Vaquita *Phocoena sinus* Norris and McFarland, 1958

Omar Vidal[a], Robert L. Brownell, Jr.[b], Lloyd T. Findley[c], Jorge Torre[d] and Richard C. Brusca[e]

[a]Ciudad de México, México; [b]NOAA Fisheries, Southwest Fisheries Science Center, Monterey, CA, United States; [c]Investigador Titular, Centro de Investigación en Alimentación y Desarrollo, Unidad Guaymas, Guaymas, Sonora, México; [d]Comunidad y Biodiversidad, A.C., Guaymas, Sonora, México; [e]The University of Arizona and Arizona-Sonora Desert Museum, Tucson, United States

Taxonomy and systematics

Scientific names

Phocoena sinus was described by Norris and McFarland in 1958 from three skulls collected on the northeast shore of Punta San Felipe and at Bahía San Felipe, Baja California (BC), in the Upper Gulf of California, the northernmost area of the Northern Gulf of California, Mexico. Two of these specimens (holotype and paratype) are deposited in the Museum of Vertebrate Zoology, University of California at Berkeley, USA. A third specimen, another paratype, is in the National Museum of Natural History, Smithsonian Institution, Washington, DC. The late Carl L. Hubbs suggested the species epithet name *sinus* to Norris and McFarland. In Latin, it means "bay," referring to the occurrence of the species in the Gulf of California (Sea of Cortés).

Common name

Vaquita (="little cow") is the name used by local fishers in the Northern Gulf of California, where for many years this porpoise has been taken incidental to fishing operations (Brownell et al., 1987; Vidal, 1993, 1995). *Cochito* (="little pig") had been a commonly used vernacular name for *P. sinus* because it was adopted by the International Whaling Commission in 1975 (Mitchell, 1975). However, in the Gulf of California "*cochito*" is used for more than one species

of small cetacean as well as for a species of triggerfish. The name vaquita has been well accepted in the scientific and popular literature since 1987.

Evolutionary history

All seven species of phocoenids have been hypothesized to represent a pedomorphic evolutionary lineage (i.e., some fetal or juvenile characters persist into adulthood). Although examples of pedomorphosis may be found in some species in other cetacean families, in no other family group is this phenomenon as universally presented and as pronounced as it is in the living phocoenids (Barnes, 1985). The vaquita is unique among phocoenids in four pedomorphic features (Mellor et al., 2009): (1) fewer numbers of ossified carpal elements; (2) rounded, rather than angular, carpal elements; (3) greater number of distal phalanges that are ovoid in shape; and (4) fewer ossified metacarpal and phalangeal diaphyses. Compared to other porpoises, the vaquita's ossified carpal elements display a pedomorphic morphology in that they are rounded rather than angular. Furthermore, relative to delphinid cetaceans (except the killer whale *Orcinus orca*) both the vaquita and the harbor porpoise *Phocoena phocoena* display a greater number of rounded phalangeal diaphyses, suggesting pedomorphosis (Mellor et al., 2009; Torre-Cosío, 1995).

Norris and McFarland (1958) discussed the possible origin of *P. sinus* from the Northern Hemisphere *P. phocoena* or from the South American Burmeister's porpoise *P. spinipinnis*. Although *P. sinus* is in some respects intermediate between these two species, they favored *P. spinipinnis* as the more likely ancestor because its cranium resembles that of *P. sinus* more than that of the harbor porpoise. Noble and Fraser (1971) noted that the axial skeleton of *P. sinus* also suggests a closer affinity to *P. spinipinnis* than to *P. phocoena*. All of the axial skeleton material that we and Torre-Cosío (1995) examined agrees generally with the specimen described by Noble and Fraser (1971).

Porpoise evolutionary history is contentious and phylogenetic studies have yielded incongruent results, especially with regard to the vaquita (Barnes, 1985; Fajardo-Mellor et al., 2006; McGowen et al., 2009; Norris & McFarland, 1958; Rosel et al., 1995). Ben Chehida et al. (2019) inferred the phylogeny of the seven species of Phocoenidae using whole mitochondrial genomes. They found that the temperate species of porpoises comprise two reciprocally monophyletic clades. The first is composed of the Southern Hemisphere species (spectacled porpoise *P. dioptrica* and Burmeister's porpoise) and vaquita. The second comprises the porpoises from the Northern Hemisphere (harbor and Dall's porpoise *Phocoenoides dalli*). Their data infer that the vaquita split from a common ancestor to the spectacled and Burmeister's porpoise ~2.39 Myr, and the spectacled and Burmeister's porpoises thus share a more recent common ancestor than either does with the vaquita, and that vaquita diverged from a southern species during the Pliocene. The low genetic diversity observed in the vaquita carried signatures of a very low population size throughout at least the last 5000 years, leaving a single relict mitochondrial lineage.

Distribution

Range

Phocoena sinus is restricted to the shallow waters of the Northern Gulf of California, with most of the records from near San Felipe, Rocas Consag, and El Golfo de Santa Clara
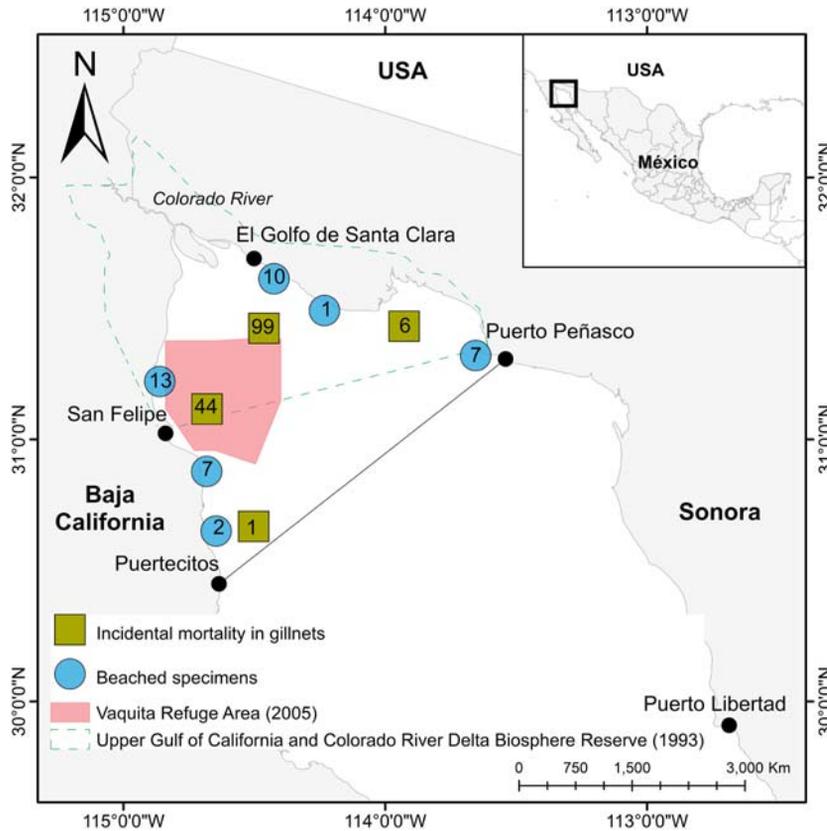
FIG. 13.1 Range of the vaquita *Phocoena sinus* up to the end of the 20th century. All confirmed records to date have been north of a line connecting Puertecitos (Baja California) and Puerto Peñasco (Sonora), Upper Gulf of California, Mexico. These include incidental catches and beached specimens (e.g., Brownell, 1983, 1986; Brownell et al., 1987; Turk-Boyer & Silber, 1990; Vidal, 1991, 1995), photographs (Jefferson et al., 2009) and sightings (e.g., Silber, 1990a; Silber & Norris, 1991; Gerrodette et al., 1995, 2011; Jaramillo-Legorreta et al., 1999, 2017, 2019, 2023; Taylor et al., 2017, 2019; Thomas et al., 2017; Rojas-Bracho, Gulland et al., 2019; Rojas-Bracho, Booth et al., 2019; Rojas-Bracho, Brusca et al., 2019; Rojas-Bracho et al., 2022). *Circles* and *squares* indicate the approximate location and number of specimens observed or beach cast. ***Map lines delineate study areas and do not necessarily depict accepted national boundaries.***

(Fig. 13.1). Recent passive acoustic monitoring has, however, revealed a substantial reduction in the area now used by the very few remaining vaquitas, since almost all detections have been in a small area (roughly 12 × 24 km) off San Felipe, where recent government enforcement efforts to stop illegal gillnetting have been focused (Jaramillo-Legorreta et al., 2023; Rojas-Bracho et al., 2022). Noteworthy, gillnetting (mainly in bottom-tethered "*chinchorro de línea*" for shrimp) within that small area has increased from at least 2019 onwards (e.g., Rojas-Bracho et al., 2022). This distribution is based on confirmed records; other reputed records of the species in the Southern Gulf of California are considered unreliable (Brownell, 1986). Ninety confirmed physical (bycatch or beached specimens) and photographic records

of *P. sinus* were documented, all north of Puertecitos (Baja California) and Puerto Peñasco, Sonora, Mexico by the end of the 20th century (Brownell, 1983, 1986; Vidal, 1991, 1995; Vidal et al., 1993). All records since 2000 are from the same northern region and are highly localized in the small area referred to above (Gerrodette et al., 2011; Jaramillo-Legorreta et al., 1999, 2017, 2019, 2023; Jefferson et al., 2009; Rojas-Bracho et al., 2022; Rojas-Bracho, Booth et al., 2019; Rojas-Bracho, Brusca et al., 2019; Rojas-Bracho, Gulland et al., 2019; Taylor et al., 2017, 2019; Thomas et al., 2017).

Movements

The distribution of vaquita in the Northern Gulf of California appears to be highly localized, with the highest densities offshore of San Felipe and Rocas Consag, and offshore of El Golfo de Santa Clara (Gerrodette et al., 1995; Silber, 1990a; Silber & Norris, 1991; Vidal, 1995). An analysis of all available sightings up to 1990 led Silber (1990a) and Silber and Norris (1991) to suggest that vaquitas occupy the Northern Gulf year-round. However, with the progressive decline of the population due to incidental mortality in legal and illegal gillnet fisheries, particularly during the last 2 decades, the remaining few vaquitas appear to be restricted to the small area mentioned above off San Felipe (Jaramillo-Legorreta et al., 2023; Rojas-Bracho et al., 2022).

Two unconfirmed sightings in 1983 near Isla Cerralvo, in the Southern Gulf of California (about 850 km south of the southernmost confirmed sighting), were reported by Silber (1990a). A strong El Niño southern oscillation (ENSO) event occurred during 1982—83 and water temperatures were unusually high in the Southern Gulf (Cane, 1983). Extralimital range records have been reported for most species of cetaceans around the world for various reasons, including ENSO events. However, based on all reliable information to date (i.e., voucher specimens, confirmed sightings, photographs, and acoustic records) there is no doubt that this species' range is confined to the northernmost Gulf of California and is the most restricted range of any cetacean.

Habitat

The Northern Gulf of California is one of the world's most biologically productive marine regions (Álvarez-Borrego et al., 1978; Brusca et al., 2017). This high productivity is driven by a unique mix of numerous factors, the predominant ones being shallow bottom, extreme tidal mixing, and strong upwelling.

The vaquita is known only from relatively shallow waters. Silber (1990a) reported 51 sightings in water depths of 13.5—37 m, and most of these sightings were 11—25 km from shore. All but two of the sightings were less than 40 km from San Felipe (mainly between this locality and Rocas Consag, a small rocky islet). 0. from 0.9 to 12 m. Both sightings by Wells et al. (1981) were in water depths of around 19 m and were about 18 km from shore. All known incidental entanglements of this species in gillnets have occurred in water depths from 4—36 m (estimated by fishers operating the nets or by reference to nautical charts) and between 3 and 33 km from shore (Vidal, 1995).

External characteristics

Biological information on the vaquita is limited, and collection of specimens and observations in the wild are extremely difficult. What is known about the external morphology of this, the world's smallest cetacean, is limited to only three published studies. Brownell et al. (1987) described the external morphology and coloration based on 13 fresh specimens collected in 1985; Hohn et al. (1996) compared the total length, body mass, and maximum girth growth curves of 56 male and female vaquitas; and Torre et al. (2014) evaluated the sexual dimorphism and isometric and/or allometric growth of the same 56 specimens examined by Hohn et al. (1996).

Coloration

Generally, the pigmentation pattern (Fig. 13.2) can be divided into three parts: dark-gray cape, pale-gray lateral field, and white ventral field (terminology of Perrin, 1972; Perrin et al., 1981). The most conspicuous features of the coloration are the relatively large black eye and lip patches (Figs. 13.2 and 13.3A and B), which contrast sharply with the surrounding pale gray of the sides of the head and thoracic regions The dark flipper stripe is also a dominant feature of the coloration. The shapes of the eye patch, lip patch, and flipper stripe all vary slightly among individuals. Additional details of the color pattern are given by Brownell et al. (1987).

Size and shape

This species is the shortest of all "delphinoids" (i.e., families Delphinidae, Monodontidae, and Phocoenidae). Selected external measurements were provided for 13 (Brownell et al., 1987) and 36 specimens (Vidal, 1995) incidentally killed in gillnet fisheries, which ranged from 70.3—148.2 cm in total length. A near-term fetus measured 71.5 cm. In lateral view, the head appears as a truncated cone with the posterior part of the melon sloping downward toward the blowhole, especially in adult males. The flippers are attenuated and apically pointed (Fig. 13.5A) much like those of *P. spinipinnis* and unlike those of *P. phocoena*. The shape and height of the dorsal fin is the most striking external feature of *P. sinus* (Figs. 13.2A and C, 13.3A, C, and D). It is proportionally much higher than in other species of *Phocoena*. The shape is roughly triangular, with the anterior edge slightly convex and longer than the posterior edge, which is nearly straight or slightly concave. In mature males we have examined, the dorsal fin is taller and less falcate (i.e., more erect) than in mature females. Small tubercles of variable development are present along the upper 1/2 to 3/4 of the anterior edge of the dorsal fin and, although the tubercles are prominent to the touch in larger individuals, none of the specimens we have examined had the more prominent horny tubercles found in *P. spinipinnis* (Allen, 1925; Brownell & Praderi, 1984). All of the 17 males we examined had a small, blind

FIG. 13.2   External views of *Phocoena sinus* incidentally caught in gillnets near El Golfo de Santa Clara, Sonora, Upper Gulf of California, Mexico, in 1985–91. (Note the gillnet scars on the posterior head region in the lower photos). *Photographs by: (A) A. Robles©, (B) J.M. Nava O. Vidal© and (C) O. Vidal©.*
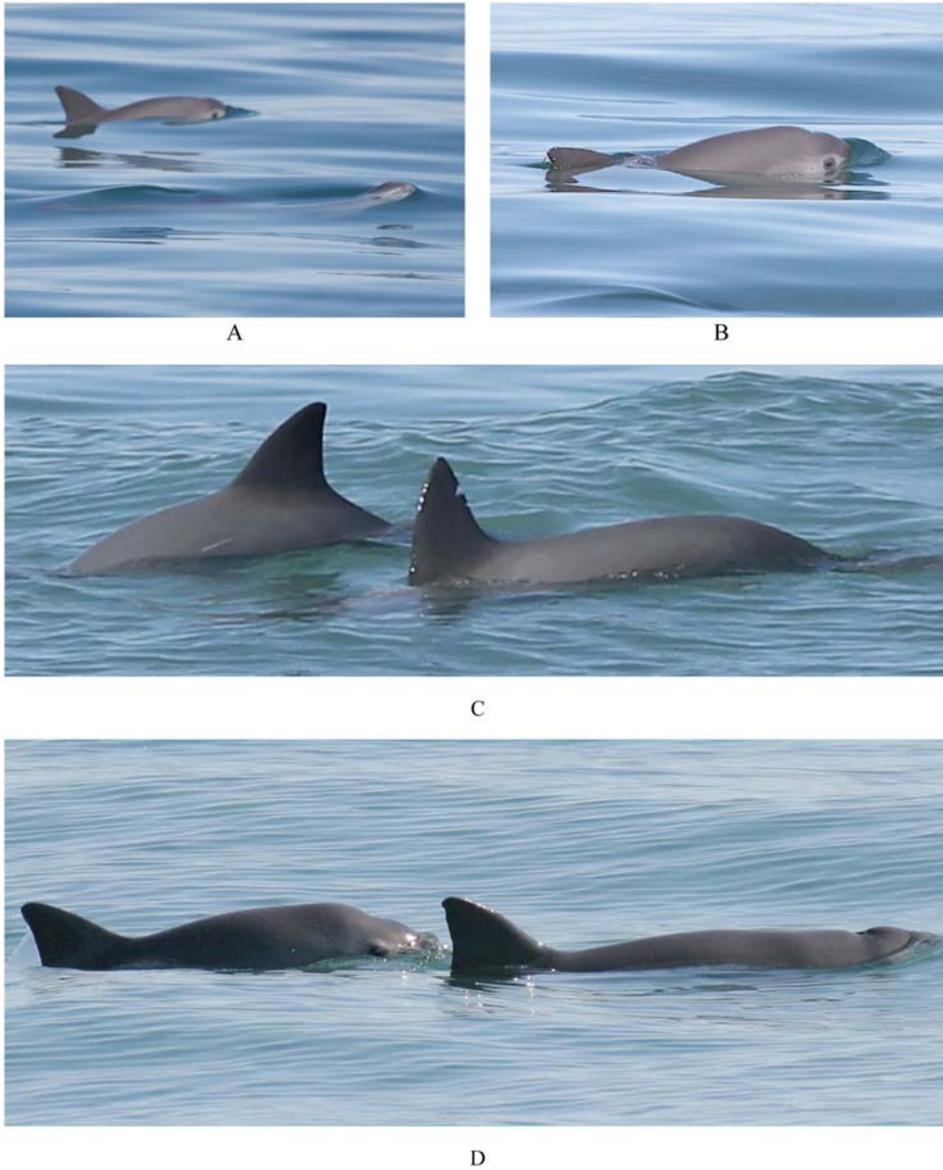
FIG. 13.3 Vaquitas *Phocoena sinus* surfacing in calm waters in the Upper Gulf of California, Mexico. *Photographs by: (A and B) T.A. Jefferson/VIVA Vaquita©, (C) R. Pitman© and (D) Paula Olson©.*

opening (not yet described in detail) just anterior to the anus that appeared to be much like that described for *Neophocaena asiaeorientalis* from Japan (Nishiwaki & Kureha, 1975). One of the males had two of these openings (parallel to each other).

The four largest males (134.5−144 cm) and the nine largest females (135−148.2 cm) examined by Brownell et al. (1987) and Vidal (1995) were all physically mature. Three additional large specimens include two females, 139 and 150 cm; and one male, 145 cm long (Brownell, 1982; Silber & Norris, 1991). Torre et al. (2014) analyzed the largest series of specimens (56) of vaquita and documented sexual dimorphism in total length, head region, anterior section of the body, dorsal fin, and genital and anal regions. Female harbor porpoises and vaquitas are larger than males (Brownell et al., 1987; Gaskin et al., 1984; Hohn et al., 1996; Read & Tolley, 1997; Vidal, 1995). In contrast, males of the other five species of porpoises are larger than the females (Gao & Zhou, 1995; Goodall & Schiavini, 1995; Jefferson, 1990; Reyes & Van Waerebeek, 1995; Shirakihara et al., 1993). Females are larger than males in several small cetaceans that exhibit a relatively simple social structure (Dines et al., 2015; Mesnick & Ralls, 2018; Ralls & Mesnick, 2009). The harbor and finless porpoises and vaquita have relatively large testes (4%−5% of body weight) indicating the potential for sperm competition (i.e., a female mates with several males during each estrus) (Hohn et al., 1996; Mesnick & Ralls, 2018; Ralls & Mesnick, 2009; Slooten, 1991). Another factor that probably contributes to the reversed sexual dimorphism is that a larger female will be able to produce a larger calf with an increased chance of survival (Mesnick & Ralls, 2018; Ralls, 1976; Ralls & Mesnick, 2009). A newborn vaquita weighs about 7.5 kg (Vidal, 1995), not far above the theoretical minimum size of 6.8 kg (for river dolphin species); below this value a neonate might be unable to maintain its body temperature due to an increasing surface area relative to its volume (Downhower & Blumer, 1988). Thus, sexual dimorphism in the vaquita may result from the combination of selection pressures favoring smaller males and larger females (Torre et al., 2014). Males present a higher dorsal fin, and its size is strongly dimorphic (Torre et al., 2014). Sexual dimorphism in dorsal-fin size has been reported for three other species of porpoises: Dall's (Amano & Miyazaki, 1993; Jefferson, 1990), Burmeister's (Reyes & Van Waerebeek, 1995), and spectacled (Goodall & Schiavini, 1995). In vaquita the potential for overheating is compounded by the fact that the species lives year-round in winter water temperatures of 14°C and summer temperatures that often reach 36°C (a higher temperature than experienced by other porpoises).

All male cetaceans have the genital aperture farther forward than females (Mesnick & Ralls, 2018; Ralls & Mesnick, 2009), but in male harbor porpoises and vaquita it is much farther forward than in any of the marine dolphins (Brownell et al., 1987; Read & Tolley, 1997). The umbilicus and anus are closer to the snout in male vaquitas than females and the anal opening is larger in males of all ages (Torre et al., 2014). Females have a larger genital aperture than males, as in other cetaceans. Vaquita growth patterns are similar to those reported for harbor porpoise (Read & Tolley, 1997) and spinner dolphin *Stenella longirostris* (Perrin, 1975). The anterior body features and flippers show negative allometric growth whereas those posteriorly from dorsal fin to the flukes have positive allometry and isometry. Developing larger flippers and anterior portions of the body in early life may ensure that calves can swim more effectively (Amano & Miyazaki, 1993).

Weight

Whole body weights of the above-mentioned 43 fresh specimens ranged from 7.5 to 47.5 kg. Total lengths of these specimens ranged from 70.3 to 148.2 cm (Brownell et al., 1987; Vidal, 1995).

Internal anatomy

Skull

Norris and McFarland (1958) described the species based on three skulls, and additional details were reported by Orr (1969), Noble and Fraser (1971), Brownell (1983), Magatagan et al. (1984), Barnes (1985), and Torre-Cosío (1995). Adult skulls are proportionally smaller and have relatively much broader and shorter rostra than other phocoenids. The condylobasal lengths of 36 skulls (immatures and matures) range from 180–243 mm. Ranges of additional selected skull measurements (mm) are zygomatic width 123–157 (n = 21), mandible length 158–184 (n = 21), and rostral length 79–93 (n = 17) (Brownell, 1983, Brownell, Jr., unpubl.; Torre-Cosío, 1995). The skull is illustrated in Fig. 13.4 and the tympanic bullae and periotics were illustrated by Brownell (1983). Based on 70 measurements of 10 and nine skulls of sexually mature females and males, respectively, Torre-Cosío (1995) found that males are larger than females in width of skull between the parietal bones, width between the paraoccipital apophyses, and height of the foramen magnum. Females were larger on average than males in maximum premaxillary width, left premaxillary width, and width of the nostrils. These characteristics are related to the respiratory system and sound production. In addition, the largest diameter of the temporal fossa and width of the foramen magnum are, on average, larger in females than males, related to the feeding apparatus and braincase, respectively. Sexual dimorphism is present in the basihyoid and thyrohyoid bones; mature males have wider thyrohyoids proportional to the condylobasal length, bones related to feeding and sound production.

Allometric growth in the skull was observed by comparing immature (n = 15) and mature (n = 13) individuals of both sexes (Torre-Cosío, 1995). Matures are larger, in proportion to condylobasal length, in maxillary length, premaxillary length, zygomatic width, zygomatic length, lacrimal length, vomerine width, mandibular height at its midpoint, mandibular symphysial length, and in the occipital condyle width and height. These characteristics are primarily associated with the ability to forage, which is more developed in mature individuals. The teeth have spatulate crowns and are uniform in size throughout the jaws, as in other species of *Phocoena*. In 24 specimens, the total number of erupted teeth in the maxillary rows was 16–22 and 17–20 in the mandibular rows (Brownell et al., 1987; Vidal, unpubl.).

Postcranial skeleton

The anterior three of the seven cervical vertebrae were fused in most individuals we examined, as is the case in *P. spinipinnis* (Brownell & Praderi, 1984). In three specimens,

FIG. 13.4   Lateral (A), dorsal (B) and ventral (C) views of skull and mandible (D) of adult female *Phocoena sinus* (SDMNH 20688) collected on April 24, 1966, ca. 24 km N San Felipe, Baja California, Upper Gulf of California, Mexico (Brownell, 1983). Total length was 139 cm; condylobasal length is 232 mm; mandible length is 171 mm. *Photographs by: Dallas Clites (SDMNH), R.L. Brownell, Jr©.*

the first four vertebrae were fused. The fourth and fifth vertebrae were also fused in another specimen but separated from the first three. There are 12–15 thoracic, 11–15 lumbar, and 26–31 caudal vertebrae, with 18–23 chevron bones (Noble & Fraser, 1971;

Brownell, 1983; Magatagan et al., 1984; Torre-Cosío, 1995; G. Carvallo-Ruiz, in litt.). The total number of vertebrae ranges between 58 and 64. The first six or seven ribs have capitular and tubercular attachments to the vertebrae. Six or seven pairs of sternal ribs are present, of which the first three are attached to the sternum. Based on counts from radiographs or prepared flipper skeletons of nine individuals, the phalangeal formula is: I 1–2, II 7–10, III 6–9, IV 3–5, V 1–3 (Torre-Cosío, 1995).

Abnormalities in the lumbar vertebrae were found in nine of 62 skeletons (both sexes and matures and immatures) examined (Torre-Cosío, 1995), consisting of hyperostosis and small protuberances on the neural spines and the fusion of vertebrae 26 and 27, or 27 and 28. Furthermore, 13 individuals presented small, already-ossified fractures in the vertebral ribs, perhaps caused by aggression between individuals or by unsuccessful predators. In immature and mature individuals, 48 examined pectoral fins displayed hyperphalangy, i.e., an abnormality in the form of a process or protuberance on the lateral portion of the third metacarpus between the third and fourth digits (Torre-Cosío, 1995). We speculate this represents a fixed non-deleterious random mutation (Torre-Cosío, 1995), and Ortega-Ortíz et al. (2000) ascribed it to genetic drift in the small vaquita population.

Soft anatomy

The range of blubber thickness in 19 vaquitas that varied in total length between 72.8 and 148.2 cm was: 8–33 mm mid-dorsal (adjacent to the anterior edge of dorsal fin), 8–19 mm mid-lateral, and 8–21 mm mid-ventral (Vidal, unpubl.). The relative blubber weight compared to total weight in one of the smallest specimens (93.5 cm) was 33.3%, but only 26.5% in one of the largest (148.2 cm). Ranges of selected organ weights from 19 specimens were presented in Vidal et al. (1999). G.E. Michel (in litt.) provided histological descriptions for tissues of 13 organs from nine vaquitas. In general, the microanatomy of *P. sinus* was found to resemble that of other "delphinoids," such as the bottlenose dolphin *Tursiops truncatus*.

Genetics

There is no evidence for more than one vaquita population (see Ben Chehida et al., 2019). Genetic studies, based on vaquitas taken at different times and locations in the Upper Gulf, found no sequence polymorphisms (i.e., no genetic variability in mitochondrial DNA), which may represent a population bottleneck, founder effect, or severe inbreeding (Rosel, 1992; Rosel & Rojas-Bracho, 1993). However, after analyzing whole-genome sequences from 20 vaquitas and integrating genomic and demographic information into stochastic individual-based simulations to quantify the species' recovery potential, Robinson et al. (2022) concluded that the vaquita's historical rarity has resulted in a low burden of segregating deleterious variation, reducing the risk of inbreeding depression, and that genome-informed simulations suggest that the vaquita can recover if bycatch mortality is immediately halted. Despite this elevated burden of weakly deleterious variants, remaining vaquita individuals appear healthy and are actively reproducing, which suggests that the species' fitness has not been severely compromised (Robinson et al., 2022).

Physiology

Thermoregulation and energetics

Very little has been published on the physiology of this porpoise. In vaquita, the potential for overheating is compounded by the fact that the species lives year-round in minimum water temperatures of 14°C and summer temperatures that can reach 36°C, which is a higher temperature than experienced by other porpoises. As discussed above, it has been hypothesized that the larger flippers, dorsal fin, and flukes of vaquita, relative to other porpoises, may be a functional adaptation to thermoregulate in such an environment (Brownell et al., 1987; Torre et al., 2014).

Senses

There have been no studies on senses specific to the vaquita.

Life history and population dynamics

Abundance and trends

The vaquita is a naturally rare species and its numbers were estimated to have ranged from 2000–5000 individuals for hundreds of thousands of years until fishing operations in its area of distribution began (Morin et al., 2021; Robinson et al., 2022; Taylor & Rojas-Bracho, 1999). Prior to 1986, only one (small) vessel cruise was specifically carried-out to survey for *P. sinus* (Wells et al., 1981). These authors surveyed a 1959 km transect that recorded only two sightings. The only other surveys wholly dedicated to *P. sinus* during the next decade were those by Silber (Silber, 1988, 1990a,b,c; Silber et al., 1988) and Gerrodette et al. (1994, 1995). A total of 4216 km of boat and aircraft surveys conducted during 77 days during 1986–89 resulted in only 58 sightings and 110 individuals (Silber, 1990a,b). In an aerial survey in the Northern Gulf, there was only one certain sighting of two vaquitas and a possible sighting of another single individual (Barlow et al., 1993). Noting the difficulty of observing vaquitas in the tidally induced turbid waters of the Upper Gulf, it was recommended that ships would be more effective for future surveys rather than aircraft (Barlow et al., 1993).

Until 1997, only three serious attempts were made to estimate the total size of the vaquita population. Based on Silber's censuses for 1986 and on 14 specimens caught incidentally in gillnets and examined during 1985 and 1986 (Brownell et al., 1987; Findley & Vidal, 1985; Robles et al., 1987), Barlow (1986) estimated 50–100 individuals as an approximate lower limit for the population. Based on four years of seasonal surveys, Silber (1990c) estimated 200–500 individuals for the entire population. The abundance of vaquita was estimated from four surveys conducted between 1986 and 1993, using a variety of methods (Barlow et al., 1997). Vaquita abundance was estimated at 503 (CV = 0.63) from 1986–93 boat surveys, 885 (CV = 0.50) from 1988–89 aerial surveys, 572 (CV = 1.43) from a 1991 aerial survey, and 224 (CV = 0.39) from a 1993 ship survey. All of these figures indicate that the population

in the early 1990s was already at a critically low level. A weighted log-linear regression indicated a rate of population decline of about 18% (95% CI = −43.2% to +19.3%) between 1986 and 1993.

After 1993, as a result of much more effort and dedicated surveys, the decline in vaquita numbers was well documented over the years using visual line-transects, acoustic monitoring, and photographic identifications (Gerrodette et al., 1994, 1995, 2011; Jaramillo-Legorreta et al., 1999, 2017, 2019, 2023; Jefferson et al., 2009; Rojas-Bracho et al., 2022; Rojas-Bracho, Booth et al., 2019; Rojas-Bracho, Brusca et al., 2019; Rojas-Bracho, Gulland et al., 2019; Taylor & Gerrodette, 1993; Taylor et al., 2017, 2019; Thomas et al., 2017). Due to the difficulty in sighting vaquitas, acoustic monitoring (Jaramillo-Legorreta et al., 2017) and photographic identification/mark-recapture (Jefferson et al., 2009) methods were developed to increase precision of estimating both abundance and trends in abundance, and a combination of visual and acoustic methods has been used afterward (Jaramillo-Legorreta et al., 2023). Between 1997 and 2015 the population declined by 92% (Taylor et al., 2017), 47% per year between 2018 and 2019 (fewer than 20 individuals were estimated for the entire population in 2018) (Jaramillo-Legorreta et al., 2019), and only around 10 individuals survived in 2021 (Rojas-Bracho et al., 2022). As abundance has declined, the distribution of vaquita has also shrunk. In May 2023, researchers focusing their attention in and around the small area off San Felipe, recorded 16 sightings and 61 acoustic encounters (Jaramillo-Legorreta et al., 2023). Using a method called expert elicitation, they estimated that the sightings included one to two calves and there was a 76% probability that the total number of vaquitas seen (including calves) was 8−13 individuals, which was considered a minimum estimate of the remaining vaquitas population, and about the same number as were estimated in 2019 and 2021 (Jaramillo-Legorreta et al., 2023).

Growth and reproduction

The life history of the vaquita appears, in many ways, to be like the harbor porpoise from the Bay of Fundy, in eastern Canada (Read & Gaskin, 1990). Almost nothing is known about the gestation period, but it is probably similar to *P. phocoena* (about 11 months) (see also Hohn et al., 1996). Neonates (n = 11) were approximately 70−78 cm in total length and weighed at least 7.5 kg; they are born mainly in March and April (Brownell, 1983; Brownell et al., 1987; Hohn et al., 1996; Silber & Norris, 1991; Vidal, 1995). Vidal (1995) also reported six other possible neonates (two referred to by fishers as "very small" and the other four estimated by them at around 50, 60, 70, and 80 cm) that died during fishing operations in March 1989 and February and April of 1990. Silber (1988, 1990a) reported seven calves (8.2% of all individuals) sighted during his surveys, six between 25 and 27 March, 1986, and one "very young, probably less than two days old" on April 9, 1987. Based on the limited data, parturition occurs in late winter and early spring, between February and April, with the peak in late March and early April (Hohn et al., 1996; Vidal, 1995). Also, calving appears to be annual (Taylor et al., 2019). The age structure of a sample killed in fishing nets was bimodal, with 62% of the specimens of 0−2 years and 31% of the specimens of 11−16 years (Hohn et al., 1996). The oldest individual was estimated to be 21 years (Hohn et al., 1996).

Brownell et al. (1987) and Vidal (1995) examined a total of 43 freshly killed individuals of known sex (19 males and 24 females). The smallest adult male and female were 128.3 and 135 cm total length, respectively. The weights of these two were 39 and 41 kg, respectively, and both were physically mature. The largest immature male and female were 127 and 128.7 cm long, respectively. Based on minimum testes weights (i.e., the weight of the smaller of the pair, with epididymis removed) of six males (284.3, 359.4, 480, 620, 642.1 and 643.8 g), the vaquita conform to a diversity of taxa where higher than expected testes mass is positively correlated with sperm competition (Dines et al., 2015). These relatively large testes fit the pattern of multiple males mating with a female and the sperm competing to fertilize the ova. The largest immature testis weight (i.e., the weight of the larger of the pair, with the epididymis removed) was 74.3 g.

Natural mortality

Several shark fishers of El Golfo de Santa Clara, who regularly captured vaquitas incidentally in gillnets, reported to one of us (O.V.) that in March 1985, February to May 1990 and 1991 they found whole or dismembered parts of vaquitas in the stomachs of several species of large sharks. The sharks were identified from photographs and/or dried jaws provided by the informants and included at least six species: white (*Carcharodon carcharias*), shortfin mako (*Isurus oxyrynchus*), Pacific lemon (*Negaprion fronto*), blacktip (*Carcharhinus limbatus*), bigeye thresher (*Alopias superciliosus*) and broadnose sevengill (*Notorhynchus cepedianus*) (Vidal, 1995; scientific and common names here updated following Page et al., 2023). Both the white and shortfin mako are known locally as "*tiburones tonina*" or "dolphin sharks" because of the nearly equal sizes of their caudal-fin lobes. On February 18, 1990, the stomach from a white shark about 3-m long and 160 kg weight was said to contain a vaquita that was bitten into three pieces. Two other "*tiburones tonina*," caught in March 1985 and in early February 1990, reportedly each had a vaquita in their stomachs. These sharks may attack free-swimming vaquitas, or perhaps feed on individuals trapped in gillnets or on carcasses of those that died of natural causes. Other large sharks that may be considered as potential predators include tiger (*Galeocerdo cuvier*) and scalloped hammerhead (*Sphyrna lewini*). However, with the decimation of shark populations in the Northern Gulf due to overfishing, especially during the past few decades (Bizzarro et al., 2009), predation events are potentially less frequent. Killer whales are potential predators of *P. sinus* and are not uncommon in the Gulf of California (Higuera-Rivas et al., 2023; Niño-Torres et al., 2011; Urbán et al., 2006; Vidal et al., 1993), and have been observed harassing and attacking larger cetaceans (Silber et al., 1990; Vidal & Pechter, 1989), but no information is available regarding potential predation on vaquitas.

Parasites and pathology

Parasites and commensals

Three parasitic trematodes from the intestine of a vaquita were identified as *Synthesium tursionis* and used in a redescription of this species by Lamothe-Argumedo (1988). Although

this author noted several characters that differed from "typical" specimens of this parasite, he considered them to be minor and not worthy of recognition as a new species. However, examination of a separate specimen of *Synthesium* from a different vaquita necropsied by us led M.D. Dailey (in litt.) to believe that recognition of a new species may be warranted. More specimens are needed to clarify the taxonomic status of this trematode in *P. sinus*. In materials resulting from necropsies of eight vaquitas in 1985, M.D. Dailey (in litt.) identified two specimens of the nematode *Crassicauda* sp., one from muscle connective tissue in the area of a mammary gland of one vaquita, and the other located in the blubber layer 1 cm below the skin and 5 cm anterior to the anus of the other vaquita. Unidentified larval nematodes were found in the stomachs of three vaquitas from the same sample and from muscle tissue in the area adjacent to a mammary gland (one vaquita) and the wall of the pleural cavity (one vaquita). Neither of the larval cestodes (*Phyllobothrium* sp. and *Monorygma* sp.) that have been found in most genera of marine odontocetes were present in the individuals we necropsied.

Commensal pseudo-stalked barnacles (*Xenobalanus globicipitis*) were found attached on or near the posterior edges of the dorsal fins, flippers and/or flukes of 14 of 43 fresh vaquitas that were examined (Brownell et al., 1987; Vidal, 1995). Also, what appeared to be parasitic copepods have been observed on the dorsal fins of vaquitas at sea (T.A. Jefferson, in litt.).

Disease

Detailed studies on disease have not been conducted on this species.

Behavior

Social organization

Like other phocoenids, *P. sinus* occurs singly or in small groups. In 58 sightings, 91% comprised from one to three individuals, with a mean group size of 1.9 and a range of 1−7 (Silber, 1990a,b). Loose aggregations in which they were dispersed as single individuals or as small subgroups (from two to four members, greatest number 8−10) throughout several hundred square meters were observed by Silber (1988) and Jefferson et al. (2009). All sightings comprised from one to three vaquitas (Gerrodette et al., 1994, 1995, 2011; Jaramillo-Legorreta et al., 1999, 2017, 2019, 2023; Jefferson et al., 2009; Norris & McFarland, 1958; Norris & Prescott, 1961; Rojas-Bracho, Gulland et al., 2019; Rojas-Bracho et al., 2022; Rojas-Bracho, Booth et al., 2019; Rojas-Bracho, Brusca et al., 2019; Taylor & Gerrodette, 1993; Taylor et al., 2017, 2019; Thomas et al., 2017; Vidal et al., 1987; Wells et al., 1981).

Interspecies associations

No mixed-species aggregations have been encountered, but Silber (1990a) reported two sightings of Bryde's whales (*Balaenoptera edeni*), and three sightings of common dolphins (*Delphinus delphis*) within <1 km and <1.5 km of groups of *P. sinus*, respectively. Numerous black storm petrels (*Halocyptena melania*) and Bonaparte's gulls (*Larus philadelphia*) were observed dipping into the wake of surfacing vaquitas (Silber, 1990a).

Locomotion and diving

Silber et al. (1988) provided the only available information on behavior and ventilation cycles of the vaquita. Two different female/calf pairs were observed for periods of about 3 h each. Dive characteristics were similar to those reported for *P. phocoena*. However, mean dive times, roll intervals, surface times, and rolls per surfacing reported for *P. phocoena* by Watson and Gaskin (1983) were of somewhat greater length than those of *P. sinus*.

Food and feeding

Based on analyses of stomach contents, vaquitas consume at least 23 different prey species, two squids and 21 teleost fishes (Table 13.1). Among the latter are bronzestriped grunt *Orthopristis reddingi* (Haemulidae) and bairdiella *Bairdiella icistia* (Sciaenidae) recovered from the stomach of one *P. sinus* carcass north of San Felipe in 1965 (Fitch & Brownell, 1968). Both fishes are found throughout the demersal zone of the Northern Gulf of California. Another beached vaquita specimen, collected near El Golfo de Santa Clara in 1984, had remains of sciaenids ("croakers" and "corvinas") in its stomach (Brownell., unpubl.). Two vaquitas collected in 1988 contained several whole fishes ("probably *Anchoa nasus* or *Sardinops* spp."), numerous unidentified fish otoliths, and squid beaks (Silber, 1990b). If the generic identification of the *Sardinops* is correct, it could only be *S. sagax*, the Pacific sardine (Alosidae, formerly in Clupeidae). Squid beaks, *Lolliguncula panamensis*, were also found in the stomachs of vaquitas collected in 1965 and 1984. Stomach contents of six vaquitas necropsied by us in 1985 yielded upper and lower beaks of the squids *L. panamensis* (103 total beaks and one whole squid) and *Lolliguncula (Loliolopsis) diomedeae* (25 total beaks) (identified by F.G. Hochberg, in litt.). The former species was present in all six stomachs analyzed, and the latter was found in two of the six. These squids appear abundant in coastal waters throughout the Gulf of California and southward.

The analysis of stomach contents from 24 vaquitas, collected between 1990 and 1993, showed the presence of the same two squids plus 17 species of fishes (Findley & Nava, 1994), the most common being the squid *L. panamensis*, the bigeye corvina *Isopisthus altipinnis* (Sciaenidae) and mimetic midshipman *Porichthys mimeticus* (Batrachoididae). The sample did not include *Sardinops* or *Anchoa nasus*, although five other species of anchovies (Engraulidae) were present. Also, the other 12 species of fishes encountered did not include the two species reported by Fitch and Brownell (1968), but we have no doubts about their identifications. All of the 17 fish species can be generally classified as pelagic, demersal or benthic species inhabiting relatively shallow water in the Upper Gulf of California (Table 13.1). It appears that the vaquita is a rather non-selective opportunistic feeder on small fishes and squids in this zone (Findley & Nava, 1994; Pérez-Cortez et al., 1996).

Acoustic behavior

Like other porpoises, vaquitas make only high-frequency narrow-band echolocation clicks in regular sequences known as click trains (Jaramillo-Legorreta et al., 2017, 2019, 2023; Silber, 1991), and click rate is relatively constant. Silber (1991) was the first to record these sounds near free-ranging vaquitas in 1986 and 1987. Clicks were sharp, intense, and narrow band

TABLE 13.1 Prey species of vaquita based on Findley and Nava (1994) complemented with Fitch and Brownell (1968)*, Silber (1990b)**, Pérez-Cortés et al. (1996)***.

Family	Species	Depth distribution	Sound emitter	Schooling behavior	FO%	FOSD	RA%	RASD	IRI	IRIDS
Squids										
Loliginidae	*Lolliguncula (Loliolopsis) diomedeae*	D	—	Yes	54.16	1.63	5.25	−0.001	284.57	0.16
Loliginidae	*Lolliguncula panamensis*	D	—	Yes	62.5	2.07	10.50	0.63	656.70	1.06
Fishes										
Ophidiidae	*Lepophidium prorates****	D	—	—	—	—	—	—	—	—
Engraulidae	*Anchoa sp.****	P	—	Yes	—	—	—	—	—	—
Engraulidae	*Anchoa helleri*	P	—	Yes	8.33	−0.75	0.72	−0.54	6.03	−0.51
Engraulidae	*Anchoa ischana****	P	—	Yes	—	—	—	—	—	—
Engraulidae	*Anchoa mundeoloides*	P	—	Yes	29.16	0.33	5.61	0.04	163.79	−0.13
Engraulidae	*Anchoa nasus (?)***	P	—	Yes	—	—	—	—	—	—
Engraulidae	*Anchovia macrolepidota*	P	—	Yes	4.16	−0.97	0.72	−0.54	3.01	−0.52
Engraulidae	*Cetengraulis mysticetus*	P	—	Yes	33.33	0.54	7.60	0.28	253.62	−0.08
Engraulidae	*Engraulis mordax*	P	—	Yes	4.16	−0.97	0.54	−0.56	2.26	−0.52
Alosidae	*Sardinops (?) sagax***	P	—	Yes	—	—	—	—	—	—
Sciaenidae	*Cynoscion othonopterus*	D	Yes	—	20.83	−0.10	2.17	−0.37	45.28	−0.41
Sciaenidae	*Cynoscion reticulatus*	D	Yes	—	8.33	−0.75	1.99	−0.39	16.60	−0.48
Sciaenidae	*Isopisthus altipinnis*	D	Yes	—	50	1.41	32.97	3.33	1648.55	3.48
Sciaenidae	*Larimus pacificus*	D	Yes	—	12.5	−0.53	1.26	−0.48	15.85	−0.49
Sciaenidae	*Micropogonias megalops*	D	Yes	—	33.33	0.54	2.71	−0.30	90.57	−0.30
Sciaenidae	*Cheilotrema saturnum*	D	Yes	—	4.16	−0.97	0.18	−0.61	0.75	−0.52
Sciaenidae	*Bairdiella icistia**	D	Yes	—	—	—	—	—	—	—
Haemulidae	*Orthopristis reddingi**	D	Yes	—	—	—	—	—	—	—
Haemulidae	*Pomadasys panamensis*	D	Yes	—	20.83	−0.10	2.52	−0.32	52.83	−0.40
Serranidae	*Diplectrum macropoma*	D	—	—	4.16	−0.97	0.18	−0.61	0.75	−0.52
Serranidae	*Diplectrum pacificum*	D	—	—	4.16	−0.97	1.26	−0.48	5.28	−0.51
Batrachoididae	*Porichthys analis*	B	Yes	—	4.16	−0.97	0.18	−0.61	0.75	−0.52
Batrachoididae	*Porichthys mimeticus*	B	Yes	—	37.5	0.76	20.47	1.82	767.66	1.33
Synodontidae	*Synodus sciuliceps*	B	—	—	37.5	0.76	3.07	−0.26	115.48	−0.24

Numericals by frequency of occurrence (FO), relative abundance (RA), and index of relative importance (IRI) with standard deviations (FOSD, RASD, and IRISD). Depth distribution is generalized as benthic (B), demersal (D) or pelagic (P). "Sound emitter" refers to fishes that can produce sounds.

(x = 1 7.1 ±: s.d. 5.38 kHz) signals in a frequency range of 122.2–146.9 kHz. Duration of clicks was 79–193 μs. The acoustic signals are similar to those reported for other phocoenids and for one genus of dolphins (*Cephalorhynchus* spp.) (Evans et al., 1988). The design and analyses of a robust acoustic monitoring program to estimate trends in the abundance of the vaquita since 2011 was described in detail by Jaramillo-Legorreta et al. (2017, 2019, 2023).

Live maintenance

The catastrophic decline of the vaquita population from about 200 to fewer than 30 individuals from 2008 to 2016 (Jaramillo-Legorreta et al., 2019; Taylor et al., 2017; Thomas et al., 2017) prompted the Mexican government (supported by scientists, aquaria, zoos, and the U.S. Navy) to facilitate the capture of vaquitas in an attempt to place them under protection in captivity (Rojas-Bracho, Gulland, et al., 2019). This US $5 million effort, called Vaquita CPR, was halted after an adult female died of capture myopathy and a juvenile was released because of capture stress (it is not known if it survived).

Human impacts

The long list of key events related to attempts to protect the vaquita over the last 66 years illustrates the various management and policy failures that have brought the species to the brink of extinction (Table 13.2). The pervasive role (such as delays or incompetence in the development of alternative fishing gear, delaying the issuance of research permits and denying incidental mortality as being the main risk factor) that Mexican fisheries authorities—the former Secretariat of Fisheries (SEPESCA), the National Commission on Aquaculture and Fisheries (CONAPESCA), and the Mexican Institute for Research on Sustainable Fisheries and Aquaculture (IMIPAS; formerly the National Institute of Fisheries, INAPESCA)—have played over decades, needs to be highlighted (e.g., Alaniz Pasini et al., 2019; Equihua et al., 2020).

Direct hunting

There is no evidence of any direct hunting of the vaquita.

Indirect killing/by-catch

The overwhelming human-induced problem affecting vaquita survival is incidental mortality in fishing gear. Vaquitas frequently die in illegal as well as past sporadically permitted "survey-sampling" gillnets principally set for the endemic totoaba (*Totoaba macdonaldi*), a very large corvina-like fish (Sciaenidae); in gillnets set for sharks, rays, mackerels (*Scomberomorus sierra* and *S. concolor*), corvinas (*Cynoscion* spp., principally *C. othonopterus*), Gulf croaker or chano norteño (*Micropogonias megalops*) and bottom-tethered gillnet ("*chinchorro de línea*") for shrimps and probably occasionally in commercial trawls for blue shrimp

TABLE 13.2 Key events and population status of vaquita *Phocoena sinus*.

Year	Event	Estimated vaquita population size (number of individuals)
Population estimated at 2000—5000 individuals for thousands of years (Morin et al., 2021; Robinson et al., 2022; Taylor & Rojas-Bracho, 1999).		
1958	Vaquita described as a new species (Norris & McFarland, 1958).	—
1975	Mexican government bans totoaba fishery.	—
1978	International Union for Conservation of Nature (IUCN) places vaquita on its Red List with status "Vulnerable".	
1979	Vaquita is listed in CITES Appendix I.	—
1985	US National Marine Fisheries Service (NMFS) adds vaquita to List of Endangered and Threatened Wildlife under the Endangered Species Act, effective February 8.	
1985	First fresh vaquita specimens from totoaba gillnets studied by scientists (Brownell et al., 1987; Findley & Vidal, 1985).	—
1986—93	First estimation of abundance using boat survey data from 1986 to 1993 (Barlow et al., 1997).	503 (CV = 0.63)
1988—89	First aerial survey estimates of abundance (Barlow et al., 1997).	885 (CV = 0.50)
1990	Listed as "Endangered" by IUCN.	—
1991	Second aerial survey estimate of abundance (Barlow et al., 1997).	572 (CV = 1.43)
1993	Upper Gulf of California and Colorado River Delta Biosphere Reserve established by Mexican government. New estimate of population (Barlow et al., 1997).	224 (CV = 0.39)
1994	Listed as endangered by Mexican government NOM-059—1994.	—
1996	Listed as "Critically Endangered" by IUCN.	—
1996/1997	International Committee for the Recovery of the Vaquita (CIRVA) established and new population estimate made (Jaramillo—Legorreta et al., 1999)	567 (CI 177—1073)
2000	Mexican National Fisheries Chart (Carta Pesquera) states that vaquita bycatch must be reduced to zero.	—
2005	Mexican government decrees a refuge area that encompasses about 80% of the area where vaquita sightings have occurred.	—
2008	Recovery Plan for the Vaquita (PACE) established by Mexican government. New population estimate (Gerrodette et al., 2011).	245 (CI 68—884)
2010	Organized crime networks in Mexico and China resume massive illegal fishing of totoaba (Cisneros-Mata, 2020; Sanjurjo-Rivera et al., 2021).	—
2015	Mexican President announces program to protect vaquita, including 2-year ban on gillnets in its habitat with Mexican Navy enforcing.	

TABLE 13.2 Key events and population status of vaquita *Phocoena sinus*.—cont'd

Year	Event	Estimated vaquita population size (number of individuals)
2016	Programs established to (1) remove "ghost" gillnets, and (2) develop fishing techniques that avoid catching vaquita (ECOFT).	—
2017	Conservación, Protección y Recuperación (CPR, Conservation, Protection and Recovery) project developed (Rojas-Bracho, Gulland, et al., 2019). Two vaquita captured (a juvenile was released because it appeared stressed, and an adult female died of capture myopathy) and CPR suspended because of risk of additional mortalities to the population (Rojas-Bracho, Gulland, et al., 2019).	—
2018	Abundance estimate of <20 individuals (Jaramillo-Legorreta et al., 2019) and USA bans fishing products caught with gillnets and imported from the Northern Gulf of California.	<20
2019–21	Abundance estimate of <10 individuals (Rojas-Bracho et al., 2022).	<10
2021	A zero-tolerance area for gillnet fishing established by Mexican government.	<10
2022	National Commission on Protected Areas (CONANP) and Mexico's Navy began sinking concrete blocks topped with metal hooks to snag illegal gillnets that are killing vaquita.	<10
2023	16 sightings, including 1–2 calves during a 2023 survey (Jaramillo-Legorreta et al., 2023).	Between 8 and 13
	In August, Mexican Navy deployed 193 concrete blocks and their hooks within a zero tolerance area off San Felipe, designed to entangle gillnets, a strategy that seems to be discouraging fishers from deploying those gillnets (Jaramillo-Legorreta et al., 2023).	
	Mexico's Navy and conservation group Sea Shepherd sign (October) agreement to expand the protected area.	

CI, Confidence Interval; *CV*, Confidence Variance.

(*Litopenaeus stylirostris*). A minimum of 143 vaquitas were killed in various fishing operations between March 1985 and January 1994 and an annual incidental mortality of 39 vaquitas was estimated (D'Agrosa et al., 1995, 2000; Vidal, 1993, 1995) (Fig. 13.5). Based on a largely separate data set, Turk-Boyer (1989) and Turk-Boyer and Silber (1990) estimated the annual fishing-related mortality was 32. These recorded kills must represent only a fraction of the total number of vaquitas that were killed in the various regional fishing operations.

The commercial fishery for totoaba in the Northern Gulf of California, initially using hook-and-line and primitive twined/tarred gillnets, began by at least the mid-1930s (Bahre et al., 2002) and unidentified small cetaceans were taken at that time (Brownell, 1982). More efficient nylon gillnets came into use during (and probably before) the 1960s and 1970s. Photographic records show that vaquitas were caught in gillnets since at least the early 1970s. Two

FIG. 13.5 *Phocoena sinus* incidentally caught in gillnets set for totoaba *Totoaba macdonaldi* in the Upper Gulf of California, Mexico, in 1985–91. *Photographs by: (A) A. Robles© and (B and C) C. Faesi O. Vidal©.*

were killed in gillnets set for totoaba in the late 1960s-early 1970s north of Puerto Peñasco, Sonora (these are shown in a photograph by Aberlardo Pino Ruíz, a.k.a. "El Kemal"; the photo and related information provided by L. Armendariz, in litt.). Also, two vaquitas (one a calf with visible fetal-fold marks, the other likely its mother) caught in gillnets set for totoaba by fishers in *pangas* operating from a shrimp boat "mothership" in 1972 were photographically documented by totoaba researcher C. Flanagan (in litt. and Brownell, 1983). After a peak catch of 2261 tons of totoaba flesh in 1942, and despite intensified fishing efforts, the annual catches declined to a minimum of approximately 59 tons in 1975, when the Mexican government declared an indefinite closed season that prohibits any capture of this species by commercial and sport fisheries (Flanagan & Hendrickson, 1976). Despite the closure and its minimal enforcement, illegal fishing for totoaba has continued mainly off the fishing towns of El Golfo de Santa Clara and San Felipe (Ben-Hasan et al., 2021; Cisneros-Mata et al., 1995; D'Agrosa et al., 1995, 2000; Lagomarsino, 1991; Román-Rodríguez, 1990; Vidal, 1995) and by 2023 was dominated by organized crime networks (Aceves-Bueno et al., 2023). Between March 1985 and January 1994, 76 vaquitas were confirmed to have been killed incidentally in totoaba gillnets (Vidal, 1995). Although lacking any quantitative data, some fishing cooperatives in the Northern Gulf claimed that the totoaba stock had "recovered" and that the fishery should be legally reopened. This pressure resulted in the issuing of some temporary permits in the mid-1980s for gillnet operations by SEPESCA to assess the population status of totoaba and to study various aspects of its biology (Barrera-Guevara, 1992; Findley & Vidal, 1985; Robles et al., 1987; Rosales & Ramírez, 1987; Vidal, 1995). To date, scientific efforts to assess the totoaba population and potential reopening of the fishery have proved difficult, largely theoretical and unsuccessful (Aceves-Bueno et al., 2021; Chávez, 2019; Cisneros-Mata, 2020; Ruíz-Barreiro, 2019). In 2021, however, the totoaba was downlisted to vulnerable from the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Endangered Species (IUCN, 2021) based on an assessment by Cisneros-Mata, True, et al. (2021). The sharp increase in illegal totoaba fishing around 2010 (see Cisneros-Mata, 2020; Sanjurjo-Rivera et al., 2021) resulted in a catastrophic decline of the vaquita population (Cisneros-Mata, Delgado, et al., 2021; Jaramillo-Legorreta et al., 2017; Taylor et al., 2017; Thomas et al., 2017). Fishers in the Upper Gulf can receive up to US $5000 per kilogram of totoaba swim bladders, or maw (locally called *buche* in Spanish) in the region's black market, although the same kilogram can be sold for US $25,000 in China's black market (EIA, 2016) or even as much as US $100,000 in an auction (EAL, 2018). China is the primary market for many types of dried seafood delicacies, including shark fins, sea cucumbers, sea snakes, abalones and fish swim bladders—including those of the totoaba (Ben-Hasan et al., 2021).

In addition to gillnet fishing for totoaba (mesh sizes 20−30.5 cm, now officially illegal), a gillnet fishery for several species of large sharks and rays (mesh size 10−15 cm) grew rapidly in the Upper Gulf beginning in the early 1940s, probably together with the totoaba fishery. The shark fishery operated without control (Bizzarro et al., 2009; D'Agrosa et al., 1995, 2000; Godínez-Padilla and Castillo-Geniz, 2016; Vidal, 1995; Vidal et al., 1994). Also, a gillnet fishery for sierra mackerels (*Scomberomorus* spp.), Gulf croaker or chano norteño (*Micropogonias megalops*), and various species of small sharks (e.g., *Rhizoprionodon longurio*, mesh size 8.5 cm) started in the Upper Gulf. Between 1985 and 1994, the shark and ray, mackerel, and *chano norteño* fisheries together incidentally captured at least 48 vaquitas during the

1990s only (D'Agrosa et al., 1995, 2000; Vidal, 1995). Also, four were killed during 1993–94 in bottom-tethered gillnets ("*chinchorro de línea*") (D'Agrosa et al., 1995, 2000). Although diminishing due to overfishing, all these fisheries were still active in 2024. Norris and Prescott (1961) mentioned a report by a fisher who had accidently captured vaquitas in a shrimp trawl. Nine vaquitas that also probably died in shrimp trawls (two in 1985, one in 1988, two between 1984–89, three in 1990, and one in 1993) were reported to O. Vidal, A. Robles, or C. D'Agrosa by residents of El Golfo de Santa Clara or San Felipe. All of the porpoises taken were referred to as "very small," probably calves or juveniles. Considering the large number (ca. 500) of shrimp boats operating in the 1990s in the Upper Gulf at the beginning of each typical shrimping season (e.g., Nava Romo, 1994; López-Martínez et al., 2010), this fishery posed an additional threat to vaquitas, particularly younger ones. However, shrimp trawling has decreased since the late 1990s due, among other factors, to the growth of shrimp farms along the shores of the Gulf of California. In an attempt to stop illegal gillnetting within the small area off San Felipe where vaquitas now concentrate, in August 2023 the Mexican Navy deployed on the seabed 193 concrete blocks with vertically rising steel hooks designed to entangle gillnets, a strategy that so far seems successful in discouraging fishers to deploy their illegal gillnets (Jaramillo-Legorreta et al., 2023).

Contaminants

Concerns have been expressed about organochlorine pollutants in the food web containing the vaquita in the Upper Gulf (Barlow, 1986; Klinowska & Cooke, 1991). When samples of blubber from eight vaquitas, incidentally killed in fishing activities during 1985 (see Brownell et al., 1987), were analyzed for chlorinated hydrocarbons (Calambokidis et al., 1993), relatively low concentrations of total DDT, alpha-BHC, and PCBs were found. These concentrations were generally much lower than those reported for various odontocetes and seabirds from many other areas. Nine vaquita carcasses were examined from 2016–18 and PCB, DDT and PBDE concentrations ranged between 94 and 180 ng/g, 500 and 1200 ng/g and 97 and 210 ng/g lipid weight, respectively, which are low compared with several other marine mammals (Gulland et al., 2020). Samples of small cetaceans collected between 2017 and 2019, including a vaquita from the Upper Gulf which had lower levels (about seven times) of DDT-related compounds and about 3.5 times lower PCBs than small cetaceans from southern Californian waters (Stack et al., 2022). Therefore, it appears that chlorinated hydrocarbons do not pose as great a threat to the vaquita as they may for populations of small cetaceans in other areas (Brusca et al., 2017; Gulland et al., 2020; Rojas-Bracho et al., 2006; Rojas-Bracho & Taylor, 1999).

Habitat loss and climate change

Some fishers and authors have suggested that decreased Colorado River flow, due to anthropogenic water impoundments and diversions, has had a negative impact on the health of the Northern Gulf of California ecosystem, particularly by increasing salinity or by reducing primary productivity and/or stock production of fishes and shellfish either through decreased nutrient input or increased salinity (e.g., Fleischer, 1996; Fleischer et al., 1996; Lau & Jacobs,

2017; Manjarrez-Bringas et al., 2018; Villa-Ramírez, 1993). Galindo-Bect (2012) and Galindo-Bect et al. (2013) argued that, although mortality of the vaquita is mainly due to fisheries bycatch, the damming of the Colorado River (purportedly) has caused declines in other species (shrimp and totoaba) and that something similar may be happening to vaquita. However, Ramírez-León et al. (2015), Brusca et al. (2017), Flessa et al. (2019) and Rojas-Bracho, Brusca et al. (2019), found no evidence that nutrient concentrations or primary productivity in the region has decreased and concluded that nutrient-related issues are not risk factors for the vaquita, and assertions that it has done so (e.g., Manjarrez-Bringas et al., 2018) deflect attention from the actual cause of decline—bycatch in legal and illegal gillnet fisheries. Furthermore, no emaciated vaquitas (including calves) have been observed, either dead or alive (e.g., Gulland et al., 2020; Jaramillo-Legorreta et al., 2023; Taylor et al., 2019; Vidal, 1995).

Behavioral disturbance

There appear to have been no detailed studies on behavioral disturbance in this species. Wells et al. (1981) suggested that vaquitas typically avoid boats, while Silber et al. (1988) noted no apparent response to their small boat when following two different female/calf pairs for several hours at distances of 40−200 m, nor to the presence of several nearby fishing skiffs (*pangas*); in each case, abbreviated surfacing sequences were noted as a possible reaction to the boats. Jefferson et al. (2009), however, reported the very close approach of vaquitas to stationary research vessels.

Other threats

There are plans underway to promote Puerto Peñasco as the most important tourist destination in Sonora, and also as a hub for large mega-infrastructure projects. We are aware of three such projects. One aims at building in Puerto Peñasco Latin America's largest and the world's eighth largest solar power plant with a planned reported investment of more than US $1.6 billion and production of 1000 MW. The second project, a large seawater desalination plant near Puerto Peñasco, was proposed by the State of Arizona which, if built, would generate large amounts of brine effluent that would be pumped back into the sea (brine is known to disrupt seagrass ecosystems, reefs, and soft-sediment communities) and create negative impacts on organisms key to the marine food web. There are also plans for constructing one of the world's largest liquefied natural gas production plants at Puerto Libertad, some 200 km southeast of Puerto Peñasco, including a deep-water port. According to Mexico Pacific, the U.S. company leading this project, the proposed facility would have a "nameplate capacity of 15 million mt/yr, with production targeted in the second half of 2027," and could be well into construction in 2024.

Epilogue

The vaquita is the world's most endangered mammal. Many aspects of the story of this porpoise's imminent demise have been recurrent with other endangered species worldwide.

These are mainly the result of the inability of governments, industries, scientists and NGOs to address—together and working with the local communities—the complex economic and social root causes of human-animal conflicts before it was too late. For five decades we have witnessed efforts to prevent the extinction of the vaquita. National and international pressure has been placed on Mexican authorities to protect this porpoise, and tens of millions of dollars have been allocated to, among others, paying fishers not to fish, and purportedly to support those who want to use more sustainable fishing techniques that do not kill vaquitas. However, there is no evidence that those funds were correctly used (i.e., invested in new selective gears, training of fishers and sustainable economic alternatives) nor were they evenly/properly distributed among fishers and fishing communities (see Alaniz Pasini et al., 2019; Equihua et al., 2020; Sanjurjo-Rivera et al., 2021). NGOs and other researchers have worked with regional fishers to develop sustainable fisheries (e.g., Acevedo-Bueno et al., 2023; Licon González et al., 2023; Senko et al., 2013; Sanjurjo-Rivera et al., 2021). All those efforts have essentially failed or were diminished because of lack of interest, support, or negligence from federal fisheries authorities. Half-way bans, simulated surveillance and monitoring, million-dollar compensations that were not transparent to fishers, and the Secretariat of Environment's (SEMARNAT) desperate attempt to capture vaquitas for conservation and reproduction in captivity (in 2017) have been of no use. Over the years, fisheries agencies and fisheries officials (e.g., Fleischer, 1996; Fleischer et al., 1996) have repeatedly undermined efforts to save the vaquita and promote sustainable fishing practices (e.g., Equihua et al., 2020; Sanjurjo-Rivera et al., 2021). Much the same can be said for a handful of Mexican researchers (Galindo-Bect, 2012; Galindo-Bect et al., 2013; Manjarrez-Bringas et al., 2018).

Saving the vaquita in light of the large commercial demand for totoaba swim bladders may seem almost impossible because organized crime networks are now so involved in their exploitation, sale, and transport. However, we believe that this porpoise can still be saved. The governments of Mexico, the United States, and China must finally take coordinated and immediate action. The Mexican government should enforce a stop—immediately and indefinitely—to all gillnetting in the Upper Gulf, including the illegal totoaba fishing, and also expand the current small protected area to include all of the vaquita's historical habitat. This will involve compensating fishers while facilitating a transition away from non-selective gillnets to gear that catches shrimp and fishes, but not vaquita. The United States government must take increasingly swift and decisive action to stop the trafficking of totoaba products across its border with Mexico. The Chinese government must immediately stop the illegal entry of totoaba products into its country. The public attention the vaquita has received has made it an emblematic "icon" of the environmental health of the Gulf of California—and much of this attention and support it has generated has indirectly benefited other endangered or depleted species. Today, virtually all Upper Gulf fisheries are overexploited. Once the vaquita is extinct, protection of the Northern Gulf's natural resources will very likely evaporate, and all of its other marine life will almost assuredly follow the same tragic path. And, in the end, regional fishers and their families will be in an even more desperate situation. It is, after all, Mexico and its rich marine environment that will suffer the consequences of the extinction of the vaquita.

Acknowledgments

References

Álvarez-Borrego, S., Rivera, J. A., Gaxiola-Castro, G., Acosta-Ruíz, M. J., & Schwartzlose, R. A. (1978). Nutrientes en el Golfo de California. *Ciencias Marinas, 5*, 53—71.

Aceves-Bueno, E., Davids, L., Rodríguez-Valencia, J. A., Jaramillo-Legorreta, A. M., Nieto-García, E., Cárdenas-Hinojosa, G., Hidalgo-Pla, E., Bonilla-Garzón, A., Díaz-de-León, A. J., Rojas-Bracho, L., & Cisneros-Mata, M. A. (2023). Derelict gear from an illegal fishery: Lessons from gear retrieval efforts in the upper Gulf of California. *Marine Policy, 147*, 105387.

Aceves-Bueno, E., Read, A. J., & Cisneros-Mata, M. A. (2021). Illegal fisheries, environmental crime, and the conservation of marine resources. *Conservation Biology, 35*, 1120—1129.

Alaniz Pasini, Y., Rivas Soto, M., Anzures Aguilar, M., Rojas Ortega, L., & Olivera Bonilla, A. (2019). *Vaquita marina ¿en qué te hemos fallado?* Greenpeace México. p. 66. Available at: https://www.greenpeace.org/static/planet4-mexico-stateless/2019/03/5e84a344-reporte-vaquita-marina.pdf.

Allen, G. M. (1925). Burmeister's porpoise (*Phocoena spinipinnis*). *Bulletin of the Museum of Comparative Zoology at Harvard College, 67*, 251—261 + 4 pls.

Amano, M., & Miyazaki, N. (1993). External morphology of Dall's porpoise (*Phocoenoides dalli*): Growth and sexual dimorphism. *Canadian Journal of Zoology, 71*, 1124—1130.

Bahre, C. J., Bourillón, L., & Torre, J. (2002). The Seri and commercial totoaba fishing (1930—1965). *Journal of the Southwest, 49*, 559—575.

Barlow, J. (1986). *Factors affecting the recovery of Phocoena sinus, the vaquita or Gulf of California harbor porpoise*. NOAA, NMFS, Southwest Fisheries Center Administrative Report LJ-86-37.

Barlow, J., Fleischer, L., Forney, K., & Maravilla-Chávez, O. (1993). An experimental aerial survey for vaquita (*Phocoena sinus*) in the northern Gulf of California, Mexico. *Marine Mammal Science, 9*, 89—94.

Barlow, J., Gerrodette, T., & Silber, G. (1997). First estimates of vaquita abundance. *Marine Mammal Science, 13*, 44—58.

Barnes, L. G. (1985). Evolution, taxonomy and antitropical distribution of the porpoises (Phocoenidae: Mammalia). *Marine Mammal Science, 1*, 149—165.

Barrera-Guevara, J. C. (1992). *Biología reproductiva de la totoaba Totoaba macdonaldi (Gilbert, 1890) (Teleostei: Sciaenidae)* [M.Sc. thesis]. Sonora, México: Instituto Tecnológico y de Estudios Superiores de Monterrey-Campus Guaymas.

Ben Chehida, Y., Thumloup, J., Schumacher, C., Harkins, T., Aguilar, A., Borrell, A., Ferreira, M., Rojas-Bracho, L., Roberston, K. M., Taylor, B. L., Vikingsson, G. A., Weyna, A., Romiguir, J., Morin, P. A., & Fontaine, M. C. (2019). Evolutionary history of the porpoises (Phocoenidae) across the speciation continuum: A mitogenome phylogeographic perspective. *Scientific Reports, 10*, 15190.

Ben-Hasan, A., de Mitcheson, Y. S., Cisneros-Mata, M. A., Jiménez, É. A., Daliri, M., Cisneros-Montemayor, A., Nair, R. J., Thankappan, S. A., Walters, C. J., & Christensen, V. (2021). China's fish maw demand and its implications for fisheries in source countries. *Marine Policy, 132*, 104696.

Bizzarro, J. J., Smith, W. D., Márquez-Farías, J. F., Tymonski, J., & Hueter, R. E. (2009). Temporal variation in the artisanal elasmobranch fishery of Sonora, Mexico. *Fisheries Research, 97*, 103—117.

Brownell, R. L., Jr. (1982). Status of the cochito, *Phocoena sinus*, in the Gulf of California. (FA0 Advisory Committee on Marine Resources Research. Mammals in the Seas: Small Cetaceans, Seals, Sirenians, and Otters). *FAO Fisheries Services 5, 4,* 85–90.

Brownell, R. L., Jr. (1983). Phocoena sinus. *Mammalian Species, 198,* 3 pp.

Brownell, R. L., Jr. (1986). Distribution of the vaquita, *Phocoena sinus*, in Mexican waters. *Marine Mammal Science, 2,* 299–305.

Brownell, R. L., Jr., & Praderi, R. (1984). Phocoena spinipinnis. *Mammalian Species, 217,* 4 pp.

Brownell, R. L., Jr., Findley, L. T., Vidal, O., Robles, A., & Manzanilla, N. S. (1987). External morphology and pigmentation of the vaquita, *Phocoena sinus* (Cetacea: Mammalia). *Marine Mammal Science, 3,* 22–30.

Brusca, R. C., Álvarez-Borrego, S., Hastings, P. A., & Findley, L. T. (2017). Colorado River flow and biological productivity in the Northern Gulf of California, Mexico. *Earth-Science Reviews, 164,* 1–30.

Calambokidis, J., Findley, L. T., Brownell, R. L., Jr., & Barlow, J. (1993). Chlorinated hydrocarbon concentrations in the Gulf of California harbor porpoise (Phocoena sinus). In *Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals,* November, Galveston, TX, USA (p. 13).

Cane, A. M. (1983). Oceanographic events during el Niño. *Science, 222,* 1189–1195.

Chávez, E. A. (2019). Simulation-based reconstruction for totoaba (*Totoaba macdonaldi* [Gilbert, 1890]; Perciformes, Sciaenidae) stock: Recovery scenario and management implications. *Journal of Aquaculture and Fisheries, 3,* 1–9.

Cisneros-Mata, M.Á. (Ed.). (2020). *Evaluación de la población de Totoaba macdonaldi.* Mexico City, México: México: INA-PESCA. 8 chapters by various authors, 105 pp.

Cisneros-Mata, M.Á., Delgado, J. A., & Rodríguez-Félix, D. (2021). Viability of the vaquita, *Phocoena sinus* (Cetacea: Phocoenidae) population, threatened by poaching of *Totoaba macdonaldi* (Perciformes: Sciaenidae). *Revista de Biologia Tropical, 69,* 588–600.

Cisneros-Mata, M. A., Montemayor-López, G., & Román-Rodríguez, M. J. (1995). Life history and conservation of *Totoaba macdonaldi. Conservation Biology, 9,* 806–814.

Cisneros-Mata, M. A., True, C., Enriquez-Paredes, L. M., Sadovy, Y., & Liu, M. (2021). Totoaba macdonaldi. *The IUCN Red List of Threatened Species 2021.* https://doi.org/10.2305/IUCN.UK.2021-2.RL. e.T22003A2780880.

D'Agrosa, C., Vidal, O., & Graham, W. C. (1995). Mortality of the vaquita (*Phocoena sinus*) in gillnet fisheries during 1993–94. *Reports of the International Whaling Commission, Special Issue, 16,* 283–291.

D'Agrosa, C., Vidal, O., & Graham, W. C. (2000). Vaquita bycatch in Mexico's artisanal gillnet fisheries: Driving a small population to extinction. *Conservation Biology, 14,* 1110–1119.

Dines, J. P., Mesnick, S. L., Ralls, K., May-Collado, L., Agnarsson, I., & Dean, M. D. (2015). A trade-off between precopulatory and postcopulatory trait investment in male cetaceans. *Evolution, 69,* 1560–1572.

Downhower, J. F., & Blumer, L. S. (1988). Calculating just how small a whale can be. *Nature, 335,* 675.

EAL (Elephant Action League). (2018). *Operation fake gold. The totoaba supply chain-from Mexico's totoaba cartels to China's totoaba maw wholesalers-an illegal trade killing the vaquita.* Available at: https://earthleagueinternational.org/wp-content/uploads/2018/07/EAL-Operation-Fake-Gold-Final.pdf.

EIA (Environmental Investigation Agency). (2016). Dual extinction: The illegal trade in the endangered totoaba and its impact on the critically endangered vaquita. In *Briefing to the 66th Standing Committee of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora).* Available at: https://eia-international.org/wp-content/uploads/EIA-Dual-Extinction.pdf.

Equihua, C., Medellín, R., & García, J. M. (2020). *Vaquita marina, irresponsabilidad y corrupción. Crónica de una tragedia. Nexos (June). (Vaquita marina, irresponsabilidad y corrupción. Crónica de una tragedia - Crisis ambiental - Blog de medio ambiente.* nexos.com.mx.

Evans, W. E., Awbrey, F. T., & Hackharth, H. (1988). High frequency pulses produced by free-ranging Commerson's dolphin (*Cephalorhynchus commersonii*) compared to those of phocoenids. *Reports of the International Whaling Commission,* (Special Issue 9), 173–181.

Fajardo-Mellor, L., Berta, A., Brownell, R. L., Jr., Boy, C. C., & Goodall, N. P. (2006). The phylogenetic relationships and biogeography of true porpoises (Mammalia: Phocoenidae) based on morphological data. *Marine Mammal Science, 22,* 910–932.

Findley, L. T., & Nava, J. M. (1994). *Food habits of the vaquita, Phocoena sinus* (p. 43). Crystal City, VA, USA: Final report to Conservation International.

Findley, L. T., & Vidal, O. (1985). La marsopa del Golfo de California. *Informacion Científica y Tecnológica, 7*(105), 15.

Fitch, J. E., & Brownell, R. L., Jr. (1968). Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits. *Journal of the Fisheries Research Board of Canada, 25*, 2561–2574.

Flanagan, C. A., & Hendrickson, J. R. (1976). Observations on the commercial fishery and reproductive biology of the totoaba, *Cynoscion macdonaldi*, in the northern Gulf of California. *Fishery Bulletin, 74*, 531–544.

Fleischer, L. (1996). Mexico progress report on cetacean research. April 1994 to March 1995. *Reports of the International Whaling Commission, 46*, 262–265.

Fleischer, L., Moncada-Cooley, R., Pérez-Cortés, H., & Polanco-Ortíz, A. (1996). Análisis de la mortalidad incidental de la vaquita, *Phocoena sinus*. Historia y actualidad (abril de 1994). *Ciencia Pesquera, 13*, 78–82.

Flessa, K. W., Calderon-Aguilera, L., Cintra-Buenrostro, C. E., Dettman, D. L., Dietl, G. P., Goodwin, D. H., Jacobs, D. K., Kowalewski, M., Nelson, S. M., Rowell, K., Schone, B. R., Smith, J. A., & Zamora-Arroyo, F. (2019). Vaquita face extinction from bycatch. Comment on Manjarrez-Bringas et al., Lessons for Sustainable Development: Marine Mammal Conservation Policies and Its Social and Economic Effects. *Sustainability 2018, 10*, 2185. *Sustainability, 11*, 2161.

Galindo-Bect, M. S. (2012). *Nutrients in the upper Gulf of California and the Colorado River Delta. Report of the 4th Meeting of the International Committee for the Recovery of the Vaquita.* Available at: http://www.iucn-csg.org/wp-content/uploads/2010/03/Report-of-the-Fourth-Meeting-of-theInternational-Committee-for-the-Recovery-of-Vaquita.pdf.

Galindo-Bect, M. S., Santa Ríos, A., Hernández-Ayón, J. M., Huerta-Díaz, M. A., & Delgadillo-Hinojosa, F. (2013). The use of urban wastewater for the Colorado River delta restoration. *Procedia Environmental Sciences, 18*, 829–835.

Gao, A., & Zhou, K. (1995). Geographical variation of external measurements and three subspecies of *Neophocaena phocaenoides* in Chinese waters [in Chinese with English summary]. *Acta Theriologica Sinica, 15*, 81–92.

Gaskin, D. E., Smith, G. J. D., Watson, A. P., Yasui, W. Y., & Yurick, D. B. (1984). Reproduction in the porpoises (Phocoenidae): Implications for management. *Reports of the International Whaling Commission*, (Special Issue 6), 135–148.

Gerrodette, T., Barlow, J., Taylor, B. L., & Silber, G. S. (1994). First population estimates of the endangered porpoise, *Phocoena sinus*, with implications for monitoring small populations. In *Abstracts of the 1994 International Meeting of the Society for Conservation Biology,* June, Guadalajara, Mexico (p. 90).

Gerrodette, T., Fleischer, L. A., Pérez-Cortés, H., & Villa-Ramírez, B. (1995). Distribution of the vaquita, *Phocoena sinus*, based on sightings from systematic surveys. *Reports of the International Whaling Commission*, (Special Issue 16), 273–281.

Gerrodette, T., Taylor, B. L., Swift, R., Rankin, S., Jaramillo-Legorreta, A. M., & Rojas-Bracho, L. (2011). A combined visual and acoustic estimate of 2008 abundance, and change in abundance since 1997, for the vaquita, *Phocoena sinus*. *Marine Mammal Science, 2*, E79–E100.

Godínez-Padilla, C. J., & Castillo-Geniz, J. L. (2016). Distribución y abundancia de elasmobranquios capturados por la flota comercial escamera de mediana altura de San Felipe, Baja California, México. *Ciencia Pesquera, 24*, 27–44.

Goodall, R. N. R., & Schiavini, A. C. M. (1995). On the biology of the spectacled porpoise, *Australophocaena dioptrica*. *Reports of the International Whaling Commission*, (Special Issue 16), 412–453.

Gulland, F., Danil, K., Bolton, J., Ylitalo, G., Okrucky, R. S., Rebolledo, F., Alexander-Beloch, C., Brownell, R. L., Jr., Mesnick, S., Lefebvre, K., Smith, C. R., Thomas, P. O., & Rojas-Bracho, L. (2020). Vaquitas (*Phocoena sinus*) continue to die from bycatch not pollutants. *The Veterinary Record, 187*, e51.

Higuera-Rivas, J. H., Hoyos-Padilla, E. M., Elorriaga-Verplancken, F. R., Rosales-Nanduca, H., Rosenthal, R., & Urbán R, J. (2023). Orcas (*Orcinus orca*) use different strategies to prey on rays in the Gulf of California. *Aquatic Mammals, 49*, 1–18.

Hohn, A. A., Read, A. J., Fernández, S., Vidal, O., & Findley, L. T. (1996). Life history of the vaquita, *Phocoena sinus* (Phocoenidae, Cetacea). *Journal of Zoology, 39*, 235–251.

IUCN (International Union for Conservation of Nature and Natural Resources). (2021). The IUCN red list of threatened species™ ISSN 2307-8235 (online) IUCN 2021: T22003A2780880.

Jaramillo-Legorreta, A. M., Bonilla-Garzón, A., Cárdenas-Hinojosa, G., Nieto, E., Taylor, B. L., Mesnick, S., Henry, A., Sánchez-Alós, L., Van Sull, F., Booth, C., & Thomas, L. (2023). *Vaquita-Survey-2023-Main-Report-FINAL-1.pdf (iucn-csg.org)*, 18 pp. Available at: https://iucn-csg.org/wp-content/uploads/2023/06/Vaquita-Survey-2023-Main-Report.pdf.

Jaramillo-Legorreta, A. M., Cárdenas-Hinojosa, G., Nieto-García, E., Rojas-Bracho, L., Thomas, L., Ver Hoef, J. M., Moore, J., Taylor, B., Barlow, J., & Tregenza, N. (2019). Decline towards extinction of Mexico's vaquita porpoise (*Phocoena sinus*). *Royal Society Open Science, 6*, 190598.

Jaramillo-Legorreta, A., Cárdenas-Hinojosa, G., Nieto-García, E., Rojas-Bracho, L., Ver Hoef, J., Moore, J., Tregenza, N., Barlow, J., Gerrodette, T., Thomas, L., & Taylor, B. (2017). Passive acoustic monitoring of the decline of Mexico's critically endangered vaquita. *Conservation Biolology, 31*, 183—191.

Jaramillo-Legorreta, A. M., Rojas-Bracho, L., & Gerrodette, T. (1999). A new abundance estimate for vaquitas: First step for recovery. *Marine Mammal Science, 15*, 957—973.

Jefferson, T. A. (1990). Sexual dimorphism and development of external features in Dall's porpoise *Phocoenoides dalli*. *Fishery Bulletin, 88*, 119—132.

Jefferson, T. A., Olson, P. A., Kieckhefer, T. R., & Rojas-Bracho, L. (2009). Photo-identification of the vaquita (*Phocoena sinus*): The world's most endangered cetacean. *Latin American Journal of Aquatic Mammals, 7*, 53—56.

Klinowska, M., & Cooke, J. (1991). Vaquita. In *Dolphins, porpoises and whales of the world, the IUCN red data book* (pp. 105—108).

Lagomarsino, I. V. (1991). *Endangered species status review: Totoaba macdonaldi*. NOAA, NMFS Southwest Region Administrative Report SWR-91-01.

Lamothe-Argumedo, R. (1988). Trematodos de mamíferos III. Hallazgo de *Syntherium tursionis* (Marchi, 1873) Stunkard y Alvey 1930 en *Phocoena sinus* (Phocoenidae) en el Golfo de California, México. *Anales del Instituto de Biología Universidad Nacional Autónoma de México Serie Zoología, 58*, 11—39.

Lau, C. L. F., & Jacobs, D. K. (2017). Introgression between ecologically distinct species following increased salinity in the Colorado Delta—Worldwide implications for impacted estuary diversity. *PeerJ, 5*, e4056.

Licon González, H. A., Sanjurjo Rivera, E., Olivares Bañuelos, N. C., Vázquez Vera, W. L., & Ortiz Rodríguez, R. (2023). Experiencias de manejo participativo en la pesquería de curvina golfina en el alto golfo de California. *Región Y Sociedad, 35*, e1678.

López-Martínez, J., Herrera-Valdivia, E., Rodríguez-Romero, J., & Hernández-Vázquez, S. (2010). Peces de la fauna de acompañamiento de la pesca industrial de camarón en el Golfo de California, México. *Revista de Biologia Tropical, 58*, 925—942.

Magatagan, M. D., Boyer, E. H., & Villa-Ramírez, B. (1984). Revisión del estado que guarda *Phocoena sinus* Norris and McFarland y descripción de tres nuevos ejemplares. *Anales del Instituto de Biología Universidad Nacional Autónoma de México Serie Zoología, 55*, 271—293.

Manjarrez-Bringas, N., Aragón-Noriega, E. A., Beltrán-Morales, L. F., Cordoba-Matson, M. V., & Ortega-Rubio, A. (2018). Lessons for sustainable development: Marine mammal conservation policies and its social and economic effects. *Sustainability, 10*(2185), 13 pp.

McGowen, M. R., Spaulding, M., & Gatesy, J. (2009). Divergence date estimation and a comprehensive molecular tree of extant cetaceans. *Molecular Phylogenetics and Evolution, 53*, 891—906.

Mellor, L., Cooper, L. N., Torre, J., & Brownell, R. L., Jr. (2009). *Paedomorphic ossification in porpoises with an emphasis on the vaquita (Phocoena sinus)*. Publications, Agencies and Staff of the U.S. Department of Commerce, p. 67. Available at: https://digitalcommons.unl.edu/usdeptcommercepub/67.

Mesnick, S., & Ralls, K. (2018). Sexual dimorphism. In B. Würsig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of marine mammals* (3rd ed., pp. 848—853).

Mitchell, E. D. (1975). Review of the biology and fisheries for smaller cetaceans. *Journal of the Fisheries Research Board of Canada, 32*, 875—1240.

Morin, P. A., Archer, F. I., Avila, C. D., Balacco, J. R., Bukhman, J. Y. V., Chow, Y. W., Fedrigo, O., Formenti, G., Fronczek, J. A., Fungtammasan, A., Gulland, F. M. D., Haase, B., Heide-Jorgensen, M. P., Houck, M. L., Howe, K., Misuraca, A. C., Mountcastle, J., Musser, W., Paez, S., … Jarvis, E. D. (2021). Reference genome and demographic history of the most endangered marine mammal, the vaquita. *Molecular Ecology Resources, 21*, 1008—1020.

Nava Romo, J. M. (1994). *Impactos a corto, mediano y largo plaza, en la biodiversidad y otras características ecológicas en la comunidad bentónico-demersal capturada por la pesquería del camarón en el norte del Alto Golfo de California, México* [MSc tesis]. Sonora, México: Instituto Tecnológico y de Estudios Superiores de Monterrey- Campus Guaymas, 86 pp.

Niño-Torres, C. A., Urbán-Ramírez, J., & Vidal, O. (2011). *Mamíferos Marinos del Golfo de California: Guía Ilustrada*. Publicación Especial 2, Alianza WWF México-Telcel, 192 pp.

Nishiwaki, M., & Kureha, K. (1975). Strange organ in the anal region of the finless porpoise. *The Scientific. Reports of the Whales Research Institute, 27*, 139–140.

Noble, B. A., & Fraser, F. C. (1971). Description of a skeleton and supplementary notes on the skull of a rare porpoise *Phocoena sinus* Norris and McFarland, 1958. *Journal of Natural History, 5*, 447–464.

Norris, K. S., & Prescott, J. H. (1961). Observations on Pacific cetaceans of Californian and Mexican waters. *University of California Publications in Zoology, 63*, 291–402.

Norris, K. S., & McFarland, W. N. (1958). A new harbor porpoise of the genus *Phocoena* from the Gulf of California. *Journal of Mammalogy, 42*, 22–39.

Orr, R. T. (1969). An additional record of *Phocoena sinus*. *Journal of Mammalogy, 50*, 384.

Ortega-Ortíz, J. G., Villa-Ramírez, B., & Gersenowies, J. R. (2000). Polydactyly and other features of the manus of the vaquita, *Phocoena sinus*. *Marine Mammal Science, 16*, 277–286.

Page, L. M., Bemis, K. E., Dowling, T. E., Espinosa-Perez, H., Findley, L. T., Gilbert, C. R., Hartel, K. E., Lea, R. N., Mandrak, N. E., Neighbors, M. A., Schmitter-Soto, J. J., & Walker, H. J., Jr. (2023). *Common and scientific names of fishes from the United States, Canada, and Mexico* (8th ed.). Bethesda, Maryland: American Fisheries Society, Special Publication 37. vii + 439 pp.

Pérez-Cortéz, H., Silber, G. K., & Villa, R.,B. (1996). Contribución al conocimiento de la alimentación de la vaquita, Phocoena sinus. INP. SEMARNAP. *Ciencia Pesquera, 13*, 66–72.

Perrin, W. F. (1972). Color patterns of spinner porpoises (*Stenella* cf. *S. longirostris*) of the eastern Pacific and Hawaii, with comments on delphinid pigmentation. *Fishery Bulletin, 70*, 983–1003.

Perrin, W. F. (1975). Variation of spotted and spinner porpoise (genus *Stenella*) in the eastern Pacific and Hawaii. *Bulletin of the Scripps Institution of Oceanography, 21*, 1–206.

Perrin, W. F., Mitchell, E. D., Mead, J. G., Caldwell, D. K., & van Bree, P. J. H. (1981). *Stenella clymene*, a rediscovered tropical dolphin of the Atlantic. *Journal of Mammalogy, 62*, 583–598.

Ralls, K. (1976). Mammals in which females are larger than males. *Quarterly Review of Biology, 51*, 245–276.

Ralls, K., & Mesnick, S. (2009). Sexual dimorphism. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (2nd ed., pp. 1005–1011). Academic Press.

Ramírez-León, M. R., Álvarez-Borrego, S., Turrent-Thompson, C., Gaxiola-Castro, G., & Heckel-Dziendzielewski, G. (2015). Nutrient input from the Colorado River water to the northern Gulf of California is not required to maintain its pelagic ecosystem productivity. *Ciencias Marinas, 41*, 169–188.

Read, A. J., & Gaskin, D. E. (1990). Changes in growth and reproduction of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. *Canadian Journal of Fisheries and Aquatic Sciences, 47*, 2158–2163.

Read, A. J., & Tolley, K. A. (1997). Postnatal growth and allometry of harbour porpoises from the Bay of Fundy. *Canadian Journal of Zoology, 75*, 122–130.

Reyes, J. C., & Van Waerebeek, K. (1995). Aspects of the biology of Burmeister's porpoise from Peru. *Reports of the International Whaling Commission, Special Issue, 16*, 249–364.

Robinson, J. A., Kyriazis, C. C., Nigenda-Morales, S. F., Beichman, A. C., Rojas-Bracho, L., Robertson, K. M., Fontaine, M. C., Wayne, R. K., Lohmueller, K. E., Taylor, B. L., & Morin, P. A. (2022). The critically endangered vaquita is not doomed to extinction by inbreeding depression. *Science, 376*(6593), 635–639.

Robles, A., Vidal, O., & Findley, L. T. (1987). La totoaba y la vaquita. *Información Científica y Tecnológica, 9*(124), 4–6.

Rojas-Bracho, L., & Taylor, B. L. (1999). Risk factors affecting the vaquita (*Phocoena sinus*). *Marine Mammal Science, 15*, 974–989.

Rojas-Bracho, L., Booth, C., Taylor, B., Thomas, L., Gerrodette, T., & Henry, A. (2019). *Report on using expert elicitation to estimate total unique vaquitas and calves in the zero tolerance area with recommendations for future research efforts.* Available at: https://iucn-csg.org/wpcontent/uploads/2021/04/Vaquita-Report-on-Using-Expert-Elicitation-Final.pdf.

Rojas-Bracho, L., Brusca, R. C., Álvarez-Borrego, S., Brownell, R. L., Jr., Camacho-Ibar, V., Ceballos, G., de la Cueva, H., García-Hernández, J., Hastings, P. A., Cárdenas-Hinojosa, G., Jaramillo-Legorreta, A. M., Medellín, R., Mesnick, S. L., Nieto-García, E., Urbán, J., Velarde, E., Vidal, O., Findley, L. T., & Taylor, B. L. (2019). Unsubstantiated scientific claims can lead to tragic conservation outcomes. *BioScience, 69*, 12–14.

Rojas-Bracho, L., Gulland, F. M. D., Smith, C. R., Taylor, B., Wells, R. S., Thomas, P. O., Bauer, B., Heide-Jørgensen, M. P., Teilmann, J., Dietz, R., Balle, J. D., Jensen, M. V., Sinding, M. H. S., Jaramillo-Legorreta, A., Abel, G., Read, A. J., Westgate, A. J., Colegrove, K., Gomez, F., … Walker, S. (2019). A field effort to capture

critically endangered vaquitas *Phocoena sinus* for protection from entanglement in illegal gillnets. *Endangered Species Research, 38*, 1—27.

Rojas-Bracho, L., Reeves, R. R., & Jaramillo-Legorreta, A. (2006). Conservation of the vaquita, *Phocoena sinus. Mammal Review, 36*, 179—216.

Rojas-Bracho, L., Taylor, B., Booth, C., Thomas, L., Jaramillo-Legorreta, A., Nieto García, E., Cárdenas Hinojosa, G., Barlow, J., Mesnick, S. L., Gerrodette, T., Olson, P., Henry, A., Rizo, H., Hidalgo-Pla, E., & Bonilla-Garzón, A. (2022). Benefits of monitoring very small populations: More vaquita porpoises survive than expected. *Endangered Species Research, 48*, 225—234.

Román-Rodríguez, M. J. (1990). Alimentación de *Totoaba macdonaldi* (Gilbert) (Pisces: Sciaenidae) en la parte norte del Alto Golfo de California. Ecológica *(Centro Ecológico de Sonora, Hermosillo, México), 1*, 1—9.

Rosales Juárez, F., & Ramírez González, E. (1987). *Estado actual del conocimiento sobre la totoaba (*Cynoscion macdonaldi*) Gilbert, 1890*. Secretaría de Pesca de México, 42 pp.

Rosel, P. E. (1992). *Genetic population structure and systematic relationships of some small cetaceans inferred from mitochondrial DNA sequence variation* [Ph.D. dissertation]. University of California at San Diego, USA.

Rosel, P. E., & Rojas-Bracho, L. (1993). Genetic variation, or lack thereof, in the vaquita. In *Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals, November, Galveston, TX, USA* (p. 13).

Rosel, P. E., Haygood, M. G., & Perrin, W. F. (1995). Phylogenetic relationships among the true porpoises (Cetacea: Phocoenidae). *Molecular Phylogenetics and Evolution, 4*, 463—474.

Ruíz-Barreiro, T. M. (2019). *Viabilidad de la reactivación de una pesquería deportivo-recreativa de totoaba (*Totoaba macdonaldi, *Gilbert 1890) en el Alto Golfo de California* [Ph.D. dissertation]. La Paz, BCS, México: Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas.

Sanjurjo-Rivera, E., Mesnick, S. L., Ávila-Forcada, S., Poindexter, O., Lent, O. R., Felbab-Brown, V., Cisneros-Montemayor, A. M., Squires, D., Sumaila, U. R., Munro, U. G., Ortiz-Rodríguez, R., Rodríguez, & Sainz, J. F. (2021). An economic perspective on policies to save the vaquita: Conservation actions, wildlife trafficking, and the structure of incentives. *Frontiers in Marine Science, 8*, 644022.

Senko, J., White, E. R., Hepell, S. S., & Gerber, L. R. (2013). Comparing bycatch mitigation strategies for vulnerable marine megafauna. *Animal Conservation, 17*, 5—18.

Shirakihara, M., Takemura, A., & Shirakihara, K. (1993). Age, growth, and reproduction of the finless porpoise, *Neophocoena phocaenoides*, in the coastal waters of western Kyushu, Japan. *Marine Mammal Science, 9*, 392—406.

Silber, G. K. (1988). Recent sightings of the Gulf of California harbor porpoise (*Phocoena sinus*). *Journal of Mammalogy, 69*, 430—433.

Silber, G. K. (1990a). Occurrence and distribution of the vaquita (*Phocoena sinus*) in the northern Gulf of California. *Fishery Bulletin, 88*, 339—346.

Silber, G. K. (1990b). *Distributional relations of cetaceans in the northern Gulf of California, with special reference to the vaquita, Phocoena sinus* [Ph.D. dissertation]. University of California at Santa Cruz, USA.

Silber, G. K. (1990c). Summary of field study of the vaquita, *Phocoena sinus. Presented to the Environment Committee, the Commission of the Californias,* 18-20, January, Tijuana, Baja California, México.

Silber, G. K. (1991). Acoustic signals of the vaquita (*Phocoena sinus*). *Aquatic Mammals, 17*, 130—133.

Silber, G. K., Newcomer, M. V., & Pérez-Cortés, M. H. (1990). Killer whales (*Orcinus orca*) attack and kill a Bryde's whale (*Balaenoptera edeni*). *Canadian Journal of Zoology, 68*, 1603—1606.

Silber, G. K., Newcomer, M. W., & Barros, G. J. (1988). Observations on the behavior and ventilation cycles of the vaquita (*Phocoena sinus*). *Marine Mammal Science, 4*, 62—67.

Silber, G. K., & Norris, K. S. (1991). Geographic and seasonal distribution of the vaquita, *Phocoena sinus. Anales del Instituto de Biología Universidad Nacional Autónoma de México Serie Zoología, 62*, 263—268.

Slooten, E. (1991). Age, growth and reproduction in Hector's dolphins. *Canadian Journal of Zoology, 69*, 1689—1700.

Stack, M. E., Cossaboon, J. M., Tubbs, C. W., Vilchis, L. I., Felton, R. G., Johnson, J. L., Danil, K., Heckel, G., Hoh, E., & Dodder, N. G. (2022). Assessing marine endocrine-disrupting chemicals in the critically endangered California condor: Implications for reintroduction to coastal environments. *Environmental Science & Technology, 21*(56), 7800—7809.

Taylor, B. L., & Gerrodette, T. (1993). The uses of statistical power in conservation biology: The vaquita and the northern spotted owl. *Conservation Biology, 7*, 489—500.

Taylor, B. L., & Rojas-Bracho, L. (1999). Examining the risk of genetic depression in a natural rare cetacean, the vaquita (*Phocoena sinus*). *Marine Mammal Science, 15*, 1004—1028.

Taylor, B. L., Rojas-Bracho, L., Moore, J., Jaramillo-Legorreta, A., Ver Hoef, J. M., Cárdenas-Hinojosa, G., Nieto-García, E., Barlow, J., Gerrodette, T., Tregenza, N., Thomas, L., & Hammond, P. S. (2017). Extinction is imminent for Mexico's endemic porpoise unless fishery bycatch is eliminated. *Conservation Letters*. https://doi.org/10.1111/conl.12331

Taylor, B. L., Wells, R. S., Olson, P. A., Brownell, R. L., Jr., Gulland, F. M. D., Read, A. J., Valverde-Esparza, F. J., Ortiz-García, O. H., Ruiz-Sabio, D., Jaramillo-Legorreta, A. M., Nieto-Garcia, E., Cardenas-Hinojosa, G., & Rojas-Bracho, L. (2019). Likely annual calving in the vaquita, *Phocoena sinus*: A new hope? *Marine Mammal Science, 35*, 1603−1612.

Thomas, L., Jaramillo-Legorreta, A., Cardenas-Hinojosa, G., Nieto-Garcia, E., Rojas-Bracho, L., Ver Hoef, J. M., Moore, J., Taylor, B., Barlow, J., & Tregenza, N. (2017). Last call: Passive acoustic monitoring shows continued rapid decline of critically endangered vaquita. *Journal of the Acoustic Society of America, 142*(5), EL512.

Torre, J., Vidal, O., & Brownell, R. L., Jr. (2014). Sexual dimorphism and developmental patterns in the external morphology of the vaquita, *Phocoena sinus*. *Marine Mammal Science, 30*, 1285−1296.

Torre-Cosío, J. (1995). *Descripción del esqueleto, dimorfismo sexual y crecimiento alométrico craneal de la vaquita, Phocoena sinus (Cetacea: Phocoenidae)* [MSc thesis]. Sonora, México: Instituto Tecnológico y de Estudios Superiores de Monterrey-Campus Guaymas.

Turk-Boyer, P. J. (1989). *Assessment of the potential impact of fishing activities in the northern Gulf of California on the Phocoena sinus population*. Washington, DC: Report submitted to the Center for Marine Conservation.

Turk-Boyer, P. J., & Silber, G. K. (1990). Estimate of vaquita, *Phocoena sinus*, mortality in gillnet fisheries in the northern Gulf of California, Mexico. In *Abstracts of the International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps, La Jolla, CA, USA* (p. 49).

Urbán, J., Guerrero, M., Pérez-Cortés, H., & Salinas-Zacarías, M. (2006). First mass stranding of killer whales (*Orcinus orca*) in the Gulf of California, Mexico. *Aquatic Mammals, 32*, 265−272.

Vidal, O. (1991). *Catalog of osteological collections of aquatic mammals from Mexico*. NOAA. Technical Report NMFS, 97, 36 pp.

Vidal, O. (1993). Aquatic mammal conservation in Latin America: Problems and perspectives. *Conservation Biology, 7*, 788−795.

Vidal, O. (1995). Population biology and incidental mortality of the vaquita, *Phocoena sinus*. *Reports of the International Whaling Commission*, (Special Issue 16), 247−272.

Vidal, O., & Pechter, G. (1989). Behavioral observations on fin whale, *Balaenoptera physalus*, in the presence of killer whale, *Orcinus orca*. *Fishery Bulletin, 87*, 370−373.

Vidal, O., Aguayo L., A., Findley, L., Robles, A., Bourillón, L., Vomend, I., Turk, P., Gárate, P. K., Maroñas, L., & Rosas, J. (1987). Avistamientos de mamíferos marinos durante el crucero "Guaymas I" en la región superior del Golfo de California, primavera de 1984. In *Memoria, X Reunión Internacional sobre Mamíferos Marinos,* 24-27 de marzo de 1985, La Paz, Baja California Sur, México (pp. 7−35).

Vidal, O., Brownell, R. L., Jr., & Findley, L. T. (1999). Vaquita *Phocoena sinus* Norris and MacFarland, 1958. In S. H. Ridgway, & R. Harrison (Eds.), *Handbook of marine mammals, volume 6: The second book of dolphins and the porpoises* (pp. 357−378). Academic Press.

Vidal, O., Findley, L. T., & Leatherwood, S. (1993). Annotated checklist of the marine mammals of the Gulf of California. *Proceedings of the San Diego Society of Natural History, 28*, 1−16.

Vidal, O., Van Waerebeek, K., & Findley, L. T. (1994). Cetaceans and gillnet fisheries in Mexico, Central America and the wider Caribbean: A preliminary review. *Reports of the International Whaling Commission, Special Issue, 15*, 221−233.

Villa-Ramírez, B. (1993). *Recovery plan for the vaquita, Phocoena sinus. NTIS Report PB93-169415*. Washington, D.C: Report to the U.S. Marine Mammal Commission, 36 pp.

Watson, A. P., & Gaskin, D. E. (1983). Observations on the ventilation cycle of the harbour porpoise, *Phocoena phocoena* (L.) in coastal waters of the Bay of Fundy. *Canadian Journal of Zoology, 61*, 126−132.

Wells, R. S., Würsig, B. G., & Norris, K. S. (1981). *A survey of the marine mammals of the upper Gulf of California, Mexico, with an assessment of the status of Phocoena sinus*. Report PB 81-1678792. Arlington, VA, USA: NTIS.