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 5,000km² of mostly shallow waters), with most records near
San Felice, 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 Felice 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 Huervanito, 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.

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.

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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).

<table>
<thead>
<tr>
<th>Date</th>
<th>Sex</th>
<th>Length</th>
<th>Weight</th>
<th>Comments</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/04/72</td>
<td>?</td>
<td>74cm</td>
<td>7.8 kg</td>
<td></td>
<td>Brownell, 1983</td>
</tr>
<tr>
<td>13/03/85</td>
<td>F</td>
<td>70.3cm</td>
<td></td>
<td></td>
<td>Brownell <em>et al.</em>, 1987</td>
</tr>
<tr>
<td>14/05/85</td>
<td>?</td>
<td><em>ca</em> 75cm</td>
<td>7.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td>06-09/04/88</td>
<td>M</td>
<td>74.3cm</td>
<td>11 kg</td>
<td>A. Robles (pers. comm.)</td>
<td>This paper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M. Román (pers. comm.)</td>
<td>This paper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>this calf and the one below</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>were incidentally killed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with one large individual</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>each (their mothers?)</td>
<td></td>
</tr>
<tr>
<td>06-09/04/88</td>
<td>M</td>
<td>70.8cm</td>
<td>10 kg</td>
<td>M. Román (pers. comm.)</td>
<td>This paper</td>
</tr>
<tr>
<td>05/04/88</td>
<td>F</td>
<td>72.9cm</td>
<td>8.5 kg</td>
<td></td>
<td>Silber and Norris, 1991</td>
</tr>
<tr>
<td>mid 03/89</td>
<td>?</td>
<td><em>ca</em> 50 cm</td>
<td>8.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td>08/04/90</td>
<td>?</td>
<td><em>ca</em> 80 cm</td>
<td>8.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Captured in a gillnet</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Captured in a shrimp boat</td>
<td></td>
</tr>
<tr>
<td>18/02/90</td>
<td>?</td>
<td><em>Very small</em></td>
<td>8.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Captured in a shrimp boat</td>
<td></td>
</tr>
<tr>
<td>02/04/90</td>
<td>M</td>
<td>78.2cm</td>
<td>12.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td>05/04/90</td>
<td>?</td>
<td><em>ca</em> 80 cm</td>
<td>12.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td>11/04/90</td>
<td>M</td>
<td>75.8cm</td>
<td>11 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td>12/03/91</td>
<td>F</td>
<td>74.9cm</td>
<td>7.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td>09/04/91</td>
<td>M</td>
<td>77.5cm</td>
<td>10.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td>11/04/91</td>
<td>F</td>
<td>72.8cm</td>
<td>8.5 kg</td>
<td></td>
<td>This paper</td>
</tr>
<tr>
<td>24/02/91</td>
<td>F</td>
<td>71.5cm</td>
<td>6.7 kg</td>
<td>Near-term foetus</td>
<td>This paper</td>
</tr>
<tr>
<td>13/05/94</td>
<td>M</td>
<td>67.0cm</td>
<td>5.0 kg</td>
<td>Stranded alive</td>
<td>CEDO, 1994</td>
</tr>
</tbody>
</table>

**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.

**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

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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 Rocos 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 Rocos 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.

*Text continues on p. 256*
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.

<table>
<thead>
<tr>
<th>Catalog number (ITESM)</th>
<th>900227</th>
<th>900408</th>
<th>900408-2</th>
<th>900411</th>
<th>900412</th>
<th>900519</th>
<th>900421</th>
<th>900526</th>
<th>900902</th>
<th>910226</th>
<th>910312-2</th>
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<tbody>
<tr>
<td>Sex</td>
<td>Female</td>
<td>Female</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
</tr>
<tr>
<td>Sexually mature</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Maturing</td>
</tr>
<tr>
<td>Physically mature</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>23.0</td>
<td>41.0</td>
<td>12.5</td>
<td>11.0</td>
<td>37.0</td>
<td>--</td>
<td>42.5</td>
<td>22.5</td>
<td>31.0</td>
<td>39.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Total length (cm)</td>
<td>109.8</td>
<td>135.0</td>
<td>78.2</td>
<td>75.8</td>
<td>131.8</td>
<td>127.0</td>
<td>142.2</td>
<td>113.7</td>
<td>133.6</td>
<td>128.3</td>
<td>74.9</td>
</tr>
<tr>
<td>Tip of upper jaw to:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Angle of gape</td>
<td>6.7</td>
<td>7.5</td>
<td>5.1</td>
<td>4.8</td>
<td>8.0</td>
<td>7.0</td>
<td>7.4</td>
<td>7.9</td>
<td>7.0</td>
<td>7.5</td>
<td>5.3</td>
</tr>
<tr>
<td>Center of blowhole</td>
<td>8.1</td>
<td>9.3</td>
<td>--</td>
<td>5.2</td>
<td>9.8</td>
<td>7.7</td>
<td>10.2</td>
<td>11.0</td>
<td>11.1</td>
<td>8.9</td>
<td>6.4</td>
</tr>
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<td>Center of eye</td>
<td>11.0</td>
<td>12.1</td>
<td>7.8</td>
<td>7.7</td>
<td>12.1</td>
<td>11.2</td>
<td>12.5</td>
<td>11.3</td>
<td>11.7</td>
<td>12.0</td>
<td>8.3</td>
</tr>
<tr>
<td>Auditory meatus</td>
<td>15.9</td>
<td>17.3</td>
<td>10.7</td>
<td>11.0</td>
<td>16.9</td>
<td>16.4</td>
<td>18.5</td>
<td>18.1</td>
<td>18.3</td>
<td>18.4</td>
<td>14.6</td>
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<td>Ant. insertion of flipper</td>
<td>23.1</td>
<td>25.7</td>
<td>17.3</td>
<td>15.5</td>
<td>25.1</td>
<td>25.0</td>
<td>27.2</td>
<td>22.5</td>
<td>24.6</td>
<td>24.2</td>
<td>15.9</td>
</tr>
<tr>
<td>Umbilical scar</td>
<td>48.5</td>
<td>57.3</td>
<td>36.8</td>
<td>36.3</td>
<td>56.3</td>
<td>--</td>
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<td>2.9</td>
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<td>22.2</td>
<td>60.0</td>
<td>48.5</td>
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**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)).

<table>
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<th>Year</th>
<th>Month</th>
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<th>Locality</th>
</tr>
</thead>
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<tr>
<td>1967-1984</td>
<td>Mar-Apr</td>
<td>At least 10</td>
<td>ca San Felipe</td>
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<td>?</td>
<td>'10'</td>
<td>'Around San Felipe'</td>
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<tr>
<td>1972</td>
<td>Apr</td>
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<tr>
<td>1984</td>
<td>Sept-Oct</td>
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<tr>
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<td>Jan, Mar, Apr, May, Jun, Nov</td>
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<td>+2</td>
<td>ca El Golfo de Santa Clara, San Felipe</td>
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<td>1987</td>
<td>Mar, Apr, Jul</td>
<td>6</td>
<td>ca El Golfo de Santa Clara, Rocos Consag</td>
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<td>Jan, Apr</td>
<td>9</td>
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<td>1989</td>
<td>Feb, Mar</td>
<td>13</td>
<td>ca El Golfo de Santa Clara, Punta Sargento, Baja, California Norte</td>
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<td>Jan, Feb, Mar, Apr, May, Jun, Aug, Sept, Dec</td>
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<td>Feb, Mar, Apr, Jul</td>
<td>22</td>
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(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 *Loligo 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 25 m, 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/calves 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, Synthesesium tursioticus, 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 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, Sphyraena 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-Rodríguez, 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 |
|------------------|--------------|-----------------|-----------------|-----------------|-----------------|
| 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          | Feb.-July    | 300             | 10-15           | 680             | 204             |
| Mackerels       | Apr.-July    | 300             | 8.5             | 459             | 138             |
| Totoaba         | 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-Ramirez, 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.

**ACKNOWLEDGMENTS**

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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. Vidal).
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).

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**Collection acronyms:** BMNH, British Museum (Natural History), London; CAS, California Academy of Sciences, San Francisco, USA; CEDO, Centro Inter Cultural 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 20-30.5 cm; GS = gillnet for sharks and rays, mesh size of 10-15 cm; OG = other gillnet, mesh size of 8.5 cm; SB = shrimp boat; SM = sexually mature; PM = physically mature) (see Fig. 1) \(^7\).

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<td>1985-86</td>
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<td>GS</td>
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<td>123</td>
<td>‘Around San Felipe’</td>
<td>early 1970s</td>
<td>GT (10 vaquitas caught)</td>
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<td>01/90</td>
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<td>125</td>
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<td>early 05/85</td>
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<td>03/89</td>
<td>SB</td>
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<td><em>ca</em> 110</td>
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<tr>
<td>128</td>
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<td>02/05/90</td>
<td>GT?</td>
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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).