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# Mortality of the Vaquita (*Phocoena sinus*) in Gillnet Fisheries During 1993–94

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ABSTRACT

Gillnet fisheries in El Golfo de Santa Clara, Sonora and neighboring fishing camps, in the upper Gulf of California, México, were monitored for 114 days, from 23 January to 7 August 1993, and on nine 1–6 day visits from 15 September 1993 to 29 March 1994, to estimate the rate of incidental mortality of the vaquita (*Phocoena sinus*). Data on fishing effort and vaquita deaths were collected by interviewing fishermen on the beach when they had returned from fishing and by placing observers on different vessels each working day. The deaths of 15 vaquitas were documented during 1993–94. Twelve vaquitas were killed in *ca* 16,000 hours of fishing effort between January and October 1993: 5 in gillnets (mesh size 10–11cm) set for chano (*Micropogonias megalops*); 3 in gillnets ('chinchorro de línea', mesh size 7cm) for shrimp (*Penaeus* spp.); 2 in gillnets (mesh size 15cm) for sharks; 1 in a gillnet (mesh size 7.6cm) for mackerel and sierra (*Scomberomorus* spp.); and 1 in either a gillnet set for chano or for sharks. Two more vaquitas were killed in October 1993 and January 1994 (the last one in a gillnet set for shrimp) and another in a commercial shrimp trawl in February 1993. Most vaquitas were caught in nets set on the bottom; some were caught in driftnets.

KEYWORDS: VAQUITA; INCIDENTAL CAPTURE; NORTH PACIFIC

## INTRODUCTION

The vaquita (*Phocoena sinus*), an endemic species only found in the upper Gulf of California, México, has the most limited distribution of any marine cetacean (Brownell, 1986; Vidal *et al.*, In press) and is in danger of extinction due to its incidental capture in gillnets (Vidal, 1993; IWC, 1995). Based on recent surveys, Gerrodette *et al.* (1994) estimated that the total vaquita population is 400–500 individuals. Genetic studies based on samples taken at different times and locations in the upper Gulf found no sequence polymorphisms (i.e. no genetic variability) in a 400 base pair segment of the control region of the mtDNA molecule, which may represent the results of a population 'bottleneck', founder effect, or severe inbreeding in the species (Rosel and Rojas-Bracho, 1993).

Gillnets are the most widely used fishing gear within the habitat range of the vaquita and these nets, particularly of large mesh sizes, are the most important factor in vaquita incidental mortality (Vidal, 1995). Until recently, they were mainly used to catch totoaba (*Totoaba macdonaldi*), a large sciaenid fish which is also endangered, although they are also used to catch sharks and rays. The totoaba fishery, once one of the most important fisheries in the upper Gulf of California, has been responsible for most vaquita deaths, at least during the last decade (Vidal, 1995). Although this fishery was banned in 1975 (Flanagan and Hendrickson, 1976), fishermen in the upper Gulf continued to fish totoaba at least until February 1992 (Vidal, 1993). In February 1992, the Mexican authorities banned the use of gillnets with a mesh size greater than 25cm (Diario Oficial de la Federación, 1992). However, this still permitted the use of nets with smaller mesh sizes

(i.e. for sharks and rays) previously proven to catch vaquitas. Renewed enforcement of the ban in 1993 and 1994 probably kept all, or most, totoaba fishermen from fishing this species. As the totoaba population decreased, fishermen turned their attention to other species such as shrimp, sharks, rays, corvinas and mackerel.

On 10 June 1993, the Mexican government declared the Biosphere Reserve of the Upper Gulf of California and the Colorado River Delta, mainly to protect the vaquita, the totoaba and their natural habitat (Vidal, 1993).

Although the information to date on fishing effort is not adequate to allow an estimation of the total pressure on the vaquita, data presented by Vidal (1995) provide a general idea of the potential impact of fishing activities. He documented a minimum of 128 vaquitas incidentally drowned in gillnets between March 1985 and February 1992: 65% died in gillnets with mesh sizes between 20–30.5cm set for totoaba; 28% in nets with mesh sizes between 10–15cm set for sharks and rays; and 7% in nets of a mesh size of 8.5cm set for mackerel and sierra (*Scomberomorus* spp.). Vidal (1995) estimates that a minimum of 35 vaquitas were killed every year between 1985 and 1991 in these fisheries. However, to date monitoring efforts have been non-continuous and highly localized to the activities of just one fishing town, El Golfo de Santa Clara, Sonora. Data on the life history of the vaquita indicates that there is some bias in those animals caught in gillnets (Hohn *et al.*, In press). There is a bimodal age structure in the sample, comprised mostly of animals incidentally killed by fishermen from El Golfo de Santa Clara, of less than three years and greater than ten years of age. Although monitoring effort of fishing activities has concentrated along the Sonoran coast and efforts to find live vaquitas have concentrated in the area between San Felipe and Rocas Consag, most of these data were collected in the spring (Silber, 1990; Vidal, 1995).

Until now, no attempt has been made to relate the mortality rates of vaquitas with fishing effort. This paper examines the rate of incidental mortality of the vaquita in gillnets during 1993–94 and provides a general description of these fisheries. However, these analyses are preliminary.

## METHODOLOGY

Monitoring concentrated on fishing from El Golfo de Santa Clara, a small town of about 1,600 people of whom almost all depend on fishing (McGuire and Greenberg, 1993) and where daily contact with the fishermen was possible. Monitoring took place from 23 January to 7 August 1993, and on nine 1–6 day visits between 15 September 1993 and 29 March 1994. Data on fishing effort and vaquita deaths were collected by D'Agrosa and at least two field assistants by non-systematically interviewing the greatest number of fishermen possible on the beach when they returned from fishing. These data include hours that the nets were in the water, kilograms of product caught per net, net size, mesh size, fishing depth, fishing location, number of boats, number of nets, and the incidental catch of vaquitas and other non-target species. Over the data collection period, a total of 48 field assistants were placed on small outboard motor boats (called *pangas*), which were also selected non-systematically, in order to corroborate the data provided by the fishermen and to collect additional data on the fishing activities (including latitude and longitude of fishing grounds using a global positioning system satellite navigation device, and climatological and oceanographical conditions). Data collected during the last two weeks of February and during two visits in March 1994 are not included in this analysis. No fishing (and thus monitoring) took place during neap tides, bad weather or during holidays.

Participant observation, a tool frequently used by anthropologists and which implies direct involvement in community life (Agar, 1980), such as helping deploy and collect the nets, attending social events and getting to know the families, was encouraged among field assistants to establish the trust of the fishermen and thus increase the reliability of the data obtained.

The rate of incidental mortality of the vaquita in gillnets was estimated by dividing the number of vaquitas caught by the number of hours the nets were in the water for each fishery. Vaquita mortality is standardized in this way so that we are able to make direct comparisons of incidental mortality by fishery, net mesh size, depth and geographic location. This also lays the groundwork for future statistical analyses.

## RESULTS

### Monitoring effort

From 23 January to 7 August 1993, 104 days of fishing activities were monitored, 9.5 days were monitored between 15 September 1993 and 29 March 1994 (Table 1). We sampled 322 (61%) of the estimated 525 trips to fish shrimp with gillnets during 1993, 367 (25%) of 1,486 trips to fish chano, 215 (46%) of 470 trips to fish sharks and rays, 30 (60%) of 50 trips to fish corvina and 232 (59%) of 390 trips to fish mackerel and sierra (see below) (Table 2 ).

### Fisheries

Although the fishing activities monitored covered the area from Punta Borrascoso, Sonora, across the Gulf, to San Felipe, Baja California (Fig. 1), only fishermen from El Golfo de Santa Clara were monitored. This included five fisheries using *pangas* with 55 and 75hp outboard motors and crews of 2–3. The percentage of hours of fishing for each

Table 1

Monitoring of gillnet fisheries in El Golfo de Santa Clara, Sonora, 23 January 1993 - 29 March 1994 (DF = days in the field; DM = days monitored; NA = number of field assistants) (see text).

| Month | DF | DM | NA | Fishery |
|---|---|---|---|---|
| **1993** | | | | |
| January | 15 | 2 | 3 | Shrimp |
| February | 28 | 14 | 6 | Shrimp |
| March | 31 | 17 | 8 | Chano |
| April | 30 | 19 | 6 | Chano |
| May | 18 | 12 | 2 | Corvina/Shark |
| June | 30 | 26 | 6 | Shark |
| July | 31 | 10 | 4 | Mackerel/Sierra |
| August | 8 | 4 | 2 | Mackerel/Sierra |
| September | 2.5 | 1 | 1 | Shrimp |
| October | 2.5 | 2 | 2 | Shrimp |
| November | 1.5 | 0 | 0 | Shrimp |
| December | 1.5 | 0 | 1 | Shrimp |
| **1994** | | | | |
| January | 1.5 | 0 | 1 | Shrimp |
| February | 5 | 2.5 | 4 | Shrimp |
| March | 6 | 4 | 2 | Shrimp/Chano |
| **Total** | 211.5 | 113.5 | 48 | |

Table 2

Survey effort in El Golfo de Santa Clara, 23 January 1993 - 15 February 1994.

| Fishery | Total trips observed | No. trips sampled | % total trips sampled | Total hours sampled | % total hours sampled |
|---|---|---|---|---|---|
| Shrimp | 525 | 322 | 61 | 3,826 | 25 |
| Corvina | 50 | 30 | 60 | 23 | 0.1 |
| Mackerel/Sierra | 390 | 232 | 59 | 2,677 | 17 |
| Shark/Ray | 470 | 215 | 46 | 6,218 | 40 |
| Chano | 1,486 | 367 | 25 | 2,787 | 18 |

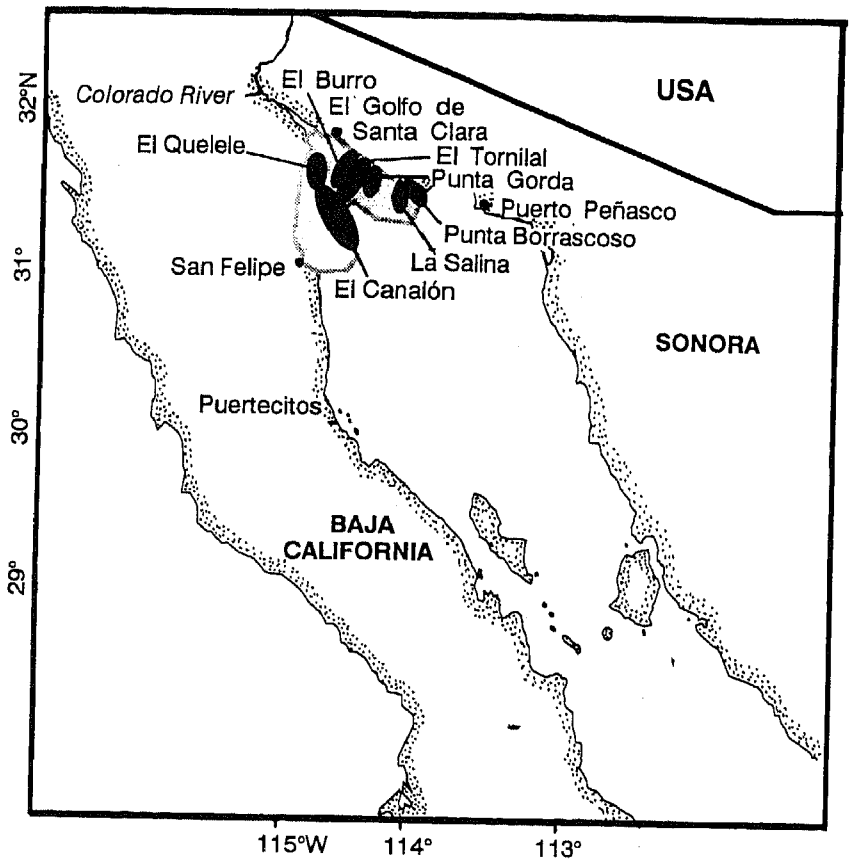


Fig. 1. Study area. Preferred fishing grounds in black, 23 January 1993–29 March 1994.

fishery from 23 January to 16 October 1993 are given in Table 2, with a total of *ca* 16,000 hours of effort monitored. These range from a high of 40% for the shark and ray fishery to a low of 0.1% in the corvina fishery. A general description of these fisheries follows (see also Table 3).

Table 3

General information of gillnet fisheries in El Golfo de Santa Clara during 1993-94 (dates are for both years unless otherwise specified).

| Fishery | Dates | Average net length (m) | Average net depth (m) | Net mesh size (cm) | Net type | Target species |
|---|---|---|---|---|---|---|
| Shrimp | Jan.-Mar. 1993; Sept. 1993-Mar. 1994 | 402 | 26 | 7 | Demersal, drift | *Penaeus stylirostris, P. californiensis* |
| Chano | Mar.-May | 342 | 17 | 10-12 | Demersal, drift | *Micropogonias megalops* |
| Shark | May-Jul. | 399 | 15 | 12-15 | Demersal, anchored | *Carcharhinus* spp., *Sphyrna* spp., *Rhizoprionodon* spp., *Mustelus* spp. |
| Corvina | May | 320 | 9 | 7-15 | Demersal, drift | *Cynoscion* spp. |
| Mackerel, Sierra | Jul.-Aug. | 504 | 0 | 7-10 | Surface, drift | *Scomberomorus sierra, S. concolor* |
| Ray | May-Jul. | 219 | 10 | 12-23 | Demersal, anchored | *Myliobatis, Rhinobatus, Dasyatis, Mobula* |

**Shrimp**

Brown (*Penaeus californiensis*) and blue shrimps (*P. stylirostris*) were fished from January to March 1993 and from September 1993 to mid-March 1994 using demersal monofilament gillnets (called *chinchorro de línea*) with a mesh size of 7cm or less. The nets are left to drift with the currents from 0.5 to 1.5 hours. They are cast and retrieved continually from sunrise to sunset. The nets are an average 402m long, 2.5m wide and drift at an average depth of 26m.

**Chano**

Fishing for chano (*Micropogonias megalops*), an endemic species of croaker, apparently increased in 1991 due to the decrease in shrimp yields, but also probably because of the renewed enforcement of the totoaba ban by the Mexican authorities, which forced some fishermen to look for other sources of income. In particular in 1993, the chano fishery was economically important for the people of El Golfo de Santa Clara, hence the large increase in fishing effort in that year. Chano were fished using demersal monofilament gillnets from mid-March to early May. These nets, which usually have a mesh size of 10–12cm, are left to drift with the current from 0.75 to 2hrs, usually beginning in mid-morning and ending in the late evening. The nets for chano are an average 342m long, 2m wide and drift at an average depth of 17m. The 1994 fishing season for chano began in late March.

**Elasmobranchs**

Various species of shark, including *Carcharhinus* spp., *Rhizoprionodon* spp., *Mustelus* spp. and *Sphyrna* spp., as well as skates and rays, such as *Rhinobatus* spp. and *Myliobatis* spp., the stingray (*Dasyatis brevis*) and mobulas (*Mobula* spp.), were fished from May through July 1993. These nets are demersal anchored monofilament gillnets with mesh sizes ranging from 12–23cm, which are deployed in the late morning or early afternoon,

checked the next morning and left in the same location if catch was good. If not, they are relocated and checked the next day. The nets most commonly used are an average of 400m long, 2m wide and set at an average of about 15m deep. During 1993, some fishermen fished only for skates and rays, using nets with an average length of 219m and set about 10m deep. These nets have the larger mesh sizes previously mentioned. Since July 1993, the only elasmobranchs fished have been caught on long-lines (from January to March 1994).

**Corvinas**

During 1993, various species (*Cynoscion* spp.) of sciaenid corvinas (sea trouts) were fished, mainly in the shallow channels of the Colorado River Delta, but for only four days in early May. This accounts for the small percentage of hours for this fishery as compared to the other fisheries. The nets used for corvinas were primarily 7–15cm mesh monofilament gillnets, with an average length of 320m and set at an average depth of 9m. According to fishermen from El Golfo de Santa Clara, corvinas were also exploited by the upstream agricultural community, who fished in this area as well as farther up the river using similar gillnets. As far as we know, between May 1993 and mid-March 1994 no corvinas had been intentionally fished, although they appear to be abundant as bycatch in most of the other fisheries. The fishermen again reported fishing corvinas within the main channel of the Colorado River beginning 22 March 1994.

**Mackerel and sierra**

From July to August, Monterey Spanish mackerel (*Scomberomorus concolor*) and sierra (*S. sierra*) were caught in monofilament gillnets set near the surface in the early evening. These nets are anchored to the *panga* and both drift with the current all night. The fishermen check them once during the night and then at dawn. The most common mesh sizes range from 7–10cm, and the average net dimensions are 504m long and 3m wide.

**Totoaba**

We know that at least nine *pangas* fished totoaba during January, February and March 1993, although the fishermen would not admit it, so there is no relevant information. However, during our first two visits to El Golfo de Santa Clara in 1994 (January 21–24, February 11–15), two fishermen admitted that they had fished totoaba in early January 1994. We do not know if the fishermen of this town are presently fishing totoaba.

**Incidental mortality of the vaquita**

Between 23 January 1993 and 29 March 1994 there have been 15 observed vaquita deaths due to fishing activities (Table 4). Of these, seven fresh carcasses were given to us by the fishermen and eight more were reported, including one which died in a commercial shrimp trawl. Twelve of these vaquitas died in *ca* 16,000 hours of fishing effort between 23 January and 16 October 1993: 5 in gillnets with a mesh size of 10–11cm set for chano, 3 in gillnets with a mesh size of 7cm set for shrimp, 2 in gillnets with a mesh size of 15cm set for sharks, 1 in a gillnet with a mesh size of 7.6cm set for mackerel and 1 in a net set either for chano or for sharks. In addition to these 12, two more vaquita deaths (in early October 1993 and in late January 1994) were reported by fishermen. We do not know for certain in which fishery the animal reported in October was taken, but it is possible that it was a gillnet for shrimp since that was the predominant fishery at that time. The animal reported in January was taken in a shrimp gillnet. Two decomposed carcasses, for which the cause of death is unknown, were found on the beach and collected in 1993. Table 5 shows the results for basic capture-rate computations for January-October 1993, which range from

Table 4

Incidental mortalities of vaquitas in fishing activities in the upper Gulf of California, 23 January 1993 - 29 March 1994[1].

| Date | Mesh size (cm) | Fishery | Locality | Length (cm) | Maturity | Sex |
|---|---|---|---|---|---|---|
| 02/02/93 | 7 | Shrimp | El Tornillal, Sonora | - | - | - |
| 02/05/93 | Trawl | Shrimp | Rocas Consag | - | - | - |
| 02/06/93 | 7 | Shrimp | Punta Gorda, Sonora | 140.0 | M | F |
| 02/22/93 | 7 | Shrimp | El Tornillal | 106.3 | I | F |
| 03/31/93 | 11 | Chano | El Quelele, Baja California | 129.8 | M | M |
| 04/03/93 | 10 | Chano | 'Canalón de la Baja' Baja California | 116.3 | I | F |
| 04/16/93 | 10 | Chano | El Quelele | 110.0 | I | F |
| 05/02/93 | 10 | Chano | El Quelele | 115.3 | I | M |
| 05/01-15/93 | 10 | Chano | Unknown | - | - | - |
| 05/15-20/93 | 10, 15? | Chano/Shark? | El Tornillal | - | - | - |
| 05/15-20/93 | 15 | Shark | Rocas Consag, Sonora | - | - | - |
| 06/15/93 | 15 | Shark | Rocas Consag | 109.4 | I | M |
| 07/19/93 | 9 | Mackerel | El Burro, Sonora | - | - | - |
| 10/15/93 | 7 | Shrimp? | El Machorro, Sonora | - | - | - |
| 01/22/94 | 7 | Shrimp? | El Tornillal | - | - | - |

[1] Also, two beached specimens (cause of death unknown) were found *ca* 6km south of El Golfo de Santa Clara: a 110cm long immature male on 05/18/93 and a 128cm long mature male on 05/28/93.

Table 5

Capture rates of vaquitas for fisheries in El Golfo de Santa Clara, 23 January - 16 October 1993.

| Fishery | Number of vaquitas caught[1] | Total hours sampled | Vaquitas caught/hour |
|---|---|---|---|
| Chano | 5 | 2,787 | 0.0018 |
| Shrimp | 3 | 3,826 | 0.0008 |
| Shark/Ray | 2 | 6,218 | 0.0003 |
| Mackerel/Sierra | 1 | 2,677 | 0.0004 |
| Corvina | 0 | 23 | 0.0000 |

[1] There is one animal which could have been caught in either the chano fishery or the shark/ray fishery, for a total of 12 (see Table 4).

zero in the corvina fishery to 0.0018 vaquitas per hour in the chano fishery. The percentages of total effort monitored for each fishery, followed by the percentages of the total number of vaquitas caught is: chano (25; 55), shrimp (61; 20), shark/ray (46; 15), mackerel/sierra (59; 10), and corvina (60; 0).

## DISCUSSION

The data presented here, plus those obtained by Vidal (1995) during 1990–1992, demonstrate that vaquitas are not only being killed in large mesh totoaba gillnets, but in virtually all mesh sizes. It also seems that no matter whether the nets are anchored or drifting, or whether they are demersal or on the surface, they catch vaquitas. Some 92% of the vaquitas killed in 1993 were caught in nets set on the bottom, 8% in surface nets. In total, 75% were caught in driftnets and 25% in set nets.

The figure of 15 vaquitas caught in fisheries between early 1993 and early 1994 is clearly a minimum, both for El Golfo de Santa Clara and for the whole range of the species, since we only monitored part of the fishing effort in the smallest (El Golfo de Santa Clara) of the three fishing ports with activities in the range of this porpoise.

**Spatio-temporal distribution of the vaquita**

Vaquitas were caught almost year-round during 1993, as has been the case in previous years. Monitoring effort for the months of January and August-December 1993 and January-March 1994 was regular but reduced to a few days each month. It appears that vaquitas are caught almost everywhere that fishermen from El Golfo de Santa Clara fish in the upper Gulf. A preliminary analysis of vaquita distribution based on catch records and confirmed sightings (reviewed by Brownell, 1986; Silber, 1990; Vidal, 1995) indicate that in the spring (March-May) vaquitas are concentrated along the Sonoran coast, between El Golfo de Santa Clara (31°41′10′N, 114°29′59′W) and Punta Gorda (31°30′00′N, 114°10′31′W), just outside of La Salina (31°29′34′N, 114°03′37′W), in the outlet of the left channel of the Colorado River Delta (*ca* 31°31′20′N, 114°40′39′W), in the middle region of El Canalón (31°26′29′N, 114°22′38′W) and in the area between San Felipe, Baja California and Rocas Consag. In the summer (June-August) there are records of vaquitas between El Machorro (31°40′N, 114°30′W) and El Tornillal (31°33′42′N, 114°17′45′W), Sonora, and in the area between San Felipe and Rocas Consag. In the fall (September-November) vaquitas have been reported in and just south of the area between San Felipe and Rocas Consag and along the Sonoran coast from El Machorro to La Salina. In the winter (December-February), they have been reported from El Burro (31°32′51′N, 114°22′38′W) to Punta Gorda, in the outlet of the left channel of the Colorado River Delta, in the middle region of El Canalón, and in the area between San Felipe and Rocas Consag. However, these conclusions are preliminary. The spatio-temporal distribution of the vaquita is not clear because: (1) there is almost no information on incidental mortality for the San Felipe and Puertecitos areas; (2) there has been limited survey effort along the northernmost coasts of Sonora and Baja California; and (3) most surveys and monitoring effort have been conducted in the spring.

In summary, the mortality of the vaquita in gillnet fisheries not previously monitored (chano, corvinas, mackerel/sierra and shrimp) suggest that overall incidental mortality may have been higher than previously estimated (i.e. >35 individuals/year), because these nets are utilized throughout the range of the vaquita in the upper Gulf of California and because previous estimates were based mostly on totoaba and shark nets. About 40% of the sightings by Silber (1990) and of those obtained by the Southwest Fisheries Science Center of the US National Marine Fisheries Service during an August 1993 survey were made outside of the boundaries of the recently declared Biosphere Reserve of the Upper Gulf of California and the Colorado River Delta (IWC, 1995). This was also the case for sightings made in surveys by the Programa Nacional de Investigación de Mamíferos Marinos of the Mexican Secretariat of Fisheries (Gerrodette *et al.*, 1995; IWC, 1995). The low population estimates and the preliminary analysis of data on incidental mortality presented here support previous conclusions that the vaquita is in danger of extinction. Every effort must be taken to decrease or eliminate incidental mortality throughout its range.

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