupapiedra de Cortés R
Tomicodon humeralis – Sonora clingfish; chupapiedra de Sonora R
Tomicodon zebra – zebra clingfish; chupapiedra cebra R

Perciformes: Gobioidei

Eleotridae – sleepers; guavinas
Eleotris picta – spotted sleeper; guavina manchada S
Gobiidae – gobies; gobios
Aruma histrio – slow goby; gobio lento R
Bathygobius ramosus – Panamic frillfin; mapo panámico R
Bollmannia ocellata – pennant goby; gobio penacho S
Coryphopterus urospilus – redlight goby; gobio semáforo R,S
Ctenogobius sagittula – longtail goby; gobio aguzado S
Evermannia sp. – estero goby; gobio de estero S
Gillichthys mirabilis – longjaw mudsucker; chupalodo grande S
Gillichthys seta – shortjaw mudsucker; chupalodo chico S,R
Gobiosoma chiquita – Sonora goby; gobio chiquito R
Gobiosoma sp. – patchscale goby; gobio parche escamitas R
Gobulus crescentalis – crescent goby; gobio creciente R
Ilypnus gilberti – cheekspot goby; gobio mejilla manchada S
Ilypnus luculentus – bright goby; gobio brillante S
Lythrypnus dalli – bluebanded goby; gobio bonito R
Microgobius brevispinis – Balboa goby; gobio de Balboa S
Microgobius cyclolepis – roundscale goby; gobio escamas redondas S
Parrella ginsburgi – darkblotch goby; gobio lunarejo S
Quietula guaymasiae – Guaymas goby; gobio guaymense S
Quietula y-cauda – shadow goby; gobio sombreado S

Perciformes: Acanthuroidei

Ephippididae – spadefishes; peluqueros
Chaetodipterus zonatus – Pacific spadefish; chambo P

Perciformes: Scombroidei

Trichiuridae – cutlassfishes; sables
Trichiurus nitens – Pacific cutlassfish; sable del Pacífico S
Scombridae – mackerels; macarelas
Auxis thazard – frigate mackerel; melva P
Scomber japonicus – Pacific chub mackerel; macarela estornino P
Scomberomorus concolor – gulf sierra; sierra golfina P
Scomberomorus sierra – Pacific sierra; sierra del Pacífico P
Istiophoridae – billfishes; picudos
Istiophorus platypterus – sailfish; pez vela P
Makaira indica – black marlin; marlin negro P

Perciformes: Stromateoidei

Stromateidae – butterfishes; palometas
Peprilus ovatus – Cortez butterfish; palometa de Cortés P
Peprilus snyderi – salema butterfish; palometa salema P

Pleuronectiformes

Paralichthyidae – sand flounders; lenguados areneros
Ancyclopsetta dendritica – threespot sand flounder; lenguado tresojos S

Etropus crossotus – fringed flounder; lenguado ribete S
Etropus peruvianus – Peruvian flounder; lenguado zapatilla S
Hippoglossina bollmani – spotted flounder; lenguado pintado S
Hippoglossina stomata – bigmouth sole; lenguado bocón S
Paralichthys aestuarius – Cortez halibut; lenguado de Cortés S
Paralichthys woolmani – dappled flounder; lenguado huarache S
Syacium ovale – oval flounder; lenguado ovalado S
Xystreurys liolepis – fantail sole; lenguado cola de abanico S

Pleuronectidae – righteye flounders; platijas
Pleuronichthys guttulatus – diamond turbot; platija diamante S
Pleuronichthys ocellatus – ocellated turbot; platija ocelada S
Pleuronichthys verticalis – hornyhead turbot; platija cornuda S

Achiridae – American soles; lenguados suelas
Achirus mazatlanus – Pacific lined sole; tepalcate S

Cynoglossidae – tonguefishes; lenguas
Symphurus chabanaudi – darkcheek tonguefish; lengua cachete prieto S
Symphurus elongatus – elongate tonguefish; lengua esbelta S
Symphurus fasciolaris – banded tonguefish; lengua listada S
Symphurus williamsi – yellow tonguefish; lengua amarillenta S

Tetraodontiformes

Balistidae – triggerfishes; cochitos
Balistes polylepis – finescale triggerfish; cochi R,S

Ostraciidae – boxfishes; peces cofre
Lactoria diaphana – spiny boxfish; cofre espinoso P

Tetraodontidae – puffers; botetes
Sphoeroides annulatus – bullseye puffer; botete diana S
Sphoeroides lispus – naked puffer; botete liso S
Sphoeroides sechurae – Peruvian puffer; botete peruano S

Fishes recorded from Rocas Consag (RC) and/or Isla San Jorge (ISJ) but not yet recorded in the Alto Golfo Biosphere Reserve

Serranidae – sea basses and groupers; cabrillas y meros
Serranus psittacinus – barred serrano; serrano guaseta: RC; ISJ

Pomacentridae – damselfishes; castañetas y jaquetas
Chromis atrilobata – scissortail chromis; castañeta cola de tijera: RC

Labridae – wrasses; doncellas y señoritas
Bodianus diplotaenia – Mexican hogfish; vieja mexicana: ISJ

Tripterygiidae – triplefins; tres aletas
Axoclinus nigricaudus – Cortez triplefin; tres aletas colinegra: RC; ISJ
Crocodilichthys gracilis – lizard triplefin; lagartija tres aletas: RC; ISJ

Labrisomidae – labrisomid blennies; trambollos
Labrisomus multiporosus – porehead blenny; trambollo cabeza porosa: ISJ
Malacoctenus tetranemus – throatspotted blenny; trambollo pintado: ISJ
Starksia spinipenis – phallic blenny; trambollito macho: RC
Xenomedea rhodopyga – redrump blenny; trambollito nalga roja: RC, ISJ

Chaenopsidae – tube blennies; trambollos tubícolas
Acanthemblemaria crockeri – browncheek blenny; tubícola cachetón: ISJ
Chaenopsis alepidota – orangethroat pikeblenny; tubícola lucio: ISJ
Coralliozetus micropes – zebraface blenny; tubícola cara de cebra: ISJ
Protemblemaria bicirrus – warthead blenny; tubícola tupido: RC, ISJ

Ptereleotridae – dartfishes; gobios dardos
Ptereleotris carinata – Panamic dartfish; gobio dardo panámico: RC

Dry Borders

Great Natural Reserves of the Sonoran Desert

Richard Stephen Felger and Bill Broyles, editors

The Defiance House Man colophon is a registered trademark of the University of Utah Press. It is based upon a four-foot-tall, Ancient Puebloan pictograph (late PIII) near Glen Canyon, Utah.

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Philip A. Hastings: The wet state of Florida was the setting for both my early life and early career. I grew up near the ocean in Pensacola, where I spent much of my time exploring the area's numerous beaches, bayous, and creeks. I received a bachelor's degree in zoology from the University of South Florida in Tampa and a master's degree in marine biology from the University of West Florida in Pensacola and then worked for four years as a marine biologist at the Harbor Branch Foundation on the state's east coast. My calling to the desert Southwest came in 1980, when, seeking a change of scenery, I entered the Ph.D. program at the University of Arizona under the direction of Donald A. Thomson. "DAT" and my fellow graduate students in the Department of Ecology and Evolutionary Biology introduced me to the Gulf of California and its fishes, as well as to the rich Sonoran Desert. After completing my degree, I remained at the university as a research scientist and later as curator of fishes and invertebrates. It was also in Tucson that I met my wife, Marty Eberhardt, who became director of the Tucson Botanical Gardens, expanding it from a small neighborhood garden to a jewel in the Tucson landscape. Our tranquil life in the Sonoran desert with our two sons was disrupted in 1999 when I was invited to join the faculty at the University of California, San Diego, and to become curator of the marvelous Marine Vertebrate Collection at the Scripps Institution of Oceanography. In many ways the move to SIO has facilitated my research in the Gulf of California.

I am a systematist in the broad sense, with interests in the diversity, evolution, ecology, and behavior of marine fishes. My students and I employ techniques spanning the fields of morphology, ethology, and molecular biology. For the past several years I have focused my studies on the family Chaenopsidae, commonly called tube blennies because of their habit of occupying vacant tests or shells of invertebrates. These curious fishes have been an interest of mine ever since I discovered and described a new species of tube blenny from the northern Gulf of Mexico over 25 years ago (*Chaenopsis roseola*, pink-flecked pikeblenny). My interest in them blossomed after I moved to the University of Arizona and discovered the rich and accessible diversity of chaenopsids in the Gulf of California.

Like most of my colleagues, I am deeply concerned about the growing negative environmental impacts of humans. This concern has led to several projects on the conservation of fishes of the Gulf of California and more recently on those of coastal California.

Lloyd T. Findley feels that he's quite a lucky fellow, having been able to study what he was interested in and do so in his adopted country of Mexico. He has been fascinated by fishes since his high-school skin-diving days in southern California. He first saw the fishes of the Gulf of California in Bahía Topolobampo as a high school foreign exchange student in Los Mochis, Sinaloa. Further trips to the gulf inspired him to earn his bachelor's degree in zoology at California State College (now University) at Long Beach. That same desire led him to a master's degree in zoology/fisheries at the University of California, Los Angeles, where Boyd W. Walker, probably the person most knowledgeable about gulf fishes, took him on as a student in fish systematics/taxonomy and gave him access to the school's great ichthyological collection from the gulf.

Findley's correspondence with Donald A. Thomson, at the University of Arizona in Tucson, eventually led to enrollment at the U of A to pursue a Ph.D. under "DAT" and to take the part-time assistant curatorship of the Fish Collection at the Department of Biology (now Ecology and Evolutionary Biology). Eight years of intensive collecting, curating, and studying gulf fishes with Thomson, John Hendrickson, and many of their students led to publication of *The Reef-Fishes of the Sea of Cortez*, by Thomson, Findley, and Alex Kerstitch.

Findley returned to Los Angeles, where he met and married the love of his life, Sandra Hull. He accepted a teaching position at the Guaymas, Sonora, Marine Sciences School of the Instituto Tecnológico y de Estudios Superiores de Monterrey (the "Tec"). Courses included oceanography, ichthyology, and eventually the biology of marine mammals. He and his students saw a great opportunity to study the whales and dolphins of the region and launched a ten-year research program on the cetaceans of the gulf, including gray and fin whales and the endangered vaquita. The research proved so successful that some scientists still consider Findley a marine mammalogist.

Since 1996 he has concentrated on gulf ichthyofauna, working with the Guaymas Unit of the Centro de Investigación en Alimentación y Desarrollo. And through former students at the Tec, he has maintained a close relationship with the Guaymas-based Gulf of California Program of Conservation International (CI). Research projects with both Mexican and American colleagues have been numerous, the most extensive being a compilation of information on the more than six thousand species of macrofauna inhabiting the Gulf of California, soon to be published with five coauthors by CI as a CD-ROM.

Another long-term project involves the systematics, ecology, and conservation of native trouts of the Sierra Madre Occidental. Findley and his colleagues, mainly Héctor Espinosa of the Instituto de Biología, Universidad Nacional Autónoma de México, have incorporated the entire Mexican ichthyofauna into the sixth edition of the American Fisheries Society's *Common and Scientific Names of Fishes from the United States, Canada, and Mexico*, the first edition to include Mexico.

Findley sees much to be done in gulf research and conservation but realizes that his luck continues, having two daughters who are "naturals" at snorkeling and fish watching in the warm waters of the Gulf of California.