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Population Biology and Incidental Mortality of the Vaquita, *Phocoena sinus*

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ABSTRACT

This paper reviews available information on the population biology and incidental mortality of the vaquita, *Phocoena sinus*. A re-examination of previous records and the collection of new records reveals that this porpoise has the most limited distribution of any marine cetacean, being restricted to the uppermost Gulf of California, México. Although no reliable abundance estimates are available, the population is very small, perhaps only in the low hundreds. Little is known of the life history of the vaquita. Twelve neonates examined ranged from 67cm to 78.2cm in length and a near-term foetus measured 71.5cm; parturition occurs in spring, with a peak in late March-early April. Sexually mature females ranged from 135 to 148.2cm in length and sexually mature males from 128.3 to 144cm. The largest immature female and male were 128.7cm and 127cm in length, respectively, and the largest adults were a 150cm female and a 145cm male. Vaquitas are taken incidentally in gillnets, especially those nets with mesh sizes of 15–30.5cm. There are records of 128 vaquitas captured incidentally between early March 1985 and early February 1992: 65% in illegal and experimental gillnets set for a sciaenid, the endangered 'totoaba' (*Totoaba macdonaldi*); 28% in gillnets for sharks and rays; and 7% in gillnets for mackerels (*Scomberomorus* spp.) and in shrimp (*Penaeus* spp.) trawls. These 128 captures certainly represent only a fraction of the total mortality from fishing operations. At least 35 vaquitas are killed each year by these industries. Considering the probable low population size, the relatively high rate of mortality in fishing operations and the difficulties and the costs of implementing and enforcing long-term conservation measures immediately, I conclude the vaquita is in immediate danger of extinction.

INTRODUCTION

Coastal small cetaceans are vulnerable to several adverse effects of human activities, including incidental mortality in fisheries (especially those using gillnets), habitat loss and degradation, direct exploitation for human consumption or for use as bait for other fisheries and culls if they are suspected of competing with fishermen (Perrin, 1989).

The Phocoenidae (sometimes called 'true porpoises') are generally inhabitants of marine coastal and shallow water areas. While two species (the Dall's porpoise, *Phocoenoides dalli*, of the northern North Pacific and the spectacled porpoise, *Australophocaena dioptrica*, of southern South America) are found regularly in the open sea as well as in coastal waters (Jefferson, 1988; Goodall, 1990), the remaining species (the harbour porpoise, *Phocoena phocoena*, vaquita, *P. sinus*, Burmeister's porpoise, *P. spinipinnis*, and finless porpoise, *Neophocaena phocaenoides*) are restricted to nearshore waters (Gaskin *et al.*, 1974; Brownell, 1983; Leatherwood and Reeves, 1983; Brownell and Praderi, 1984). As noted by Perrin (1989), coastal habitats are more restricted and

more vulnerable to degradation and depletion. Moreover, all phocoenids are subjected to direct or accidental exploitation (e.g. Mitchell, 1975; Perrin, 1989) and indeed as a threatened group of small cetaceans they are second only to the river dolphins (superfamily Platanistoidea), being particularly vulnerable to incidental capture in gillnets (e.g. Bjørge *et al.*, 1994; Donovan, 1994).

The population biology of most phocoenids is still poorly understood. Most of the existing quantitative data relate to the harbour porpoise (about 90% of published literature) and to the Dall's and finless porpoises (Gaskin *et al.*, 1984). The population biology of the vaquita and the Burmeister's and spectacled porpoises is virtually unknown.

The purpose of this paper is to review briefly and discuss the available information on the population biology and incidental mortality of probably the least known of all porpoises, the vaquita, a species only found in the upper Gulf of California, México.

METHODS

In addition to reviewing the literature, additional information on incidental kills and fishing effort was obtained from: (1) personal interviews with local fishermen (who were familiar with the external appearance of the vaquita) conducted by experienced biologists in El Golfo de Santa Clara, Sonora, between 1985 and 1988; (2) personal communications from biologists who regularly visited the upper Gulf of California since 1985; (3) several field trips (conducted by the author) during 1990 to El Golfo de Santa Clara (February 18, 27–28; March 10–11, 24–25; April 6–14, 20–21; May 19–20, 26–27; September 1–2, 15; October 6) and Puerto Peñasco (February 17), Sonora, San Felipe and Puertecitos, Baja California (Norte) (BCN) (April 9–10; September 16; October 6–7), in an attempt to monitor the incidental mortality of the vaquita during commercial fishing activities; (4) data collected by biologists (principally C. Navarro of ITESM-Campus Guaymas) in semi-continuous residence in El Golfo de Santa Clara from early January to late May 1991 and in one field trip to this village on early October 1991 and four (31 January-1 February, 21–23 February, 10–12 April and 9 May) in 1992; and (5) statistics of fishing effort (i.e. numbers of boats, species exploited, dates and localities) for El Golfo de Santa Clara, Puerto Peñasco, San Felipe and Puertecitos, provided by local officials of the Mexican Secretariat of Fisheries (Secretaría de Pesca de México, SEPESCA), by the fishermen themselves and by direct observations by the author.

RESULTS AND DISCUSSION

Distribution and abundance

Geographical range

Locality data for all confirmed vaquita records are shown in Appendix Tables 1 and 2 and Fig. 1. These are based on: (1) osteological materials (mostly skulls and skeletons) and decomposed whole carcasses recorded on beaches (summarised by Brownell, 1986; Vidal, 1991; this paper); (2) specimens that had been captured incidentally during fishing activities (Brownell, 1982; 1983; Findley and Vidal, 1985; Brownell *et al.*, 1987; Pérez-D, 1987; Robles *et al.*, 1987; Silber and Norris, 1991; Vidal, 1991; this paper); and (3) sightings of free-ranging animals (Brownell, 1986; Vidal *et al.*, 1987; Silber, 1988; 1990a; b; Silber and Norris, 1991; Barlow *et al.*, 1993). These data clearly show that the vaquita is restricted to the upper Gulf of California, an area roughly defined as the region north of a line connecting Puertecitos in Baja California Norte and Puerto Peñasco in Sonora (approximately 5,000km^2 of mostly shallow waters), with most records near

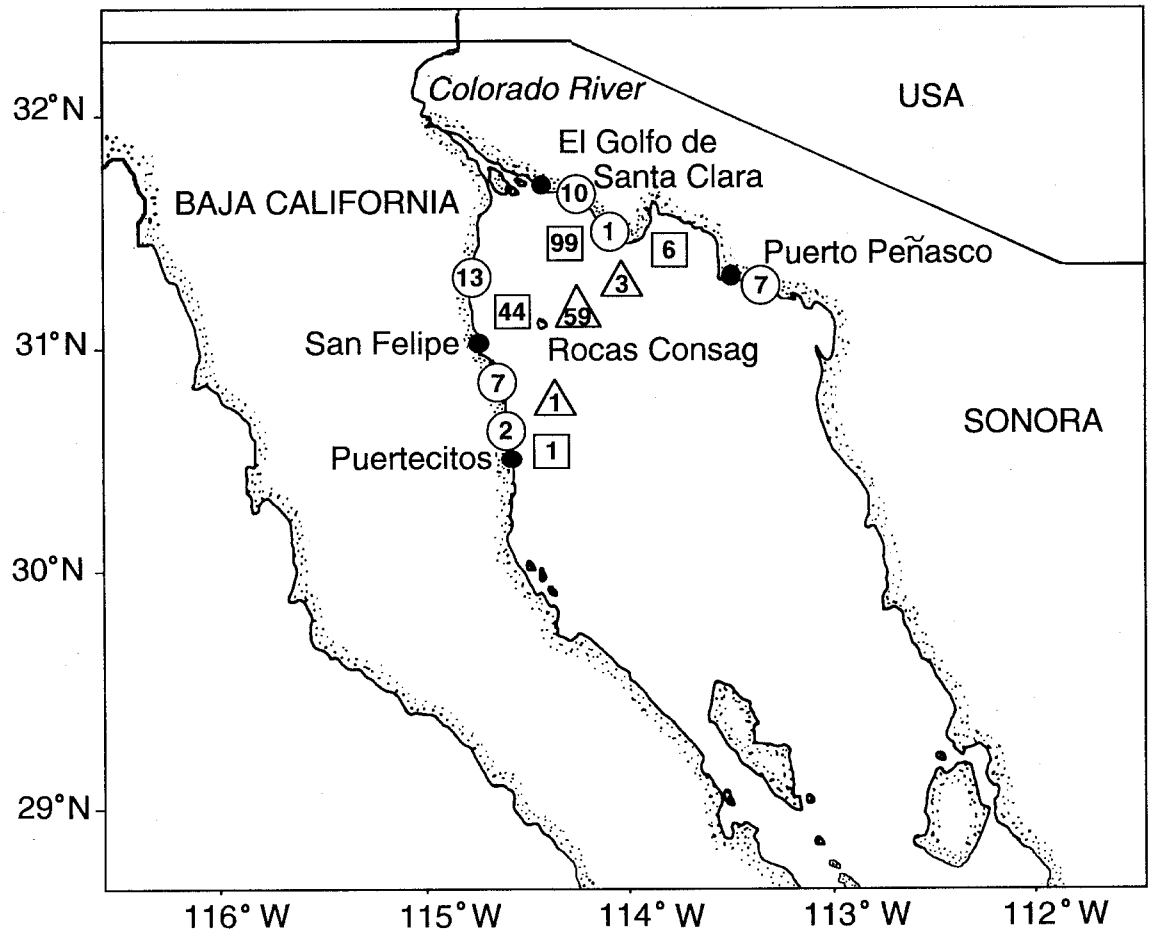

Fig. 1. Locality map of the northern half of the Gulf of California, México, showing the distribution of the vaquita, *Phocoena sinus*, based on confirmed records. Circles indicate beached specimens collected, squares indicate entanglements and triangles indicate sightings (see Appendix Tables 1, 2 and text; for more recent data, see D'Agrosa, 1995).

San Felipe, Rocas Consag and El Golfo de Santa Clara (Fig. 1). In fact, this species has the most limited distribution of any marine cetacean.

Two unconfirmed sightings near Isla Cerralvo, south of Bahía de La Paz, Baja California Sur (*ca* 850km south of the southernmost confirmed sighting) were reported by Silber (1990b). These sightings and a few previous reports for Bahía de Topolobampo, Sinaloa and Guaymas, Sonora (Norris and McFarland, 1958; Norris and Prescott, 1961), led Silber (1990b) to suggest that individuals may occur throughout the Gulf and that the species may have had a much greater historical range. However, Brownell (1986) discounted the unconfirmed sightings by Norris and his co-workers (see below).

From 12–25 June 1986, the author together with Alejandro Robles and Hugo Montiel surveyed both coasts of the Gulf to obtain information on the distribution of the vaquita and other cetaceans in the upper half of this sea. No physical evidence (i.e. osteological material) was found of the vaquita and of the more than thirty fishermen interviewed, only those in San Felipe and El Golfo de Santa Clara were familiar with the species. However, we found whole carcasses and osteological remains of other small cetaceans common dolphins, *Delphinus spp.*, and bottlenose dolphins, *Tursiops truncatus*) quite frequently along these same beaches. In addition to several of the small intermediate fishing camps, we visited Bahía de los Angeles, Punta Final, El Huerfanito, Bahía San Luis Gonzaga,

Puertecitos and San Felipe, Baja California Norte; and El Golfo de Santa Clara, Puerto Peñasco, Puerto Lobos, Puerto Libertad, El Desemboque, Punta Chueca and Bahía Kino, Sonora. No records of the vaquita have been obtained by myself or colleagues (principally Lloyd T. Findley) in other parts of the Gulf since we began to work with marine mammals in 1979 (see Vidal *et al.*, 1993).

More than 1,400 physical records from 34 extant aquatic mammal species have been collected from México (mostly in the Gulf of California and along the Pacific coast of the Baja California peninsula) between 1868 and 1990 (Vidal, 1991), including 68 vaquita records. Together with the 29 additional specimens reported here, a total of 97 records exist, none of which were found south of Puertecitos and Puerto Peñasco (Table 2 and Appendix Table 1). This supports the view that the present geographical range of the vaquita is limited to the uppermost Gulf of California, as concluded by Brownell (1983; 1986). The two sightings reported near Isla Cerralvo (Silber, 1990b) were in 1983, a year with a strong *El Niño* Southern Oscillation event, when water temperatures in the region were unusually high (Cane, 1983). Therefore, these records, even if valid, do not necessarily imply a wider geographical range of the vaquita. In the absence of confirmed records (i.e. supported by voucher specimens or photographs) from the southern Gulf, it must be concluded that the species' range includes only the northernmost Gulf[1].

Population size

Little is known about the abundance of the vaquita. Most reported sightings are opportunistic and cannot be used to reliably estimate population size. Between 1985 and 1986 at least 24 sightings were made from commercial shrimp vessels and small fishing boats (*pangas*) near San Felipe (Pérez-D, 1987; S. Pérez-D, pers. comm., 10 January 1990).

Prior to 1986, only one dedicated vaquita survey was carried out but during 1,959km of effort, only two sightings were made (Wells *et al.*, 1981). Since then, Silber and co-workers have carried out a number of dedicated surveys (Silber, 1988; 1990a; b; Silber *et al.*, 1988). A total of 4,216km of boat and aircraft surveys conducted during 77 days in 1986–89 resulted in only 58 sightings, representing a total of 110 individuals (Silber, 1990a; b). Forty-three vaquitas (19 sightings) were recorded during 1,715km of vessel transects, a sighting rate of 2.51 individuals/100km surveyed (Silber, 1990b). The remainder of the sightings occurred while transect surveys were not conducted (Silber, 1990a).

Based on Silber's censuses for 1986 ('30 individuals in 11 sightings'; later amended by Silber, 1988, to 27 and 12, respectively) and on 14 specimens caught incidentally in gillnets during 1985–86 (Brownell, *et al.*, 1987; Robles *et al.*, 1987), Barlow (1986) estimated 50–100 individuals as a rough lower limit for the population, noting that it was not possible to estimate an upper limit from the available data.

Based on the four years of surveys, Silber (1990c) surmised, but did not quantify, an estimate of 200–500 individuals for the entire population. Given the nature of the surveys, the surfacing behaviour of the vaquita (see Silber *et al.*, 1988; Silber, 1990a) and the difficulty in identifying individuals, this total may well include some duplicate sightings both within and between surveys. The scarcity of sightings relative to survey effort and the limited geographical range of the vaquita make it clear that the population is very small, perhaps in the low hundreds[2].

[1] Information made available since this paper was completed confirms this view (D'Agrosa, 1995; D'Agrosa *et al.*, 1995; Gerrodette *et al.*, 1995).

[2] Since this paper was completed, this view has been confirmed by a line transect survey carried out in August 1993; based on 22 sightings, Gerrodette (1994) estimated the population size to be 316 (95% CI 118–847).

Table 1

Twelve confirmed and four possible (reported by fishermen, indicated by an asterix) neonates and one near-term foetus of *Phocoena sinus* (see Table 2 and Appendix Tables 2 and 3).

Date	Sex	Length	Weight	Comments	Source
09/04/72	?	74cm			Brownell, 1983
13/03/85	F	70.3cm	7.8 kg		Brownell *et al.*, 1987
14/05/85	?	*ca* 75cm	?	A. Robles(pers. comm.)	This paper
06-09/04/88	M	74.3cm	11 kg	M. Román (pers. comm.) this calf and the one below were incidentally killed with one large individual each (their mothers?)	This paper
06-09/04/88	M	70.8cm	10 kg	M. Román (pers. comm.)	This paper
05/04/88	F	72.0c	?		Silber and Norris, 1991
mid 03/89	?	*ca* 50*cm	?	Captured ina gillnet	This paper
08/04/90	?	*ca* 80*cm	?	Captured in a shrimp boat	This paper
18/02/90	?	'Very small'*	?	Captured in a shrimp boat	This paper
02/04/90	M	78.2cm	12.5 kg		This paper
05/04/90	?	*ca* 80*cm	?	Found on the beach	This paper
11/04/90	M	75.8cm	11 kg		This paper
12/03/91	F	74.9cm	7.5 kg		This paper
09/04/91	M	77.5c	10.5 kg		This paper
11/04/91	F	72.8cm	8.5 kg		This paper
24/02/91	F	71.5cm	6.7 kg	Near-term foetus	This paper
13/05/94	M	67.0cm	5.0 kg	Stranded alive	CEDO, 1994

Life history parameters and population dynamics

Little is known about age at maturity, life span, reproductive cycle or population dynamics of the vaquita. The available information is summarised below[3].

Neonatal size and calving season

Twelve confirmed (as evidenced by umbilical scars and foetal folds) and four possible records of neonates exist and these are summarised in Table 1. These include a neonate (67cm long) with the umbilicus still attached, that stranded alive near Puerto Peñasco on 13 May 1994 (CEDO, 1994). A near-term pregnant female with a foetus (71.5cm long) was recovered from gillnets on 24 February 1991.

Silber (1988; 1990b) reported seven calves (8.18% of all individuals) during his surveys: six between 25–27 March 1986 and one 'very young, probably less than two days old' on 9 April 1987. Although the sample size is small, this suggests that parturition occurs in spring, between February and April, with a peak possibly in late March-early April.

Gaskin *et al.* (1984) reviewed estimates of gestation period for harbour, Burmeister's and Dall's porpoises and found that most were around 11 months. They also reported a mating season from June-August and parturition from May to early August for harbour porpoises from the Bay of Fundy, Canada and the northwest coast of the USA. Assuming

[3] A paper on this subject is currently in press (Hohn *et al.*, In press). This is summarised in IWC (1995a); the vaquita life history appears similar to that of the highly exploited harbour porpoise population from the Bay of Fundy, Canada, except that calving does not appear to be annual.

similar values for the vaquita and that parturition occurs from February-April (smallest calf observed on 13 March), suggests that mating may occur between April and June. This is clearly a preliminary conclusion as taxonomic affinity does not necessarily imply similarity in life cycle (Gaskin *et al.*, 1984), especially when the habitats are so different.

Postnatal growth and maturity

Of the 54 individuals of known sex examined (28 males and 26 females), nine males and ten females were mature (Table 2 and Appendix Tables 2 and 3). Work is in progress with respect to the anatomical measurements and possible sexual dimorphism of the vaquita. A 145cm male and two females (139cm and 150cm, both decomposed) must have also certainly been mature (Brownell, 1983; Silber and Norris, 1991), making 22 mature specimens in all. The smallest mature female was 135cm and the smallest mature male was 128.3cm. Females were considered sexually mature if a *corpus albicans* was present on one or both ovaries. Sexual maturity for males was determined on the basis of testis weight and confirmed histologically (Hohn, In press). The largest immature female and male were 128.7cm and 127cm long, respectively. A male of 133.6cm was maturing (A. Hohn, pers. comm., 8 February 1993). Although the sample size is small, females appear to be larger than males, as suggested by Brownell *et al.* (1987) and as is found in the harbour porpoise (Gaskin *et al.*, 1984) and some other odontocetes, e.g. the franciscana, *Pontoporia blainvillei*, the baiji, *Lipotes vexillifer* and the tucuxi, *Sotalia fluviatilis* (Ralls, 1976; Best and da Silva, 1984; Brownell, 1984). Brownell (1984) noted that 'the only obvious common factor among the toothed cetaceans where the female is larger is an apparently simple social structure (i.e. small school size)'.

Ecology and behaviour

Habitat utilisation

Silber (1990b) reported that 86% of his sightings occurred in water depths from 21–35m, with water visibility from 0.9–12m. Most sightings were between 11 and 25km from shore. The two sightings by Wells *et al.* (1981) were in water depths of *ca* 19m and were about 18km from shore. All known incidental gillnet entanglements have occurred in water depths of 4–36m (estimated with some accuracy by the fishermen operating the nets, or by reference to nautical charts) and between 3 and 33km from the shore (Appendix Table 2).

All but two of Silber's sightings were less than 40km from San Felipe (mostly between this locality and Rocas Consag), but this may partially reflect the distribution of sighting effort (Silber, 1990b). Most of the documented vaquitas caught in gillnets have come from near El Golfo de Santa Clara (Table 3 and Appendix Table 2). In the upper Gulf nearly all the survey effort and thus the sightings have been in spring (Silber, 1990a; b; Silber and Norris, 1991). The picture is somewhat similar for the vaquitas caught in gillnets (Table 3).

Analysis of published reports and recent sightings in autumn, led Silber (1990b) and Silber and Norris (1991) to suggest that vaquitas occupy the upper Gulf year-round. They note that the vaquita distribution in the upper Gulf appears to be highly localised, with densities possibly highest near San Felipe (although this may be partly due to more survey effort in that area) and relatively high in the areas of Rocas Consag and El Golfo de Santa Clara. Data on incidental gillnet mortality summarised here and more recent data collected by D'Agrosa (1995) and D'Agrosa *et al.* (1995) tend to support this, as do more recent sightings data summarised by Gerrodette *et al.* (1995). It is important to carry out surveys throughout the upper Gulf at all times of the year and to monitor incidental mortality in San Felipe in order to define accurately the movements and seasonality of the vaquita within its range.

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Table 2

Selected external measurements (following Norris, 1961) (in cm) of 36 specimens of *Phocoena sinus* incidentally killed in gillnet fisheries in the upper Gulf of California, México during February 1990 - May 1993. Footnotes: [1] Specimens ITESM900519, ITESM910313-2 and ITESM910313-3 were collected fresh but partially eaten by coyotes, therefore some measurements could not be taken; [2] Pregnant.

Catalog number (ITESM)	900227	900408	900408-2	900411	900412	900519	900421	900526	900902	910226	910312-2
Sex	Female	Female	Male	Male	Male	Male	Male	Male	Male	Male	Female
Sexually mature	No	Yes	No	No	Yes	No	Yes	No	Maturing	Yes	No
Physically mature	No	Yes	No	No	Yes	No	Yes	No	No	Yes	No
Weight (kg)	23.0	41.0	12.5	11.0	37.0	--	42.5	22.5	31.0	39.0	7.5
Total length	109.8	135.0	78.2	75.8	131.8	127.0	142.2	113.7	133.6	128.3	74.9
Tip of upper jaw to:											
Angle of gape	6.7	7.5	5.1	4.8	8.0	7.0	7.4	7.9	7.0	7.5	5.3
Center of blowhole	8.1	9.3	--	5.2	9.8	7.7	10.2	11.0	11.1	8.9	6.4
Center of eye	11.0	12.1	7.8	7.7	12.1	11.2	12.5	11.3	11.7	12.0	8.3
Auditory meatus	15.9	17.3	10.7	11.0	16.9	18.4	18.1	15.6	16.4	16.3	11.9
Ant. insertion of flipper	23.1	25.7	17.3	15.5	25.1	25.0	27.2	22.5	24.6	24.2	15.9
Umbilical scar	48.5	57.3	36.8	36.3	56.3	--	59.6	48.8	56.0	55.7	36.2
Tip of dorsal fin	64.7	76.0	48.7	47.4	70.5	*ca* 67.5	72.6	67.3	78.1	72.7	46.4
Center of genital slit	68.3	90.0	43.1	42.5	68.6	--	74.0	60.0	68.2	67.9	49.0
Center of anus	74.0	93.3	56.6	55.3	92.7	87.0	95.6	76.5	90.3	89.6	51.4
Ant. length of flipper	23.5	26.6	16.1	17.9	27.4	28.2	28.6	24.1	28.7	27.7	18.1
Axilla length of flipper	18.1	20.4	13.0	13.2	20.9	20.4	22.1	18.7	22.4	21.8	13.6
Max. width of flipper	9.1	10.1	6.7	6.6	8.6	10.8	10.9	9.4	10.7	10.3	6.8
Height of dorsal fin	12.5	15.1	7.5	8.0	18.5	--	18.5	12.3	16.4	16.2	7.6
Length of dorsal base fin	16.7	22.3	13.2	12.6	24.5	20.5	21.5	19.2	21.7	20.2	11.1
Width of flukes	32.8	40.0	20.7	21.8	39.8	--	46.3	33.4	--	43.0	20.0
Width of fluke, from notch to nearest point on anterior border	8.7	10.4	6.9	6.7	10.9	10.0	12.7	10.1	10.2	11.5	7.3
Depth of notch	2.0	1.2	1.2	1.2	1.7	1.7	2.2	1.9	1.8	1.5	0.9
Width of blowhole	2.1	2.5	2.1	0.8	2.6	2.6	3.0	2.1	2.9	2.6	--
Girth, at axilla	64.7	73.0	56.5	54.6	70.2	--	74.1	63.8	68.0	72.6	48.2
Girth, maximum	72.8	86.4	62.5	59.0	82.1	--	82.6	70.7	76.8	81.4	50.0
Girth, at anus	44.6	56.0	34.3	34.2	56.9	49.0	53.1	43.1	44.7	57.4	30.2

Table 2. (Continued.)

Catalog number (ITESM)	910313-1	910313-2	910313-3	910409	910411-1	910421	910519-1	910521	910207	910222-1
Sex	Female	Male	Male	Male	Female	Male	Female	Female	Female	Female
Sexually mature	Yes	Yes	Yes	No	No	No	No	No	No	No
Physically mature	Yes	Yes	Yes	No	No	No	No	No	No	No
Weight (kg)	47.5	--	>43	10.5	8.5	11.5	16.0	34.0	25.0	29.0
Total length	139.7	139.7	144.0	77.5	72.8	82.2	92.5	125.3	116.0	120.7
Tip of upper jaw to:										
Angle of gape	7.5	8.0	7.6	4.9	5.0	4.7	6.5	7.7	8.0	8.3
Center of blowhole	10.4	10.9	10.3	5.8	7.3	6.4	8.6	10.2	9.5	10.5
Center of eye	12.1	13.7	12.1	8.4	8.4	8.0	10.5	12.0	11.8	12.8
Auditory meatus	17.5	--	17.9	11.7	11.6	11.5	14.4	17.1	16.4	17.2
Ant. insertion of flipper	26.2	29.5	26.6	16.7	15.8	17.6	19.8	24.8	23.5	24.4
Umbilical scar	58.5	62.1	--	36.3	36.4	38.8	40.5	53.3	51.8	54.3
Tip of dorsal fin	78.6	--	76.0	48.0	46.1	49.0	54.0	73.2	67.2	70.0
Center of genital slit	89.7	75.1	76.8	43.8	50.7	46.5	58.5	83.1	72.1	76.5
Center of anus	94.0	97.8	100.0	55.5	53.0	58.0	62.0	87.0	79.4	81.6
Ant. length of flipper	27.6	26.1	27.3	16.7	15.1	18.0	18.5	27.4	24.9	27.2
Axilla length of flipper	22.0	22.0	21.2	13.1	11.2	13.3	14.0	20.3	19.1	20.7
Max. width of flipper	10.2	10.2	10.4	6.2	6.1	6.5	7.3	9.5	9.0	9.5
Height of dorsal fin	16.7	--	18.0	7.6	7.4	7.6	9.1	13.5	14.5	13.6
Length of dorsal base fin	22.0	20.2	24.2	10.5	10.1	11.0	13.5	21.5	21.2	21.5
Width of flukes	43.2	40.7	40.3	21.5	20.3	22.7	26.1	38.3	--	38.0
Width of fluke, from notch to nearest point on anterior border	12.0	10.5	11.1	7.0	6.5	7.9	7.5	10.1	8.8	10.1
Depth of notch	1.5	1.7	2.8	1.1	1.1	1.1	1.5	1.6	--	1.7
Width of blowhole	2.8	--	3.0	--	1.7	1.9	2.1	2.7	--	2.8
Girth, at axilla	77.0	--	72.1	53.5	50.0	53.7	60.0	73.8	67.6	70.2
Girth, maximum	87.5	--	--	58.0	53.2	61.0	64.0	86.5	73.1	76.4
Girth, at anus	57.5	--	63.4	34.1	29.5	36.4	41.4	53.7	45.2	49.7

Table 2. (Continued)

Catalog number (ITESM)	910312-1	910407	910224-1	910304	920202	910331	920120	920124	910224	930206
Sex	Male	Male	Female	Female	Female	Female	Female	Female	Female[2]	Female[2]
Sexually mature	No	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Physically mature	No	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Weight (kg)	23.0	43.0	6.7	31.0	44.0	46.0	26.3	24.7	57.5	55.0
Total length	109.1	135.8	71.5	128.7	148.2	140.5	116.6	113.2	140.9	145.2
Tip of upper jaw to:										
Angle of gape	7.0	7.7	4.9	8.2	8.1	8.5	8.2	6.5	7.5	8.5
Center of blowhole	9.2	10.5	7.1	10.7	11.1	10.2	9.5	9.5	9.6	11.2
Center of eye	11.5	11.9	7.7	13.0	13.0	13.2	12.6	10.8	12.5	13.4
Auditory meatus	16.0	17.7	11.5	17.8	18.5	18.3	17.3	16.7	17.5	18.7
Ant. insertion of flipper	21.9	25.7	16.5	25.5	29.7	27.0	23.0	23.8	25.7	27.1
Umbilical scar	50.8	55.3	34.3	54.5	61.5	58.5	51.4	51.4	61.4	--
Tip of dorsal fin	63.6	73.5	42.7	74.2	86.1	81.2	67.6	66.2	80.0	81.3
Center of genital slit	59.5	66.9	46.8	80.3	93.0	92.1	75.5	75.5	95.3	96.8
Center of anus	76.2	89.3	48.5	83.9	98.1	96.7	78.9	78.6	98.5	100.9
Ant. length of flipper	24.6	28.2	13.2	26.6	29.0	28.0	26.0	24.6	29.9	27.5
Axilla length of flipper	18.3	21.5	7.7	20.4	23.0	21.2	19.6	18.0	23.0	21.7
Max. width of flipper	9.0	10.2	6.6	9.7	11.3	10.4	9.3	9.1	10.9	10.7
Height of dorsal fin	13.8	17.8	9.0	12.6	14.8	15.1	12.8	13.8	16.0	13.7
Length of dorsal fin base						22.3	20.2	18.0	21.5	20.5
Width of flukes	35.4	43.8	21.1	37.4	40.0	41.0	34.8	32.2	44.2	39.7
Width of fluke, from notch to nearest point on anterior border	9.0	11.0	7.0	9.7	11.8	10.7	--	8.9	11.5	10.5
Depth of notch	2.2	1.8	1.4	2.0	2.0	1.0	2.2	2.5	2.6	1.9
Width of blowhole	2.5	2.6	1.7	2.8	3.0	3.2	2.6	2.4	2.7	2.4
Girth, at axilla	65.4	74.8	42.0	69.2	75.9	77.5	65.0	63.2	83.5	81.0
Girth, maximum	70.8	89.0	47.9	78.0	84.0	90.2	74.1	71.1	116.6	107.0
Girth, at anus	43.7	50.4	28.6	51.9	55.0	58.3	45.0	43.5	59.0	71.4

Table 2. (Continued)

Catalog number (ITESM)	930206-1	930331	930403	930502	930518
Sex	Female	Male	Female	Male	Male
Sexually mature	No (foetus)	Yes	No	No	No
Physically	No	Yes	No	No	No
Weight (kg)	4.3	41.0	24.0	25.0	20.0
Total length	*ca* 64.4	129.8	116.3	116.4	109.4
Tip of upper jaw to:					
Angle of gape	4.6	6.5	8.5	7.2	6.3
Center of blowhole	6.3	8.6	10.0	10.1	9.3
Center of eye	7.9	10.2	12.9	11.8	10.2
Auditory meatus	11.3	14.7	17.7	16.5	15.2
Ant. insertion of flipper	14.3	23.5	25.0	24.5	22.6
Umbilical scar	30.8	53.5	50.4	---	49.0
Tip of dorsal fin	40.4	72.0	69.0	---	66.0
Center of genital slit	42.5	67.5	75.7	---	58.0
Center of anus	44.0	88.9	80.0	80.0	75.0
Ant. length of flipper	14.4	26.1	25.0	24.1	23.0
Axilla length of flipper	10.8	20.2	19.5	18.9	16.6
Max. width of flipper	5.4	9.9	9.5	9.2	8.3
Height of dorsal fin	7.3	19.1	13.2	14.0	14.3
Width of flukes	20.1	42.0	34.3	35.8	35.2
Width of fluke, from notch to nearest point on anterior border	6.0	11.5	9.7	9.2	9.5
Depth of notch	0.8	1.6	2.7	1.7	2.2
Width of blowhole	1.5	2.8	2.5	2.6	2.9
Girth, at axilla	37.5	71.7	64.3	65.0	64.5
Girth, maximum	40.3	90.0	76.0	74.0	71.3
Girth, at anus	22.2	60.0	48.5	80.0	43.7

Social organisation

Like other phocoenids, the vaquita usually occurs in small groups. Silber (1990a; b) found that 91% of sightings were of 1–3 individuals, with a mean group size of 1.9 and a range of 1 to 7. Silber (1988) reported aggregations of single individuals or small groups (usually 2–4, maximum 8–10) throughout several hundred square meters. All previous sightings were of 1–3 individuals (Norris and McFarland, 1958; Norris and Prescott, 1961; Wells *et al.*, 1981; Vidal *et al.*, 1987) as well as the sighting by Barlow *et al.* (1993) and the more recent sightings summarised in D'Agrosa (1995) and Gerrodette *et al.* (1995).

Wells *et al.* (1981) suggested that the vaquita usually avoids boats, but Silber *et al.* (1988) noted no apparent directional response to their vessel when following two female/calf pairs for some hours at a distance of 40–200m, nor to the presence of several skiffs. In each case, however, abbreviated surfacing sequences were noted, possibly in response to the boats.

Feeding

Little has been published about the food habits of the vaquita. The remains of a bronze-striped grunt, *Orthopristis reddingi*, a croaker, *Bairdiella icistia* (Fitch and Brownell, 1968) and squid (Brownell, 1982) were found in the stomach of an adult female examined on a beach near San Felipe. Squid beaks, (of *Lolliguncula panamensis*) were also found in the stomachs of two porpoises collected by R.L. Brownell, Jr. in 1965 and 1984

Table 3

Summary of the incidental mortality of *Phocoena sinus* in fishing activities in the upper Gulf of California (for details see Table 2 and Appendix Table 2; for recent data see D'Agrosa *et al.* (1995) and D'Agrosa (1995)).

Year	Month	Number	Locality
1967-1984	Mar-Apr	At least 10	*ca* San Felipe
'Early 1970's'	?	'10'	'Around San Felipe'
1972	Apr	2	*ca* El Golfo de Santa Clara
1984	Sept-Oct	1	*ca* El Golfo de Santa Clara
1985	Jan, Mar, Apr, May, Jun, Nov	35	*ca* El Golfo de Santa Clara, Rocas Consag, San Felipe
1986	Feb, Mar, Jun	+2	*ca* El Golfo de Santa Clara, San Felipe
1987	Mar, Apr, Jul	6	*ca* El Golfo de Santa Clara, Rocas Consag
1988	Jan, Apr	9	*ca* El Golfo de Santa Clara
1989	Feb, Mar	13	*ca* El Golfo de Santa Clara, Punta Sargento, Baja California Norte
1990	Jan, Feb, Mar, Apr, May, Jun, Aug, Sept, Dec	36	*ca* El Golfo de Santa Clara, Punta Sargento, Rocas Consag, San Felipe
1991	Feb, Mar, Apr, Jul	22	*ca* El Golfo de Santa Clara, Rocas Consag, San Felipe
1992	Jan, Feb	5	*ca* El Golfo de Santa Clara

(Vidal *et al.*, In press). Two specimens collected in 1988 contained squid beaks, several whole fishes (probably *Anchoa nasus* or *Sardinops* spp.) and numerous unidentified fish otoliths (Silber, 1990a). Squid beaks, (of *L. panamensis* and *Loliopsis diomedeae*) were found in the stomachs of six vaquitas collected in 1985 (Vidal *et al.*, In press). The stomachs of 40 vaquitas incidentally killed in gillnets and recovered fresh by biologists and of two decomposed carcasses, all collected between 1985 and 1994, are currently under analysis. Silber (1990b) reported that during four vaquita sightings, the boat's depth sounder indicated concentrated layers at 15, 23 and 25m, representing schooling bait fish or squid upon which the vaquitas may have been feeding.

Diving and swimming

Silber *et al.* (1988) provided the only available information on the behaviour and respiration cycles of the vaquita. Two different female/calf pairs were observed for periods of about three hours each. Dive characteristics were similar to those reported for the harbour porpoise but mean dive times, roll intervals, surface times and rolls per surfacing reported for the harbour porpoise by Watson and Gaskin (1983) were somewhat higher.

Factors affecting natural mortality

Commensals and parasites

One to five individuals of the commensal pseudo-stalked barnacle, *Xenobalanus globicipitis*, were found attached on or near the trailing edges of the dorsal fins, flippers

and flukes of 14 vaquitas incidentally caught in gillnets (Brownell, *et al.*, 1987; Vidal *et al.*, In press). Three parasitic trematodes, *Synthesium tursionis*, were found in the intestine of a male vaquita (Lamothe-Argumedo, 1988) and Vidal *et al.* (In press) reported two specimens of the nematode *Crassicauda* sp., one from the muscle connective tissue in the area of a mammary gland of one vaquita and the other from the blubber near the anus of another vaquita.

Predation

Several fishermen of El Golfo de Santa Clara, who regularly capture vaquitas in their nets, reported to the author that between February and May 1990 and 1991 they found whole or chewed parts of vaquitas in the stomachs of several species of large sharks. These were identified from photographs and/or jaws provided by the informants and they included at least six species: the great white, *Carcharodon carcharias*; the shortfin mako, *Isurus oxyrinchus*; the lemon, *Negaprion brevirostris*; the black-tipped, *Carcarhinus limbatus*; the bigeye thresher, *Alopias superciliosus*; and the broad-snout seven-gill, *Notorynchus cepedianus*. The great white and mako are both known locally as '*tiburones tonina*' ('dolphin sharks'). On 18 February 1990 a great white shark of *ca* 3m and 160kg (jaws now housed at ITESM, Campus Guaymas) was found to have in its stomach a vaquita cut into three pieces. Two more *tiburones tonina* caught in March 1985 and in early February 1990 also had a vaquita in their stomachs. These sharks may attack free-swimming vaquitas or perhaps pull them dead from gillnets. The flukes and/or flippers of several vaquitas incidentally killed in gillnets and examined by the author show notches or scars which could have been the result of (unsuccessful) shark attacks. Other large sharks that may be considered as potential predators includes the tiger, *Galeocerdo cuvier*, and the scalloped hammerhead, *Sphyrna lewini*. Arnold (1972) documented several records of predation by the great white shark on harbour porpoises and concluded that this shark was a potentially significant predator for this cetacean in the Canadian Atlantic. In the North Pacific, killer whales, *Orcinus orca*, have been reported as preying on finless, harbour and Dall's porpoises (see review in IWC, 1982).

It is important that attempts are made to determine the magnitude and impact of shark predation on the vaquita population. Killer whales are not uncommon in the Gulf of California (Vidal *et al.*, 1993) and they have been observed attacking and harassing other cetaceans (Vidal and Pechter, 1989; Silber *et al.*, 1990), but as yet there have been no reports of their predation on vaquitas although they must be regarded as potential predators.

Human effects

Incidental mortality

The vaquita is particularly vulnerable to incidental mortality in large-mesh gillnets. Table 3 (and Appendix Table 2) summarises all available data up to mid-1993 related to the mortality of this species during fishing activities. A detailed analysis of recent data is presented in D'Agrosa (1995) and D'Agrosa *et al.* (1995).

In the upper Gulf, gillnets are the most common and widespread type of fishing gear (Vidal *et al.*, 1994). They are used mainly to catch totoaba, *Totoaba macdonaldi*, a large sciaenid fish (which itself is endangered due to over-exploitation, Flanagan and Hendrickson, 1976; Anon., 1979; Lagomarsino, 1991), as well as smaller sciaenids and

several species of large sharks and rays. However, the vaquita is also caught during other fishing activities, such as those for smaller fishes using smaller meshed-gillnets or trawls by shrimp boats. At least 35 vaquitas are incidentally killed each year.

GILLNETS

Vidal *et al.* (1994) summarise the history of the commercial fishery for totoaba with gillnets. The main fishing fleets (which included shrimp boats and small skiffs, both using gillnets) operated from San Felipe, El Golfo de Santa Clara and Puerto Peñasco. The main fishing areas were near these towns and near the mouth of the Colorado River. In fact, these cities developed principally as a result of the revenues generated by this fishery.

Due to a major decline in catches from a peak of 2,261 tons of meat in 1942 to 59 tons in 1975, the Mexican government declared a permanent ban on fishing the species, which was declared in danger of extinction (Flanagan and Hendrickson, 1976). Despite this, illegal gillnetting and poorly planned 'experimental' survey fishing (i.e. temporary permits issued by SEPESCA, since 1983, to assess [unsuccessfully] the population status of the totoaba) have continued in El Golfo de Santa Clara and San Felipe. It has been estimated that about 70 tons of totoaba were taken each year until 1992 e.g. Román-Rodriguez, 1990; Lagomarsino, 1991; J.C. Barrera, unpublished data for 1985–9; M. Almeida (Centro Ecológico de Sonora, Hermosillo), pers. comm., April 1991; pers. obs., 1990–92, and it was still possible to buy totoaba fillets in regional markets and restaurants in 1992 (Robles *et al.*, 1987; pers. obs., 1990–92). Although lacking any quantitative data, some fishing cooperatives in the northern Gulf claim that the totoaba stock has recovered and that the fishery should be opened (pers. comms to A. Robles of ITESM and Conservation International, and J. Balderas, the SEPESCA official in San Felipe). Although a majority of this catch is sold in cities of northwest México, it is believed that some of the totoaba meat is being smuggled out for markets in the USA, particularly in California (Lagomarsino, 1991; M. Lizárraga, Instituto Nacional de Pesca, SEPESCA, pers. comm., 1991). These markets (both in the USA and in México) are the major reason the fishermen continue fishing for totoaba. A gillnet fishery for several species of large sharks and rays has also been growing rapidly in the upper Gulf of California since the early 1940s, probably together with the totoaba fishery and continues to operate without control. This too threatens both the vaquita and totoaba populations.

The vaquita has probably been incidentally caught in gillnets since the mid-1920s. It can be assumed that the significant expansion of the fishing industry during the early 1940s further reduced the population. A minimum of 166 vaquitas are known to have been incidentally killed since the early 1970s (Table 3; D'Agrosa *et al.*, 1995; Appendix Table 2).

Table 3 summarises the available data until 1992. Most records begin after 1985, when the first fresh specimens were recovered by biologists (Brownell, *et al.*, 1987), particularly as a result of the increased awareness of regional biologists of the need to monitor incidental mortality. Between early March 1985 and early February 1992 at least 128 vaquitas were killed in fisheries: 65% in the totoaba fishery (nets with mesh size of 20–30.5cm), 28% in the shark and ray fishery (mesh size of 10–15cm), and 7% in the mackerel (*Scomberomorus sierra* and *S. concolor*) (mesh size of 8.5cm) and in commercial shrimp (*Penaeus californiensis* and *P. stylirostris*) trawl fisheries. This figure should be considered a minimum, since the monitoring effort was non-continuous (except for 1985 and 1990–91) and highly localised to the activities of fishermen of just one fishing town (the smallest, El Golfo de Santa Clara). The apparent absence of recorded dead vaquitas in October may be attributed, at least partially, to little or intermittent monitoring during this month.

However, the monthly numbers of dead vaquitas in gillnets correlated strongly with the seasonal fishing for totoaba (mostly from early February to early May) and to some extent that also for sharks and rays (mostly from early February to late July).

SHRIMP TRAWLS

Norris and Prescott (1961) briefly mentioned a report by a fisherman who had accidentally captured vaquitas in a shrimp trawl. The deaths of eight vaquitas in shrimp trawls in 1985 (2), 1988 (1), 1984–9 (2) and 1990 (3), with all but one referred to as 'very small' (probably calves or juveniles), were reported to the author, A. Robles and to H. Pérez-Cortés (pers. comms) (Centro Regional de Investigaciones Pesqueras, La Paz, BCS) by fishermen of El Golfo de Santa Clara (5), San Felipe (2) and by the San Felipe SEPESCA official (1). Considering the large number of shrimp boats operating in the uppermost Gulf of California, this fishery poses an additional threat to the vaquita population, particularly to the slow-swimming calves.

SUMMARY OF THREAT BY FISHERIES

The data presented in Table 4, although not complete, provide a general idea of the fishing effort for the fisheries that pose a threat to the survival of the vaquita. A similar approach was adopted by Turk-Boyer (1989). The urgent need to monitor the mortality in these fisheries and to determine ways to reduce the incidental mortality of the vaquita led to the study reported in D'Agrosa *et al.* (1995).

Pollution

As noted by several authors (e.g. see review by Reijnders, 1988), the reproductive potential of coastal marine mammal populations can be drastically reduced by the

Table 4

Summary of information (for 1990) of fisheries that may incidentally take vaquitas. Information provided by local SEPESCA officials, fishermen and direct observations by the author.

Species	Period	No. gillnets	Mesh size (km)	Length of net (m)	Total length (km)
El Golfo de Santa Clara (226 *pangas*)					
Sharks, rays	Feb.-July	126	15	680	86
Mackerels	Apr.-July	125	8.5	459	57
Totoaba	Jan.-May	at least 30	20-30.5	180	5.4
[Also 16 shrimp boats, most trawling locally, October-May]					
San Felipe (260 *pangas*)					
Sharks, rays	Feb.-July	300	10-15	680	204
Mackerels	Apr.-July	300	8.5	459	138
Totoaba[1]	Jan.-May	?	20-30.5	180	at least 5.4
[Also 33 shrimp boats, trawling locally, October-May]					
Puerto Peñasco (?? *pangas*)					
Sharks	Sept. 89-Jan 90	32	10		
Sharks	Sept. 89-Jan 90	88	15	*ca* 93	
Sharks	Sept. 89- Jan 90	16	25-30.5		
Small fish	Sept. 89-Jan 90	52	7.5-9	24	
[Also 204 shrimp boats, most trawling locally, October-May]					
Puertecitos (30 *pangas*, 40 fishermen)					
Sharks	Nov.-Aug.	30	10-15	900	27

[1] No accurate estimate available. Some local fishermen and those from El Golfo de Santa Clara believed at least similar to El Golfo de Santa Clara.

presence of high concentrations of organochlorine pollutants, particularly PCBs, DDT and DDE. Coastal odontocetes inhabiting waters near agricultural areas appear to be particularly susceptible to accumulation of these contaminants. Some coastal phocoenids have been found to have accumulated high concentrations of these pollutants (Holden and Marsden, 1967; O'Shea *et al.*, 1980; Gaskin *et al.*, 1982; 1983; Aguilar and Borrell, 1995). Although reproductive disorders and population declines in European harbour porpoises have been attributed by some authors to high PCB concentrations (Otterlind, 1976; Verwey and Wolff, 1981; both cited by Barlow, 1986), Reijnders (1992) concluded that this view was not supported by present information (and see IWC, 1995b).

After detecting high concentrations of DDT in bivalve molluscs near the Colorado River mouth, Guardado (1975) concluded that the Mexicali Valley, with all its agricultural activities, is an important source of pollutants in the upper Gulf of California. Pollutants could also have been carried to the region by the flow of this river after irrigating agricultural areas in the USA. However, samples of blubber from eight incidentally caught vaquitas (see Brownell *et al.*, 1987) analysed for chlorinated hydrocarbon concentrations (Calambokidis *et al.*, 1993), showed relatively low concentrations of DDT compounds, alpha-BHC and PCBs compared to those reported for odontocetes in many other areas. They concluded that chlorinated hydrocarbon pesticides do not apparently pose a threat to the vaquita population of the Gulf of California.

Vázquez-Cuevas *et al.* (1994) analysed four vaquitas (one adult female and three male calves) for heavy metals, and the highest concentrations (ppm) were of Zn(307–634), Fe (99–120), Hg (33–97), Al (50) and Pb (21–38).

Barlow (1986) reported that two drilling platforms were erected (and later removed) near Puerto Peñasco and El Golfo de Santa Clara in the early 1980s. Although it is not known if other explorations for fossil hydrocarbons are being planned in the upper Gulf, future development could pose a serious problem for the vaquita if a large oil spill occurs (Vidal *et al.*, In press).

RESEARCH NEEDS AND RECOMMENDATIONS

As pointed out by Barlow (1986), the most direct and probably the only sure way to promote the recovery of the vaquita would be to reduce the level of human-inflicted mortality. Several authors agree on what must be known and what must be done in order to ensure its survival (e.g. Brownell, 1982; Barlow, 1986; Silber, 1990b). In the original version of this paper, I summarised their suggestions and gave others for the rational management of this species. These are given below, along with a short summary (in italics) of any progress made.

(1) Eliminate incidental mortality of the vaquita in the illegal totoaba fishery by: (a) full enforcement of existing laws prohibiting this fishery; (b) elimination of the so-called 'experimental' permits to catch totoaba; (c) stopping the market of totoaba meat in México, particularly in Baja California Norte and Sonora; and (d) stopping importation of totoaba meat for USA markets and making the customers aware of the problem. *In February 1992, the Mexican Government banned the use of nets with mesh sizes >25cm and in June 1993 declared the Biosphere Reserve of the Upper Gulf of California and the Colorado River Delta mainly to protect the vaquita, totoaba and their habitat (see Vidal, 1993 and D'Agrosa et al., 1995).*

(2) Determine the magnitude of incidental mortality in other gillnet fisheries (i.e. for sharks and rays, sciaenid corvinas, mackerels, shrimp) by monitoring these fisheries. *Progress is reported in D'Agrosa et al. (1995).*

(3) Obtain accurate estimates of population size and more information on the total range and possible seasonal movements of the vaquita, by conducting census surveys. *Progress is reported in Gerrodette (1994) and Gerrodette et al. (1995).*
(4) Modify fishing effort, timing and technique for the shark and ray fishery by (a) restricting fishing areas; (b) restricting fishing periods; and (c) investigating alternative fishing methods or other economically viable alternatives. (*See numbers 1 and 10*).
(5) Analyse, as soon as possible, the information on food habits of the vaquita to determine if competition exists with commercial fisheries.
(6) Collect data on sources and magnitude of natural mortality.
(7) Determine the age at sexual maturity, calving interval and longevity of female vaquitas. *Progress is reported in Hohn et al. (In press).*
(8) Design and implement an educational program to increase the awareness of local fishermen and the general public of the plight of the vaquita. *NGO's and Government Agencies are working on this matter within the framework of a management plan which is being prepared for the Biosphere Reserve (see number 10).*
(9) Monitor plans for future oil exploration and development in the northern Gulf and assess the possible effects of oil spills.
(10) Design and implement a comprehensive management plan for the upper Gulf of California by multidisciplinary scientific and management effort. *The Mexican Secretariat of the Environment, Natural Resources and Fisheries, together with NGOs and academic institutions prepared a draft plan which is expected to be ready in late 1995.*

Status of the vaquita

P. sinus was listed as 'Vulnerable' in 1978 by the IUCN-The World Conservation Union [formerly the International Union for Conservation of Nature and Natural Resources (IUCN)] in their Red Data Book (IUCN, 1978) and also in the Mexican list of wild vertebrates in danger of extinction (Villa-Ramírez, 1978). The vaquita was also listed in Appendix I of the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora on 28 June 1979 (Brownell, 1983), and in February 1985 as an endangered species under the USA Endangered Species Act (Barlow, 1986). Recently, this porpoise was classified as 'Endangered' (a taxon in danger of extinction and whose survival is unlikely if the causal factors continue operating) in the IUCN Cetacean Red Data Book (Klinowska, 1991). Considering (1) the probable small population size and very limited range of *P. sinus*; (2) current levels of incidental (and potential) mortality in fishing activities; (3) the difficulties and the costs needed to implement and to enforce long-term conservation measures quickly; (4) the present lack of alternative means for fishermen to make a living; and (5) the several factors negatively affecting the upper Gulf ecosystem; I conclude that the vaquita is in immediate danger of extinction. If we do not succeed in reducing the incidental mortality soon, we will certainly face the extinction of the first cetacean species as a direct result of human short-sightedness and disregard for the ecological balance of the world in which we live.

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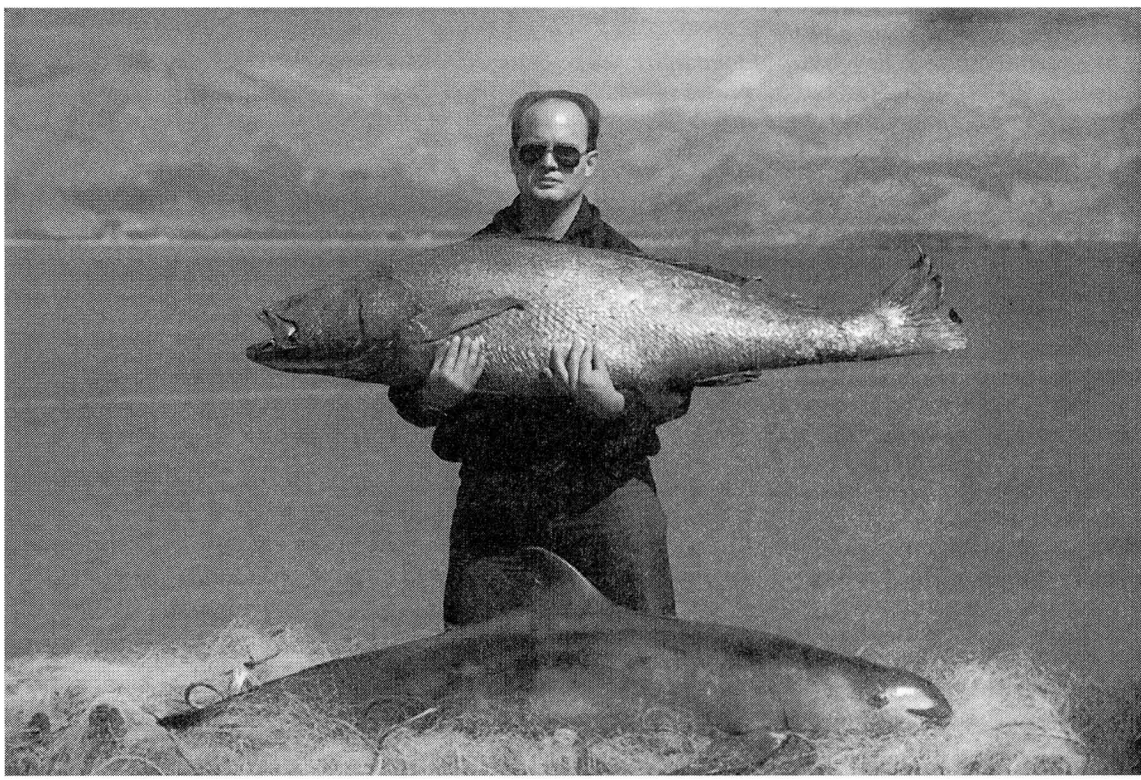

Plate I. C. Navarro with a vaquita and totoaba taken in totoaba nets at Golfo de Santa Clara (photo by O. Vídal).

APPENDIX

Table 1

Confirmed records of *Phocoena sinus* from the Gulf of California, Mexico (arranged from north to south) (SN=skeleton; PS=partial skeleton; SK=skull; PSK=partial skull; FP=fluid-preserved (complete specimen); F= frozen (complete specimen) OB=other bones, (e.g. vertebrae) (summarised by Brownell, 1986; Vidal, 1991; this paper) (see Fig. 1).

No.	Locality	Date of collection	Museum number	Nature of specimen	Reference
1	*ca* Isla Montague	26/02/91	ITESM910226	SN	This paper
2	5km N of El Golfo de Santa Clara	01/03/85	ITESM850301	SK,OB	This paper
3	3km N and 1km E of El Golfo de Santa Clara	05/02/71	LACM33496	PS	Brownell, 1983
4	*ca* El Golfo de Santa Clara	19/05/90	ITESM900519	SN	Vidal, 1991
5	*ca* El Golfo de Santa Clara	17/05/85	ITESM850517-01-'9'	SN	Brownell *et al.*, 1987
6	*ca* El Golfo de Santa Clara	20/05/90	ITESM900520	PS,SK	Vidal, 1991
7	*ca* El Golfo de Santa Clara	20/05/90	ITESM900521	PS,SK	Vidal, 1991
8	*ca* El Golfo de Santa Clara	24/02/91	ITESM910224	SN	This paper
9	*ca* El Golfo de Santa Clara	24/02/91	ITESM910224-1	FP	(A near term foetus of the above individual), this paper
10	El Golfo de Santa Clara	/02/69	UALP3408	PSK,OB	Brownell, 1983
11	El Golfo de Santa Clara	07/05/84	IBUNAM3839	SN	Brownell, 1986
12	El Golfo de Santa Clara	05/04/88	IBUNAM	SN	Silber and Norris, 1991
13	El Golfo de Santa Clara	21/04/88	IBUNAM	SN	Silber and Norris, 1991
14	El Golfo de Santa Clara	04/03/91	ITESM910304	SN	This paper
15	El Burro, *ca* El Golfo de Santa Clara	12/03/85	ITESM850312-01-'1'	SN	Brownell *et al.*, 1987
16	El Burro	12/03/85	ITESM850312-02-'2'	SN	Brownell *et al.*, 1987
17	El Burro	13/03/85	ITESM850313-01-'26'	SN	Brownell *et al.*, 1987
18	El Burro	13/03/85	ITESM850313-02-'27'	SN	Brownell *et al.*, 1987
19	El Burro	13/03/85	ITESM850313-03-'25'	FP	Brownell *et al.*, 1987
20	El Burro	13/03/85	ITESM850313-04-'24'	SN	Brownell *et al.*, 1987
21	El Burro	14/03/85	ITESM850314-01-'3'	SN	Brownell *et al.*, 1987
22	El Burro	21/02/86	IBUNAM	SN	Lamothe-Argumedo, 1988
23	El Burro	17/03/86	ITESM860317	SN	Vidal, 1991
24	El Burro	09/04/88	FCMM0123	SN	Vidal, 1991
25	El Burro	09/04/88	FCMM0124	SN	Vidal, 1991
26	El Burro	27/02/90	ITESM900227	SN	Vidal, 1991
27	El Burro	11/04/90	ITESM900411	FP	Vidal, 1991
28	El Burro	12/04/90	ITESM900412	SN	Vidal, 1991
29	El Burro	21/04/90	ITESM900421	SN	Vidal, 1991
30	El Burro	22/02/91	ITESM910222-1	SN	This paper
31	El Burro	12/03/91	ITESM910312-1	SN	This paper

Table 1 (cont.)

No.	Locality	Date of collection	Museum number	Nature of specimen	Reference
32	El Burro	12/03/91	ITESM910312-2	FP	This paper
33	El Burro	31/03/91	ITESM910331	F	This paper
34	El Burro	07/04/91	ITESM910407	SN	This paper
35	El Burro	11/04/91	ITESM910411-1	FP	This paper
36	El Burro	21/04/91	ITESM910421	FP	This paper
37	El Burro	19/05/91	ITESM910519	FP	This paper
38	El Burro	02/02/92	ITESM920202	SN	This paper
39	Between El Burro & El Tornillal, *ca* El Golfo de Santa Clara	13/03/91	ITESM910313-1	SN	This paper
40	Between El Burro & El Tornillal	13/03/91	ITESM910313-2	SN	This paper
41	Between El Burro & El Tornillal	13/03/91	ITESM910313-3	SN	This paper
42	Between El Tornillal & La Salina, *ca* El Golfo de Santa Clara	14/05/85	IBUNAM3947	SN	Brownell *et al.*, 1987
43	El Tornillal	14/05/85	IBUNAM3948	SN	Brownell *et al.*, 1987
44	El Tornillal	27/04/86	ITESM860427	SN	Vidal, 1991
45	El Tornillal	26/05/90	ITESM900526	SN	Vidal, 1991
46	El Tornillal	07/02/91	ITESM910207	SN	This paper
47	El Machorro, *ca* El Golfo de Santa Clara	12/05/85	ITESM850512-01-'4'	SN	Brownell *et al.*, 1987
48	El Machorro	20/08/90	ITESM900902	SN	Vidal, 1991
49	El Quelele, Baja California	08/04/90	ITESM900408-2	FP	Vidal, 1991
50	El Quelele	08/04/90	ITESM900408	SN	Vidal, 1991
51	El Quelele	20/01/92	ITESM920120	F	This paper
52	El Quelele	24/01/92	ITESM920124	F	This paper
53	*ca* El Moreno, *ca* El Quelele	09/04/91	ITESM910409	FP	This paper
54	El Macho, *ca* El Quelele	21/05/91	ITESM910521	SN	This paper
55	Playa Estación, Puerto Peñasco	20/11/79	IBUNAM17057	SN	Magatagan *et al.*, 1984
56	Playa Estación	20/11/79	IBUNAM19588	SN	Magatagan *et al.*, 1984
57	Las Conchas, Puerto Peñasco	/12/80	IBUNAM19589	SK	Magatagan *et al.*, 1984
58	Las Conchas	27/06/91	IBUNAM	SN	CEDO News, 1991
59	Las Conchas	28/06/91	IBUNAM	SN	CEDO News, 1991
60	Puerto Peñasco	10/05/84	IBUNAM3840	PS	Brownell, 1986
61	Puerto Peñasco	30/04/87	CEDO0007	SN	Silber and Norris, 1991
62	18km NE of Rocas Consag	/06/85	FCMM0067	SN	Vidal, 1991
63	18km NE of Rocas Consag	/06/85	FCMM0068	SN	Vidal, 1991
64	*ca* Rocas Consag	14/05/85	ITESM850514-01-'5'	SN	Brownell *et al.*, 1987
65	*ca* Rocas Consag	14/05/85	ITESM850514-02-'6'	SN	Brownell *et al.*, 1987
66	*ca* 24.5km off Punta Felipe	07/07/87	ITESM870707	SN	Vidal, 1991
67	*ca* 24km N of San Felipe	24/04/66	SDNHM20688	SN	Brownell, 1983
68	*ca* 24km N of San Felipe	01/04/67	LACM28259	SN	Brownell, 1983

Table 1 (cont.)

No.	Locality	Date of collection	Museum number	Nature of specimen	Reference
69	*ca* 24km N of San Felipe	01/04/67	----	OB	Brownell, 1986
70	*ca* 24km N of San Felipe	/10/67	USNM395722	PSK	Brownell, 1986
71	20km N of San Felipe	10/07/70	LACM51138	PSK	Brownell, 1986
72	*ca* 20km N of San Felipe	/11/67	USNM395723	PSK	Brownell, 1986
73	*ca* 19km N of San Felipe	06/02/66	SDNHM20689	OB	Brownell, 1986
74	*ca* 19km N of San Felipe	/64	BMNH69.678	PS,SK	Noble and Fraser, 1971
75	*ca* 17km N of San Felipe	23/09/66	LACM27407	PSK	Brownell, 1986
76	*ca* 16.5km N of San Felipe	03/02/64	MCZ51490	PSK	Brownell, 1986; Vidal, 1991
77	15km N of San Felipe	23/04/66	SDNHM20690	OB	Brownell, 1986
78	NE shore of Punta San Felipe	18/03/50	MVZ120933	SK	Norris and McFarland, 1958
79	5km N of San Felipe	/06/82	NMFS(NMML)	SK	Brownell, 1986
80	San Felipe	/60	SDNHM20697	PSK	Brownell, 1986
81	San Felipe	11/04/88	IBUNAM	SN	Silber and Norris, 1991
82	Bahía de San Felipe	/12/51	MVZ120934	PSK	Norris and McFarland, 1958
83	Bahía de San Felipe	/12/51	USNM303308	PSK	Norris and McFarland, 1958
84	S of Bahía San Felipe	26-28/11/64	LACM	PSK	Brownell, 1986
85	S of Bahía San Felipe	22/11/62	LACM	PSK	Brownell, 1986
86	S of San Felipe	/04/66	----	PS,PSK	Brownell, 1986
87	27km S of Punta Diggs	Easter 1966	SDNHM21555	PSK	Brownell, 1986
88	*ca* 10km N Puertecitos	18/08/68	CAS14631	PSK	Orr, 1969
89	*ca* 3km S Puertecitos	Spring 61	USNM395892	PSK	Brownell, 1986
90	Gulf of California	89	SWFC0113	SK	Vidal, 1991

Collection acronyms: BMNH, British Museum (Natural History), London; CAS, California Academy of Sciences, San Francisco, USA; CEDO, Centro Intercultural para el Estudio de Desiertos y Océanos, Puerto Peñasco, Sonora, México; FCMM, Facultad de Ciencias, Universidad Nacional Autónoma de México, México, DF; IBUNAM, Instituto de Biología, Universidad Nacional Autónoma de México, México, DF; ITESM, Instituto Tecnológico y de Estudios Superiores de Monterrey-Campus Guaymas, Sonora; LACM, Natural History Museum of Los Angeles County, California; MCZ, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA; MVZ, Museum of Vertebrate Zoology, University of California, Berkeley; NMFS (NMML), National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, Washington; SDNHM, San Diego Natural History Museum, California; SWFC, Southwest Fisheries (Sciences) Center, National Marine Fisheries Service, La Jolla, California; UAZLP, University of Arizona, Laboratory of Paleontology, Tucson, Arizona, USA; and USNM, National Museum of Natural History, Smithsonian Institution, Washington, DC.

Table 2

Incidental mortality of *Phocoena sinus* in fishing activities in the Gulf of California, México (arranged from north to south) (EGSC = El Golfo de Santa Clara; GT = gillnet for totoaba, with a mesh size of 20-30.5cm; GS = gillnet for sharks and rays, mesh size of 10-15cm; OG = other gillnet, mesh size of 8.5cm; SB = shrimp boat; SM = sexually mature; PM = physically mature) (see Fig. 1) [1].

No.	Locality	Date	Cause of death	Dist. from shore(km)	Depth(m)	Sex	Length (cm)	Weight (kg)	SM	PM
1	*ca* Isla Montague	26/02/91	GT		*ca*. 14	M				
2	EGSC09	09-10/84	GT	*ca* 3.6	*ca* 14			*ca* 20		
3	EGSC	05/04/88	G?			F	72.0		No	No
4	EGSC	10/90	SB							
5	EGSC	01/03/91	OG			F				
6	Offshore from EGSC	09/04/72	GT			F				
7	Offshore from EGSC	09/04/72	GT				74.0			
8	Offshore from EGSC	06/90	GS							
9	Offshore from EGSC	17/12/90	GT						No	No
10	Offshore from EGSC	24/02/91	GT	*ca* 27	*ca* 13	F			Yes	Yes
11	El Machorro, *ca* 8km S of EGSC	21/04/88	GT				*ca* 100			
12	El Machorro	21/04/88	GT				*ca* 100			
13	El Machorro	12/05/85	GS	*ca* 10	*ca* 27	F	110.0	23.7	No	No
14	El Machorro	10/06/90	GS		*ca* 16		*ca* 115			
15	El Machorro	20/08/90	OG			M	133.6	31.0	No	No
16	Between El Tornillal and La Salina, *ca* EGSC	14/05/85	GS	*ca* 33	18-22	F	90.3	14.7	No	No
17	La Salina, *ca* EGSC	1-5/11/85	SB	*ca* 3.3						
18	La Salina	1-5/11/85	SB	*ca* 3.3						
19	La Salina	08/04/90	SB		27		'calf'		No	No
20	La Salina	07/09/90	OG		36					
21	El Tornillal, *ca* EGSC	14/05/85	GS	6	22-27	M	94.5	17.7	No	No
22	El Tornillal	08/05/85	?	*ca* 4.5	*ca* 30			*ca* 18	No	No
23	El Tornillal	04/87	GS							
24	El Tornillal	04/87	GS							
25	El Tornillal	25/02/90	GT							
26	El Tornillal	mid 02/90	GT		*ca* 14					
27	El Tornillal	16/04/90	GT		*ca* 16					
28	El Tornillal	24/05/90	GS	*ca* 18	18	M				
29	El Tornillal	*ca*10/06/90	GS							
30	El Tornillal	*ca*07/02/91	GT		*ca* 16	F				
31	El Tornillal	13/03/91	GT		*ca* 14	M				
32	El Tornillal	13/03/91	GT		*ca* 14	M				
33	8km off El Tornillal	13/05/85	GS	*ca* 8	*ca* 31		*ca* 110	*ca* 20		
34	Between El Tornillal and El Burro, *ca* EGSC	03-06/89	GS		*ca* 14					
35	Between El Tornillal and El Burro	03-06/89	OG		*ca* 14					
36	Between El Tornillal and El Burro	26/02/91	GT		*ca* 14					
37	Between El Tornillal and El Burro	13/03/91	GT		*ca* 13	F				
38	El Burro, *ca* 20km ESE of EGSC	12/03/85	GT	7	12.6	M	103.0	21.7	No	No
39	El Burro	12/03/85	GT	7	12.6	F	108.6	23.7	No	No
40	El Burro	13/03/85	GT	4	12.6	F	135.0	42.7	Yes	Yes

Table 2 (cont.)

No.	Locality	Date	Cause of death	Dist. from shore(km)	Depth(m)	Sex	Length (cm)	Weight (kg)	SM	PM
41	El Burro	13/03/85	GT	4	12.6	F	135.0	43.7	Yes	Yes
42	El Burro	13/03/85	GT	4	12.6	F	70.3	7.8	No	No
43	El Burro	13/03/85	GT	4	12.6	M	134.5	46.7	Yes	Yes
44	El Burro	14/03/85	GT	4	12.6	F	106.9	22.2	No	No
45	El Burro	04?/85	GT	*ca* 10	*ca* 22					
46	El Burro	21/02/86	GT	*ca* 3	*ca* 11	M	114.0	20.5		
47	El Burro	24/03/86	GT	*ca* 4	*ca* 13	M	131.5	41.0	Yes	Yes
48	El Burro	03/87	GT							
49	El Burro	03/87	GT							
50	El Burro	6-9/04/88	GT		*ca* 18	M	74.3	11.0	No	No
51	El Burro	6-9/04/88	GT		*ca* 18	M	70.8	10.0	No	No
52	El Burro	6-9/04/88	GT		*ca* 18	F(?)				
53	El Burro	6-9/04/88	GT		*ca* 18	F(?)				
54	El Burro	late/02/89	GT							
55	El Burro	mid/03/89	GT				*ca* 50		No	No
56	El Burro	03/89	GT							
57	El Burro	03/89	GT							
58	El Burro	03/89	GT							
59	El Burro	03/89	GT							
60	El Burro	03/89	GT							
61	El Burro	10/02/90	GT		*ca* 11					
62	El Burro	14/02/90	GT		*ca* 14		*ca* 150			
63	El Burro	14/02/90	GT		*ca* 14		*ca* 150			
64	El Burro	20/02/90	GT		10.5	F	109.8	23.0	No	No
65	El Burro	25/02/90	GT		*ca* 11					
66	El Burro	02/03/90	GT		*ca* 11					
67	El Burro	11/04/90	GT		*ca* 11	M	75.8	11.0	No	No
68	El Burro	12/04/90	GT		*ca* 11	M	131.8	37.0	Yes	Yes
69	El Burro	19/04/90	GT		*ca* 16	M				
70	El Burro	22/02/91	GT	2	*ca* 15	F				
71	El Burro	12/03/91	GT		*ca*16	F				
72	El Burro	12/03/91	GT		*ca* 4					
73	El Burro	31/03/91	GT		*ca* 13	F				
74	El Burro	04/04/91	GT		*ca*14				No	No
75	El Burro	07/04/91	GT		*ca* 14					
76	El Burro	11/04/91	GT		*ca* 13					
77	El Burro	11/04/91	GT		*ca* 13					
78	El Burro	12/01/92	GT							
79	El Burro	02/02/92	GT			F	148.2	44.0	Yes	Yes
80	El Quelele, 10km off Punta Sargento, Baja California	17/05/85	GS	*ca* 14	9	M	110.0	23.2	No	No
81	El Quelele	12/05/85	GT	*ca* 10	*ca* 14		*ca* 100	*ca* 18		
82	El Quelele	12/05/85	GT	*ca* 10	*ca* 14		*ca* 100	*ca* 18		
83	El Quelele	09/05/85	GT	*ca* 10	*ca* 14			*ca* 20		
84	El Quelele	03-05/89	GS		*ca* 8					
85	El Quelele	03-05/89	GS		*ca* 8					
86	El Quelele	mid/03/89	GT	*ca* 10	*ca* 14					
87	El Quelele	02/04/90	GT		*ca* 12.6	F	135.0	41.0	Yes	Yes
88	El Quelele	02/04/90	GT		*ca* 12.6	M	78.2	12.5	No	No
89	El Quelele	01/92	GT							
90	El Quelele	20/01/92	GT			F	116.6	26.3	No	No
91	El Quelele	24/01/92	GT			F	113.2	24.7	No	No
92	*ca* El Quelele	09/04/91	GT		*ca* 7				No	No

Table 2 (cont.)

No.	Locality	Date	Cause of death	Dist. from shore(km)	Depth(m)	Sex	Length (cm)	Weight (kg)	SM	PM
93	Off Pta Borrascoso	26/01/88	GT	*ca* 3	*ca* 8					
94	30 km N of Rocas Consag	14/05/85	GS		*ca*22		*ca* 75	*ca* 12		
95	18km NE of Rocas Consag	06/5	GS				F	140.0	Yes	Yes
96	As 95	06/85	GS				M	95.0	No	No
97	*ca* 10km N of Rocas Consag	14/05/85	GS		18-22	M	93.5	16.7	No	No
98	As 97	14/05/85	GS		18-22	F	143.5	45.7	Yes	Yes
99	NW of Rocas Consag and NE of San Felipe	07/07/87	GS	*ca* 24.5	16	M	109		No	No
100	5km N of Rocas Consag	01?/85	GT		*ca* 36					
101	N of Rocas Consag	11/05/85	GS	*ca* 20	*ca* 22			*ca* 13		
102	N of Rocas Consag	13/05/85	GS	*ca* 20	*ca* 22		*ca* 100	*ca* 20		
103	N of Rocas Consag	17/05/90	GS							
104	N of Rocas Consag	19/05/90	GS		*ca* 23					
105	*ca* Rocas Consag	18/05/90	GS			M	127.0		No	No
106	*ca* Rocas Consag	06/90	GS							
107	*ca* Rocas Consag	08//90	GS							
108	*ca* El Cantiloso, *ca* 9km S of Rocas Consag	18/02/90	SB		*ca* 72				No	No
109	El Chinero, *ca* San Felipe	12/04/85	GT	*ca* 7	*ca* 9	M	*ca* 110			
110	El Chinero	10/05/85	GS		*ca* 7					
111	El Chinero	04/90	GT		16					
112	El Chinero	04/90	GT		16					
113	*ca* Campo Don Abel, San Felipe	03-04/ 1967-84	GT,GS, SB	('at least 10 vaquitas caught')						
114	Campo Don Abel	1985-86	GT							
115	Campo Don Abel	1985-86	GT							
116	Campo Don Abel	1985-86	GT							
117	Campo Don Abel	1985-86	GT							
118	Campo Don Abel	1985-86	GT							
119	San Felipe	11/04/88	G?			F	129			
120	Near San Felipe	1985-87	GT							
121	Near San Felipe	06/90	GS							
122	Near San Felipe	07/90	GS							
123	'Around San Felipe'	early 1970s	GT	(10 vaquitas caught)						
124	Isla Salvatierra, Islas Encantadas	01/90	GS							
125	'Upper Gulf'	early 05/85	GS							
126	'Upper Gulf'	03/89	SB				*ca* 110			
127	Upper Gulf	02-05/90	GT?							
128	Upper Gulf	02-05/90	GT?							

[1] Reported by: Brownell (1982): No. 123; Brownell (1983): 6, 7; Brownell *et al.* (1987): 13, 16, 21, 38-44, 80, 97, 98; Pérez-D (1987): 95, 96; Silber and Norris (1991): 3, 119; Present paper: pers. obs. by Vidal and/or communications of reliable fishermen (1, 2, 4, 5, 8-10, 14, 15, 19, 20, 22-32, 34-37, 46, 54-79, 84-92, 103-113, 120, 121, 124, 126-128); and pers. comms of A. Robles (17, 18, 33, 45, 81-83, 94, 100-102, 125), J.C. Barrera (11, 12, 47-49, 93), S.A. Pérez (114-118), M. Román (50-53) and F. Maldonado (99).