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Survey report for Vaquita Photographic Identification Research 2019

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INTERNATIONAL WHALING COMMISSION

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Executive Summary

Three weeks of effort to estimate the number of vaquitas in the Zero Tolerance Area took place between September 2 and October 27, 2019. Two ships (the *Narval* and either the *Farley Mowat* or the *Sharpie*) used experienced observers to find and track vaquitas with methods developed for the earlier effort to capture vaquitas in 2017. There were only 4 days when winds were low enough to sight and track vaquitas, and only 2 photographs were matched to previous efforts. Of the 7 sightings, there were no photographic matches within the 3 weeks. All but one sighting contained a smaller individual that could have been a calf. All individuals appeared in robust health.

Because there were insufficient photographs to make a mark-recapture estimate, the method of expert elicitation was used. Observers were independently given a number of questions with the goal of estimating both the range and most likely values for the number of calves and the number of total individuals. The mean estimate for number of calves seen was 3 with a 63% belief that there were at least 3 calves. Clearly, the remaining vaquitas are continuing to produce young at very healthy levels, which makes concerns about inbreeding depression far less than concerns about mortality in gillnets.

The mean estimate for the number of unique vaquitas seen in all 7 sightings was 9.7 with 63% belief that there were at least 9. The mean number of vaquitas estimated in 2018 was 9 individuals (ranging from 6 to 19). Because there is much uncertainty, it is unclear if the population has continued to decline at 50%/year, but the expected number would be 4-5 individuals and an absolute minimum of 6 have survived. The 2018-2019 totoaba season was potentially more dangerous than in previous years because the ships removing totoaba nets had to leave early due to violent attacks by fishermen, and consequently the net removal efforts were greatly reduced. Therefore, having experts believe that a mean of 9.7 vaquitas were seen in 2019, and a 25% chance that there were at least 12, is surprising. It is possible that these remaining vaquitas, several of whom have net scars, are not a random selection following the deaths of over 98% of the species, but rather are selected individuals that are especially wary of nets. Guarding these net-wise vaquitas that are having robust calves could still save the species.

However, many gillnets were observed being deployed within the Zero Tolerance Area (ZTA) (documented in Appendix 3 and also in the data records). The photograph shows a vaquita pair near a panga with gillnet deployed in the background. This occurred within the ZTA. No enforcement actions were observed. These gillnets are not those used for totoaba and thus represent an increase in the amount of illegal fishing. There is a lack of enforcement even within the small area of the ZTA (a rectangle on about 288 km^2 or roughly 12 by 24 km, which is a bit smaller than the urban area of Tijuana).

Main Report

The decline in vaquita numbers has been well documented. The first effort to cover the full vaquita distribution used visual line-transect methods (Jaramillo-Legorreta et al. 1999). This effort noted the difficulty in sighting this species because of small group size, inconspicuous surfacing and avoidance of the survey vessels. Imprecise abundance estimates raised concerns about timely detection of potential declines in abundance (Taylor and Gerrodette, 1997). Acoustic monitoring methods were developed to increase precision of estimating both abundance and trends in abundance (Jaramillo-Legorreta et al. 2017), and a combination of visual and acoustic methods were used to estimate vaquita abundance in 2008 (Gerrodette et al., 2011) and 2015 (Taylor et al., 2016). Acoustic monitoring indicated that the vaquita population continued to decline rapidly, about 50%/year, through 2018 (Thomas et al. 2019). Recent developments, however, have made both acoustic monitoring and visual line-transect methods difficult. Fishermen have begun removing the acoustic devices (CPODs) used to record vaquita clicks. The data recorded on each device is lost, and it is expensive to replace the stolen CPODs. Unless enforcement of the fishing ban is effective and the theft of equipment is stopped, acoustic monitoring cannot collect data as it has in the past. Visual line-transect methods face a different problem. The number of vaquitas is now so low that the number of sightings would not be sufficient to estimate the necessary parameters. If a line-transect survey were carried out utilizing the same ship as in past surveys (the *David Starr Jordan/Ocean Starr*), an estimate of abundance would be possible with relatively few sightings, because the probability of detection is known for this ship. However, chartering this vessel and hiring experienced observers for the necessary time would be expensive, at least US$3,000,000 for a survey. Unless such funds are available, the size of the 2020 vaquita population cannot be estimated using line-transect methods.

Faced with these difficulties, vaquita researchers have turned to photographic identification, which requires high quality photographs to identify individual vaquitas. Photographic identification of vaquitas began in 2008 (Jefferson et al. 2009). Opportunistic efforts resumed in 2017 during the VaquitaCPR effort. In September 2018 a dedicated effort produced the first evidence that vaquitas could calve annually (Taylor et al. 2019) and showed that a minimum of 6 healthy animals remained in a small area near San Felipe, Mexico. This minimum abundance estimate was the number of animals seen simultaneously and was influential in the abundance estimate for that year (Jaramillo-Legorreta et al. 2019).

Two short efforts focused on photographic identification were conducted in 2019. The first effort (Period 1) had sightings during the set up period in late August and during the survey period from September 2 to 6. The survey period was triggered by a window of weather predicted to be good for vaquita sightings with winds less than 7 knots. The second, and larger, effort from October 15-27 (Period 2) was chosen because that time period had calm winds in the past and calm weather in later months was less common. Each period is described separately because the effort levels differed.

Period 1 (September 2 – 6, 2019)

This effort used experienced observers who could get to San Felipe quickly to take advantage of a short period of good weather. During this period, two vessels were involved: the Museo de Ballena's vessel *Narval* and the Sea Shepherd Conservation Society's (SSCS) vessel *Sharpie*. The Narval housed and fed most of the visual observation teams for both ships. On the *Sharpie*, two pairs of big eyes (Fujinon 25x binoculars) were mounted on the flying bridge. A tracking system was set up to be able to map the ship's tracks and plot vaquita sightings. The tracking system comprised of a computer with monitor, a

GPS and digital magnetic compass. The computer ran a program specifically created to track vaquitas called Vaquita WinCruz (available upon request from Barbara Taylor). During the setup period prior to the arrival of the full team, one experienced observer worked with the SSCS team and had sightings on August 19 and August 20. No photographs were obtained. The sightings were described as one large and one small vaquita.

On the *Narval*, the observation team used hand held binoculars. There was also an acoustic team that had already analyzed acoustic data from earlier and determined where vaquitas were detected. The acoustic team provided data from a limited number of acoustic detection locations during the Period 1 effort, as well as locations from data collected prior to the start of the Period 1 effort.

From Sep 2-6 personnel included the following: Lorenzo Rojas-Bracho, Armando Jaramillo-Legorreta, Edwyna Nieto, Gustavo Cardenas, Barbara Taylor, Jay Barlow, Robert Pitman, Paula Olson, Sarah Mesnick, Tim Gerrodette, Eva Hidalgo. The focus was entirely on photographic identification. A Mexican CITES permit allowing export of a biopsy to the San Diego Zoo's frozen zoo collection was not obtained, so no biopsy effort was made.

Search effort was concentrated in the part of the Zero Tolerance Area (ZTA) where vaquitas had been detected acoustically in the previous few weeks. The acoustic sampling grid was used as a reference to navigation and communication (Appendices 1 and 2). Effort was planned to run generally from southeast to northwest starting at dawn to keep the sun to observers' backs. Survey speed was between 5-7 knots. Search effort was also carried out west of the ZTA, in an area closer to land where detections were made last year, but where no acoustic effort was possible this year because of theft of acoustic devices.

Only 2 full days of effort with conditions with less than 7 knots of wind were possible in Period 1. On 3 September, a vaquita pair was sighted (sighting 001) at 9:22am at N31:04.32 W114:38.71, and both vessels were brought within a mile of the sighting. Two pangas and 1 RHIB were deployed. Vaquitas were tracked for 64 minutes and good photographs were obtained. (Fig 1a). Both animals were adult size. All of the photos from this sighting are somewhat distant but one animal can be identified as an individual based on the unique shape of its dorsal fin (individual "A", also seen in 1b and 1d).

Left and right side photos of "A" were compared to the photos from Jefferson *et al.* (2009) and to the photos from 2017 (Wells, unpub.) and 2018 (Taylor and Rojas-Bracho, unpub). Individual "A" was matched to individual "D" (Figure 1c and 1e) from September 2018. In 2018 "D" was part of a loose aggregation of 4-6 vaquitas.

Figure 1. a. Pair of vaquita photographed 03 September 2019. Individual "A" is on the right. (Martinez_3994)

b. Individual "A" in 2019. (Rosales_3563)

c. Individual "D" in 2018. (Ortiz_8774)

1d Individual "A" in 2019. (Taylor_1710)

1e Individual "D" in 2018. (AdamU_3754)

The minimum number of vaquitas present between Aug 19 and Sept 6 was 4 vaquitas: the adult pair that was photographed (03 September) and a likely mother and calf seen prior to the Period 1 effort (during set-up on the Sharpie) on August 19 that was not photographed.

Period 2 (October 15-27)

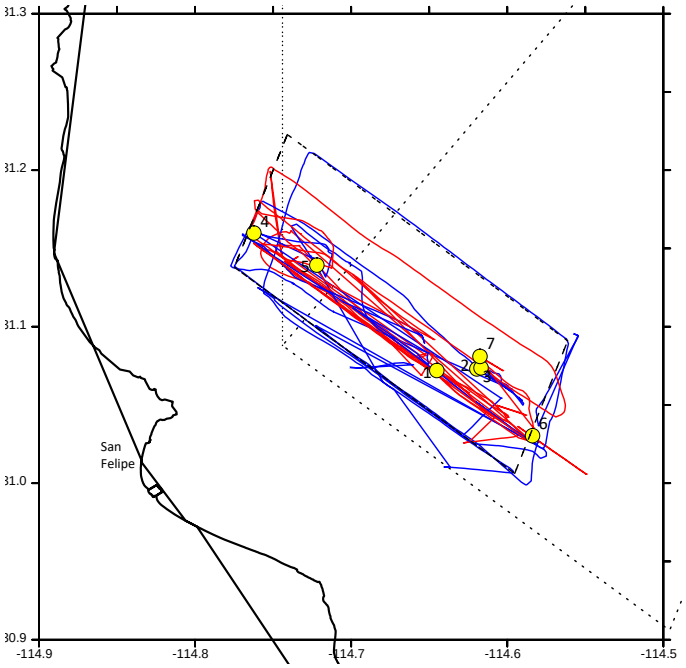
This effort involved 2 full teams (each with 2 pairs of big eyes and a tracking system) on the *Narval* and the SSCS *Farley Mowat*. Because of accumulated losses of CPODs (52 prior to this survey period) and ongoing illegal gillnetting, no acoustic effort was possible. The same system of navigational points used in Period 1 was used in Period 2 (Appendices 1 and 2). The daily searching pattern was that same as described for Period 1.

Personnel were as follows:
Chief Scientists: Lorenzo Rojas-Bracho, Barbara Taylor (*Narval*), Tim Gerrodette (*Farley Mowat*)
Recorders: Sarah Mesnick (*Narval*), Eva Hidalgo (*Farley Mowat*)
Observers (changing vessels on different days): Juan Carlos Salinas, Ernesto Vazquez, Sergio Martinez, Hiram Rosales, Jay Barlow, Paula Olson, Robert Pitman, Todd Pusser, Suzanne Yin, Adam Ü, Chris Hoefer, Nick Kellar, Tom Jefferson
Biopsy specialists: Gustavo Cardenas, Zach Swain

Wind conditions were worse than anticipated. During the first week there were only 2 days of marginal weather (no Beaufort 0, virtually no Beaufort 1). Despite the poor weather, vaquita were regularly sighted but could not be successfully tracked and photographed. On 17 October, a mother/juvenile-calf pair was observed for 16 minutes (sighting 003) from both ships. There are distant photographs and video of the pair with a panga pulling a gillnet in the background. The photographs are not sufficient quality for photographic identification. Five hours later a likely mother/calf pair was sighted (sighting 004) about 10 miles from sighting 003. The small boats were deployed for photo-ID but the animals could not be approached successfully for photo-ID. Observers who saw both sightings described the dorsal fins of the adults to be different, making it likely that although the pair could have swum the distance in the elapsed time, it is more likely than not that these were two separate mother/calf pairs. . With these two sightings (003 and 004), and the two adults photographed on 3 September, the absolute minimum number of vaquita is between 4 and 6 and more likely to be 6.

Sighting 004 was of 4 animals on 19 October: a likely mother/calf pair and a nearby adult pair. Sighting 005 was a brief sighting of a single animal seen about 30 minutes after leaving sighting 004. On 27 October, a group of 4 vaquitas (sighting 006), probably all adults, was followed for 44 minutes, and good photographs were obtained of 2 animals. A little less than an hour later and 3.2 miles away, a mother-calf pair was seen (sighting 007) but no photographs were obtained. Figure 2 shows tracklines and sighting locations. Details of all 7 sightings are given in Appendix 4.

Figure 2. Track lines followed during the survey onboard Farley Mowat (blue lines) and Narval (red lines). Sightings are presented with yellow circles, indicating numbering in main text. Vaquita Refuge presented with small broken line. Zero Tolerance Area presented with large broken line.



Pangas with gillnets deployed were seen within the Zero Tolerance Area (ZTA) on every day that we searched for vaquitas. Numerous photographs of fishing pangas were taken, with metadata that include date, time, latitude and longitude. Because our effort had to focus on vaquita, only sporadic locations were given for pangas with gillnets in the water in the regular data recording system[1]. In addition, a dedicated effort in a separate panga was made to document the amount of illegal gillnetting within the ZTA (see Appendix 3). Note that the ZTA coordinates given on the map in Appendix 1 are the official coodinates but also fall on locations of acoustic detectors. During Period 2 the Museo de Ballena placed delimiting buoys that added a 500m buffer, which was agreed with the Profepa representative aboard the Narval, to provide safety for future acoustic devices deployed in the ZTA. These buoys were placed so that fishermen could see the location of the ZTA. The area demarked by the buoys is 239.5 km^2 with a perimeter of 68-9 km and approximate sides of 23.5x10.9 km.

All 7 sightings covering both Periods 1 and 2 are given in Appendix 4. Raw data files (called DAS files) are available from Lorenzo Rojas-Bracho upon request and are also maintained at the Southwest Fisheries

[1] These locations are in the data files recorded by the tracking system and are recorded as 'objects' or 'Navy dolphins' because these function keys allowed a rapid position to be added. Comments are typically recorded afterwards to clarify that these are actually pangas.

Science Center. Given that the acoustic data were heavily compromised in 2019 due to theft of acoustic detectors, this fall effort was likely the best estimate of the minimum number of remaining vaquitas alive in 2019. Photographic identification was insufficient to use mark-recapture methods to estimate the numbers within the small area surveyed. Therefore, an expert elicitation was conducted using observers as the experts.

Experts were provided with the exact information in Appendix 4 and asked to provide their expert opinion on a number of questions (Appendix 5). Some logical inconsistencies were seen after reviewing the responses. A second elicitation is common practice and was deemed important in this case both because the probability problem presented to experts was complex and the initial elicitation was given hurriedly to expert observers at the end of the survey. A second elicitation was warranted to provide the best estimate of vaquitas remaining in the ZTA. This elicitation used responses from the first elicitation to give the experts some feedback that would aide in their estimation of the total number of calves seen and the total number of vaquitas seen. For example, sightings 002 and 003 both had animals that could have been calves and could have been resightings of the same pair at different times during the same day. Therefore, depending on the probabilities that each small individual was a calf and that the sightings were the same or different, there could be zero, one or two calves. The experts were given these probabilities from their original responses (Appendix 5 shows the probabilities for an anonymous expert, but each expert was only provided their own probabilities).

Detailed elicitation results are given in Appendix 6. Figure 3 (below) shows the percent experts believed given their observations for the number of calves present for all 7 sightings. The mean estimate for number of calves seen was 3 with a 63% expert confidence that there were at least 3 calves.

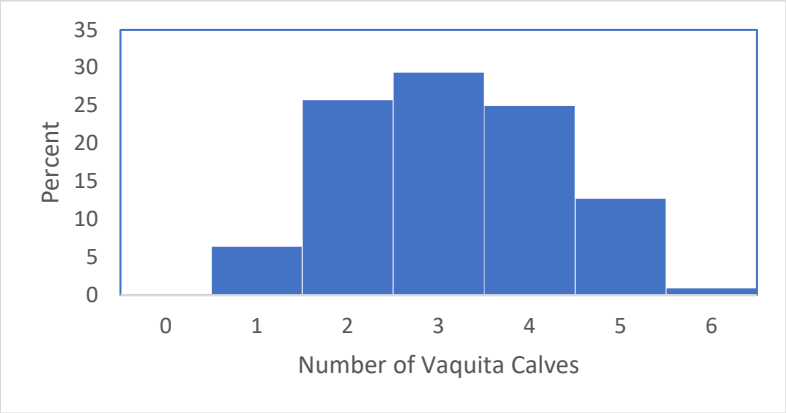


Figure 3. Percent belief for the number of calves in 7 sightings where all effort took place within the zero tolerance area from the second elicitation (see Appendices 5 and 6).

The mean estimate for the number of vaquitas seen in all 7 sightings was 9.7 with 63% expert confidence that there were at least 9. Figure 4 shows that the plausible range is fairly large such that there is a 25% belief that there were at least 12.

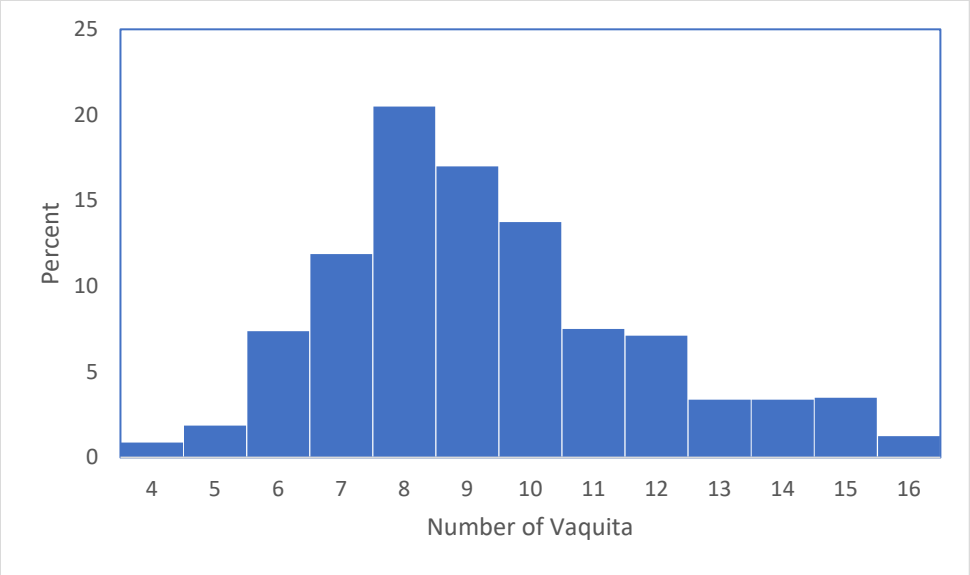


Figure 4. Percent belief from expert elicitation 2 (Appendices 5 and 6) for numbers of vaquitas in 7 sightings where all effort took place within the zero tolerance area.

The final question was optional as experts had to decide whether they could remember efforts in both 2018 and 2019. Five experts responded to the following question:
Comparing 2019 to 2018 within the Zero Tolerance Area, please distribute 10 likelihood points to:

a. There were less than half the number of vaquitas in 2019 compared with 2018
b. There was between half and the same number of vaquitas in 2019 compared with 2018
c. There were about the same number of vaquitas in 2019 compared with 2018
d. There were more vaquitas in 2019 than in 2018

Roughly 80% of the experts belief went to b and c with about 10% each to a and d.

Discussion

Overall, the ability to find and track vaquitas remained good despite the lack of consistent acoustic effort. The data and any conclusions are limited, however, in estimating numbers over a short time frame only within the ZTA. Concentrating effort in the ZTA is logical given acoustic data indicating that the last vaquitas are most reliably found in this small area. However, the numbers in this report can only reflect the numbers in that area and therefore may not account for the full number of vaquitas remaining. That said, recent acoustic evidence suggests that the numbers of vaquitas outside the ZTA are likely very low.

The poor success at obtaining photographs was due primarily to marginal wind conditions. Animals could be sighted but not tracked for the prolonged periods needed to obtain photographs of sufficient quality to identify individuals. Much more time would be needed to ensure obtaining a sufficient number of photographs for a mark-recapture estimate of abundance for the ZTA. In 2019, 3 weeks of effort resulted in only 4 days of weather conducive to sighting vaquitas. We should also stress here that the impossibility of monitoring the vaquitas with the acoustic devices reduces the chances of finding vaquitas since we have no near-real-time information to guide the vessels to where vaquitas were acoustically encountered and must rely on data from months or even years in the past.

The use of two ships with full observer teams worked well, but was twice the cost of a single ship. Two strategies remain viable that were exemplified by Period 1 and 2 of this study: 1) use locally skilled observers and respond quickly to a predicted good weather window, and 2) choose dates in advance to bring in skilled observers but increase the suvey time to account for unknown weather. Either strategy could work depending on the amount of funding available and how many skilled observers can be found on short notice.

The result of finding about 3 calves is most encouraging. Clearly, the remaining vaquitas are continuing to produce young at very healthy levels, which makes concerns about inbreeding depression far less than concerns about mortality in gillnets. The estimated numbers are also encouraging. The mean number of vaquitas estimated in 2018 was 9 individuals (range: 6-19). The estimates a year later if the roughly 50%/year decline persisted would be 4-5. The 2018-2019 totoaba season was potentially more dangerous to vaquita survival than in previous years as the net removal efforts were greatly reduced. The ships had to leave early due to violent attacks by fishermen. So having experts believe that a mean of 9.7 vaquitas (range: 4-17) were seen in 2019, and a 25% chance that there were at least 12, is surprising. It is possible that these remaining vaquitas, several of whom have net scars, are not a random selection following the deaths of over 98% of the population, but rather are selected individuals that are especially wary of nets. Guarding these net-wise vaquitas that are having robust calves could still save the species.

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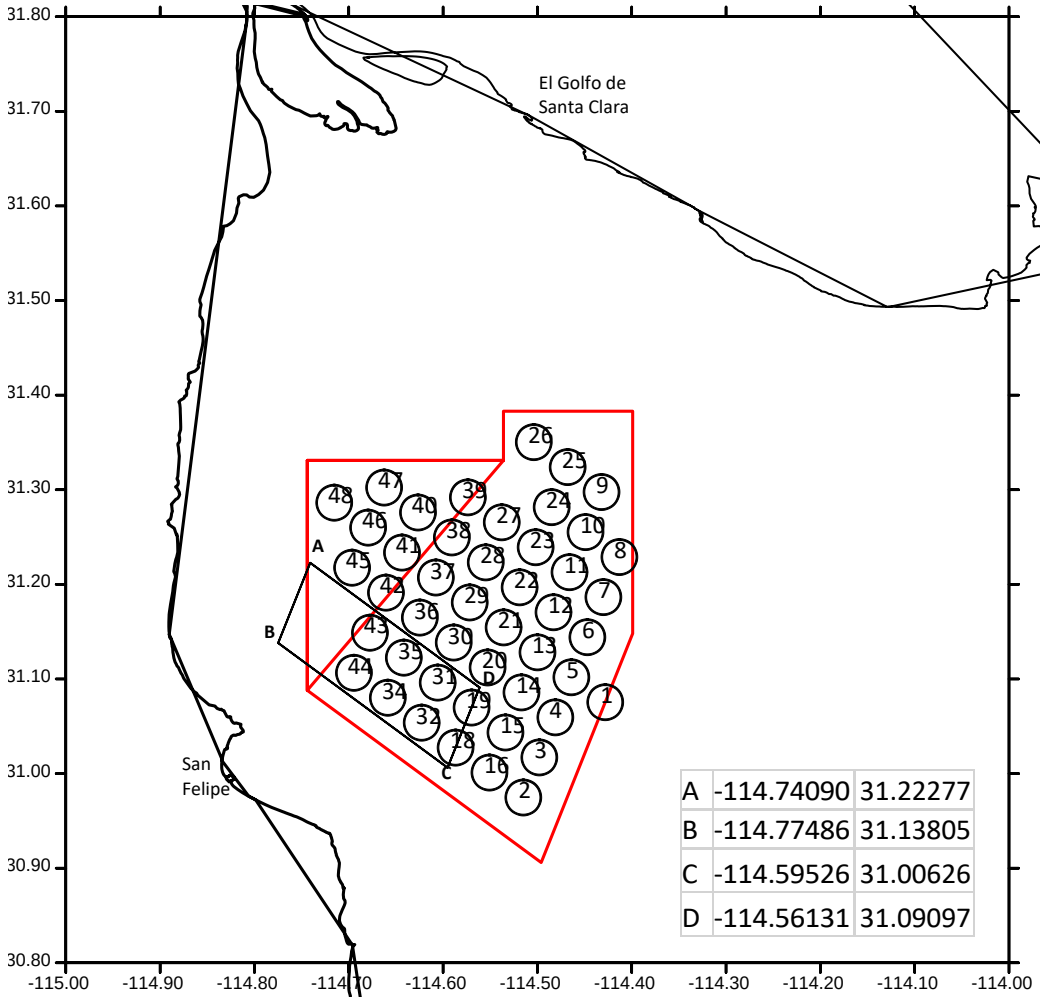
Appendix 1 Period 1 map and waypoint locations

Period 1 used the standard acoustic sampling sites listed below as waypoints to direct the ship for photographic identification efforts.

ACOUSTIC SAMPLING SITES OF VAQUITA MONITORING PROGRAM



A	-114.74090	31.22277
B	-114.77486	31.13805
C	-114.59526	31.00626
D	-114.56131	31.09097

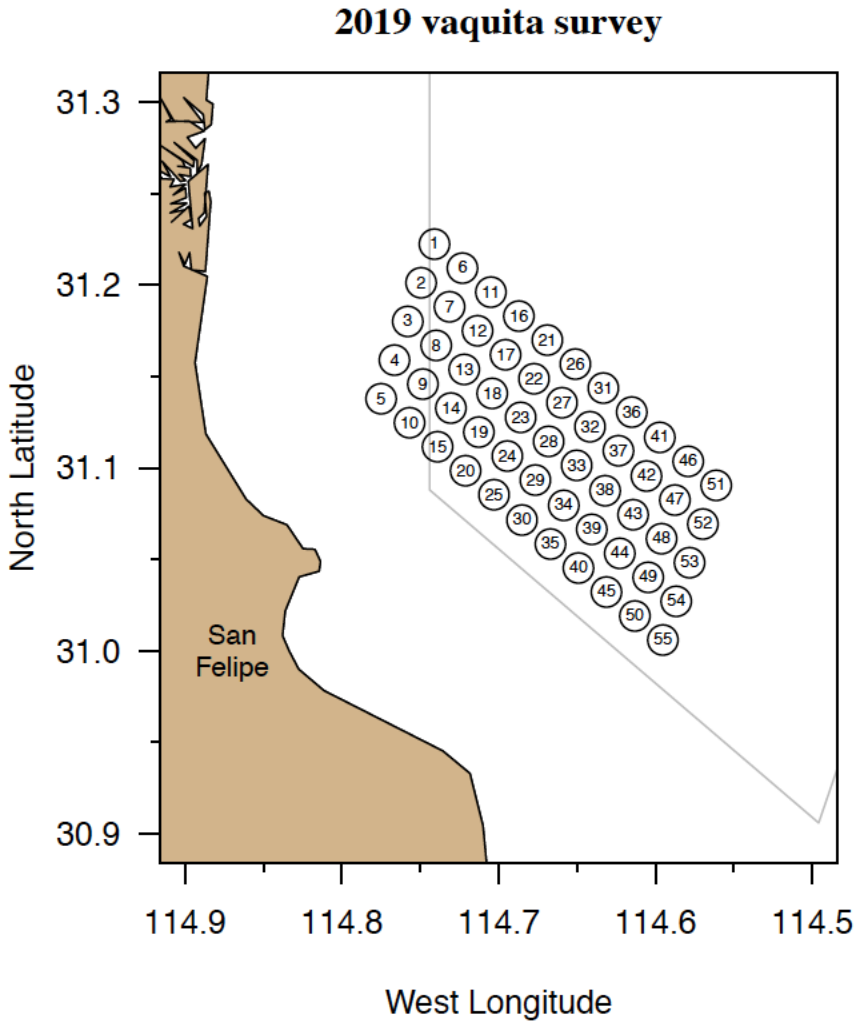
Site	Longitude	Latitude
1	-114.42809	31.07543
2	-114.51494	30.97472
3	-114.49796	31.01708
4	-114.48098	31.05943
5	-114.46400	31.10179
6	-114.44703	31.14415
7	-114.43005	31.18651
8	-114.41307	31.22887
9	-114.43201	31.29759
10	-114.44899	31.25523
11	-114.46597	31.21287
12	-114.48294	31.17051
13	-114.49992	31.12815
14	-114.51690	31.08579
15	-114.53388	31.04344
16	-114.55086	31.00108

Site	Longitude	Latitude
18	-114.58678	31.02744
19	-114.56980	31.06979
20	-114.55282	31.11215
21	-114.53584	31.15451
22	-114.51886	31.19687
23	-114.50188	31.23923
24	-114.48490	31.28159
25	-114.46793	31.32395
26	-114.50384	31.35031
27	-114.53780	31.26559
28	-114.55478	31.22323
29	-114.57176	31.18087
30	-114.58874	31.13851
31	-114.60572	31.09615
32	-114.62269	31.05380
34	-114.65861	31.08015

Site	Longitude	Latitude
35	-114.64163	31.12251
36	-114.62465	31.16487
37	-114.60768	31.20723
38	-114.59070	31.24959
39	-114.57372	31.29195
40	-114.62662	31.27595
41	-114.64359	31.23359
42	-114.66057	31.19123
43	-114.67755	31.14887
44	-114.69453	31.10651
45	-114.69649	31.21759
46	-114.67951	31.25995
47	-114.66253	31.30231
48	-114.71543	31.28631

Appendix 2 Period 2 waypoint locations

More waypoints were added in October to allow close operation of 2 ships with full observer capacity. These waypoints were used to set trackline effort and communicate locations between the ships.



Oct 2019 effort

Way point	**Longitude**	**Latitude**	Way point	**Longitude**	**Latitude**
1	-114.74090	31.22277	29	-114.67657	31.09333
2	-114.74939	31.20159	30	-114.68506	31.07215
3	-114.75788	31.18041	31	-114.63314	31.14369
4	-114.76637	31.15923	32	-114.64163	31.12251
5	-114.77486	31.13805	33	-114.65012	31.10133
6	-114.72294	31.20959	34	-114.65861	31.08015
7	-114.73143	31.18841	35	-114.66710	31.05898
8	-114.73992	31.16723	36	-114.61518	31.13051
9	-114.74841	31.14605	37	-114.62367	31.10933
10	-114.75690	31.12487	38	-114.63216	31.08815
11	-114.70498	31.19641	39	-114.64065	31.06697
12	-114.71347	31.17523	40	-114.64914	31.04580
13	-114.72196	31.15405	41	-114.59723	31.11733
14	-114.73045	31.13287	42	-114.60572	31.09615
15	-114.73894	31.11169	43	-114.61420	31.07497
16	-114.68702	31.18323	44	-114.62269	31.05380
17	-114.69551	31.16205	45	-114.63118	31.03262
18	-114.70400	31.14087	46	-114.57927	31.10415
19	-114.71249	31.11969	47	-114.58776	31.08297
20	-114.72098	31.09851	48	-114.59625	31.06180
21	-114.66906	31.17005	49	-114.60473	31.04062
22	-114.67755	31.14887	50	-114.61322	31.01944
23	-114.68604	31.12769	51	-114.56131	31.09097
24	-114.69453	31.10651	52	-114.56980	31.06979
25	-114.70302	31.08533	53	-114.57829	31.04862
26	-114.65110	31.15687	54	-114.58678	31.02744
27	-114.65959	31.13569	55	-114.59526	31.00626
28	-114.66808	31.11451			

Appendix 3 Panga Survey

PANGAS AND VAQUITA IN THE ZERO TOLERANCE AREA (2019/10/17)

Pangas were counted in the southern and western part of the ZTA. The count was made from a research panga and with the help of 15x50 binoculars on 17 October 2019.

To count the number of pangas we stopped at the sites marked with red numbers on the map below (Figure1). The presence of pangas was surveyed 360 degrees around the research panga. The red numbers indicate the number of pangas counted. Clam fisher, tourist, military or trawler vessels were excluded. It is inferred that the distance between the positions where vessels were counted decreased the chances of counting the same boat in more than one location. In total, 87 pangas were observed on the water in the ZTA. In addition to the pangas, gillnets were observed. The length of some nets was estimated to be approximately 1 km. The total time to complete the counting from the 13 sites was 3 hours and 42 minutes.

The black numbered circles in Figure 1 indicate the acoustic sampling sites we attempted to monitor between September and December. Sadly, 30 moorings and acoustic detectors were stolen in November. The three black circles with a green circle around them are the only sites where acoustic activity was detected between June and September, from the standard 46 sampling grid. The solid green circle is the location of the confirmed mother/calf pair sighting on 17 Oct 2019, during our photo-id survey. Fishing activity was appreciably more intense in the vaquita detection zone (dark blue ellipse), while towards the coast of Baja California (light blue ellipse) fishing activity was significantly lower. ***IT IS CLEAR THAT THE INCREASED FISHING ACTIVITY IS OPERATING IN THE MOST SENSITIVE AREA FOR VAQUITA.***

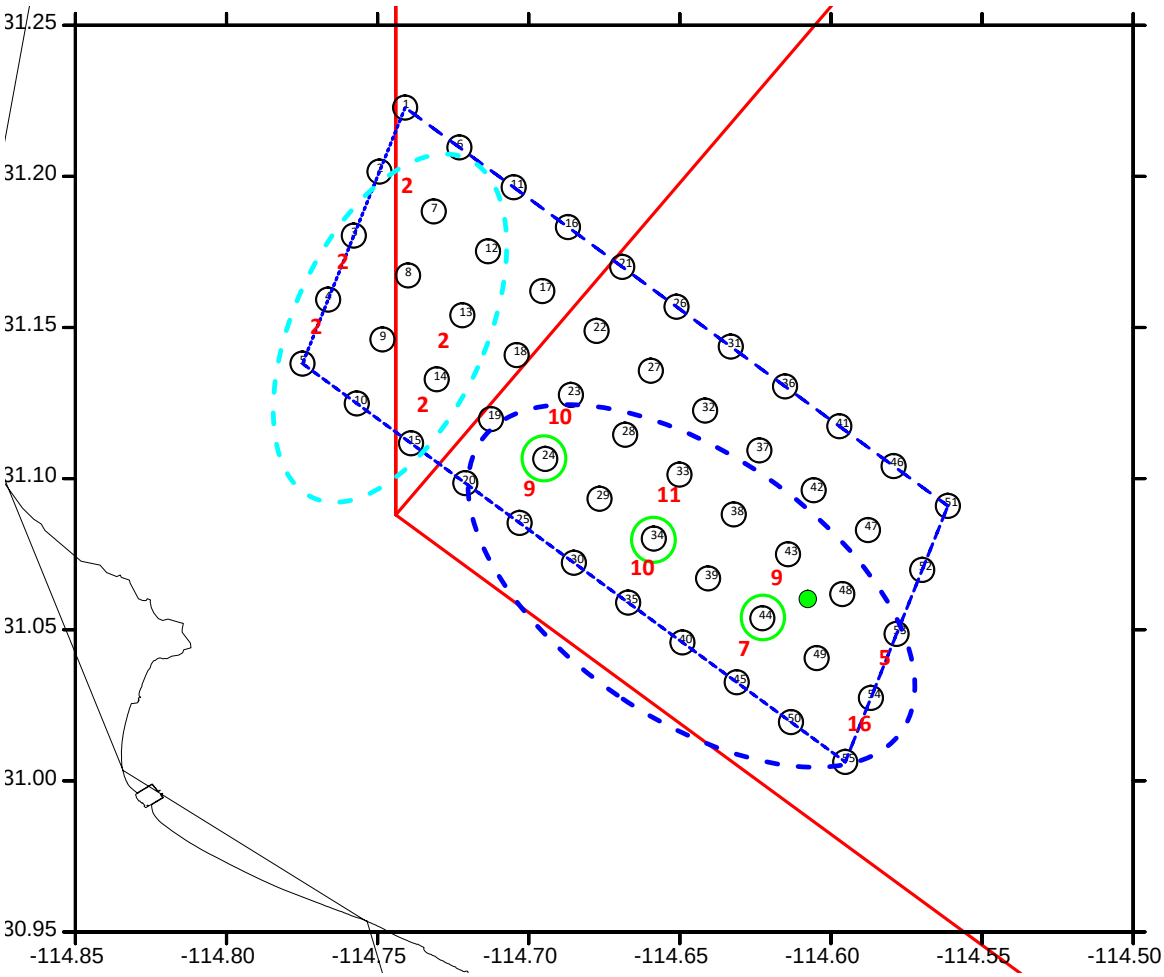


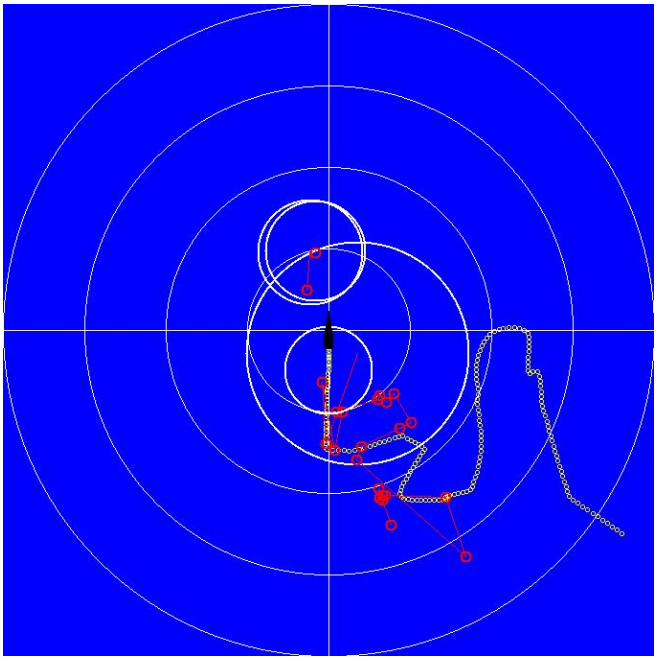
Figure 1.Map showing the acoustic sampling grid (black circles) inside the ZTA (blue rectangular polygon). Position where fishing vessels were counted around are marked with red numbers, which indicate the number of vessels observed. The ellipses depict two areas of distribution of fishing vessels. In blue the area with higher number of vessels and with cyan the area with lower numbers. Below is a photo of a typical fishing vessel, with a couple of vaquitas close by.

Appendix 4 Sighting details (evidence given to experts prior to the elicitations)

OBSERVATIONS ON VAQUITA SIGHTINGS 3 SEPTEMBER, 17, 19, & 27 OCTOBER 2019

General information on vaquitas and porpoise

The average group size of vaquitas in all surveys (1997, 2008, 2015) was 2. Although the winter period remains mostly unobserved, neonate vaquitas have been recovered from early totoaba fishing in February. Thus, calves in October would be 6-8 months old, which is thought to be roughly the age of weaning. The individual marked below as C18 was considered very likely to be a calf.



The red symbols are that same pair from 2018 recorded in a WinCruz screen shot. The pair had a meandering pattern. The circular grid (regularly spaced, concentric circles) has 1 nmi spacing. (Ignore the bright circles of differing sizes.) The total time of the sighting was 1 hour. Within the hour, a straight-line distance between farthest points tracked measure 4 nmi apart. Conceivably if vaquitas travelled in a straight line, they could cover 8 nmi/hr, but it is more likely you wouldn't expect them to move more than what is seen here (about 4 nmi).

Notes for 2019

Even though there were only 7 sightings, it may be helpful to write each down and draw lines connecting various sightings that could be duplicates to help with your final estimate of the plausible numbers seen in 2019.

Summary of Observations of the 7 sightings in 2019

3 September 2019
Sighting number 001
2 individuals were sighted by Robert Pitman at 09:22. 3 small boats were launched but the vaquitas did not surface as closely to those vessels as to the 2 ships (Narval and Sharpie) where the best photographs were taken. Tracking was halted at 10:21 when it was determined that photographs of ID quality had been taken and the search could resume for different vaquitas. This was the only sighting of the September 2-6 period. This pair were adults and one was matched to a photograph from 2018. The pair remained closely associated throughout the period but did not surface with one routinely in the 'calf' position.

17 October 2019
Two sightings of vaquita were detected on 17 October 2019, occurring approximately *five and a half hours* and 10 nautical miles apart (sightings no. 002 and no. 003). Both groups consisted of a pair of animals, one larger and one smaller.

Paula Olson (Farley Mowat):
In sighting no. 002 the larger animal was adult size and the smaller was juvenile size. Five surfacings were observed over a 16 minute period. The pair were always within one body length of one another and the smaller animal was always observed to be trailing the larger. Swim directions at the surface were South, East, South, South, and South. On the fourth surfacing, the pair emerged less than 30 meters from a panga. Distant photos were obtained from this surfacing.

Adam Ü was on the Narval and observed both pairs (below). Based on his description of the dorsal fin of the adult in the second pair (sighting no. 003), I think the dorsal fins of the adults may have been different shapes. He described the second adult has having a conical, erect dorsal fin. I had good, multiple looks at the dorsal fin of the first adult; this adult appeared to have a more backward-oriented dorsal fin and faintly falcate.

Given the different shapes of the dorsal fins, and the distance between the sightings (although certainly vaquita could travel ten nmiles in four hours) these may have been different pairs.

Adam Ü (Narval):
Sighting 002 was initially seen from the Farley Mowat. Once the Narval was alerted to the sighting we were able to see the pair of animals for 4-5 surfacings. The animals were seen swimming along a "slick". A gillnet panga rapidly transiting the area stopped ~30m from the animals and appeared to be preparing to set their net. The animals surfaced again ~30m from the other side of the panga, at which point photos and videos were obtained. There were two animals visible on each surfacing of this sighting, with the 2nd animal being smaller and positioned slightly behind the first in the "calf position".

Sighting 003 was only seen for three surfacings. The first surfacing appeared to be a single animal and it was so quick that I was unable to confirm that it was in fact a vaquita. I gave the bearing and reticle (3.1 or 3.2) to Sarah (data recorder) to input as an "object" and alerted Bob on the 2nd set of bigeyes that I had a potential vaquita sighting. We decided to slow down and turn towards the potential sighting to confirm. Maybe 15 seconds later I saw the animal a second time (3.4-5 reticles) and was able to confirm it was indeed a vaquita. ~15 seconds after that I saw the animal a third and final time (3.8 reticles) and noticed there was a 2nd animal swimming in the "calf position" alongside and slightly behind the first

animal. The 2nd animal's fin looked significantly smaller but since it was on the opposite side of the larger animal I did not get a good view of the entire body/surfacing. All three surfacings of the larger animal gave clear perpendicular views (heading W) and the fin of the larger animal was noticeably not falcate; the trailing edge seemed to have a bit of a convex flare to it instead of a concave/falcate curve. We called the Farley Mowat over to assist with tracking and launched our two small boats but unfortunately we were unable to locate the animals after the third surfacing. I was the only person to see this sighting. I did not get a good enough look at the animals in sighting 002 to be able to confirm/deny that they were the same individuals in sighting 003 but PAO's description of the first sighting suggests the adult animals could have been different.

19 October 2019

Paula Olson (Farley Mowat):
Sighting no. 004 was initially detected over 2 nmiles from the ship; this detection consisted of a single animal with a tall, conical dorsal fin. The animal was seen twice and was swimming south while at the surface. The ship turned toward the sighting location and after moving some distance a resight was made, approximately 0.25 nmile from the original location. This time the group consisted of a mother/calf pair. Both dorsal fins were slightly falcate. The calf was smaller than the juvenile in sighting no. 002 from 17 October. Distant photos were obtained of the mother calf pair (Adam Ü). A third resight was made, again in almost the same location; this time the mother/calf pair was seen as well as a second pair, two adults, that surfaced several body lengths from the mother/calf pair. The two pairs did not surface at the same time. (See Ernesto's comments, below.) The final resighting from the Farley Mowat was that of the mother/calf pair. The mother/calf were always observed swimming within one body length of one another. The initial single animal may have been one of the pair of adults. A single animal was seen later by the Narval (see below).

Ernesto Vazquez #125 (Farley Mowat):
Resight of sighting no. 004. As the cow /calf was resighted for a couple surfacings, while this 2 went down another couple vaquitas surfaced some body lengths to their right, seen just one time at the surface, they did not surface at the same time, never had a view with the 4 vaquitas at the same time at surface. The pair that was leading the 4 seemed different in size, one larger than the other, but cannot say that was another cow/calf pair, although they were close to each other by a body length.

R. Pitman #005 (Narval) seen about 30 min after the last resight of sighting 004 within about 1-2 miles. A single individual seen twice as it rolled over perpendicular to the vessel. It appeared small and I suspect that an adult was nearby but unseen

October 27 Sightings 006 and 007
Sighting #006
This sighting is seen for 48 minutes. It takes 44 minutes to confirm that there are 4 animals and they are described as not surfacing super close together with one a ‘tiny bit smaller’ than the others. The two photographed were by then somewhat separate and appeared to be similar in size (see below and

compare to photo of cow/calf above). This photo taken from a panga estimated to be about 75-100 m away.

From Tom Jefferson: TAJ- I was on the port bigeyes. I have little to add, except the following. On multiple surfacings of the group, I saw 4 animals, all of adult/juvenile size, but none looked to be a calf of the year. On one surfacing, I saw the 4 animals surface in quick succession, and then another surfacing about 4-5 sec later. That final surfacing could possibly have been a fifth animal, but I think it much more likely that it was one of original 4 surfacing a second time. On later resights of the group, I never saw any indication of a fifth animal.

Adam's photo from this group appears to be a different animal to the pair above. He feels this photo matches to one he saw in sighting 003 above (17 October, which had an adult and a smaller individual).

Sighting 007 seen 51 minutes after the last resight of 006 about 3.2 miles away

From Adam: ACÜ –A mom/calf pair was tracked for a handful of surfacings, during which time Tom and I had multiple good broadside looks at the pair slow-rolling, with the calf being noticeably smaller than mom (Tom says "calf of the year" size") and surfacing in the calf position every time. We launched the small boats but were not able to track the pair for close approaches.

Throughout the sighting Tom and I felt confident that the calf in 007 was smaller than the juvenile we had seen in 006. My photos from sighting 006 showed the aforementioned closely associated pair, but if the pair in 007 were part of 006 it would mean they split from the other pair and traveled in a straight line away from the area they had been consistently occupying when we were following them and away from the direction of travel they were swimming when we first saw them.

From Todd: -- I was able to see several surfacings of both animals, often times nice broad side views in good light as they milled around a small area near two pangas that had gillnets in the water. It was quite obvious that it was a cow/calf pair and the calf was small, I would estimate around half the body length of the adult. The dorsal fin was considerably smaller and I realized instantly that it was a different animal from the group of 3 to 4 (sighting 006) I had seen earlier in the day.

After the sighting, it was asked if it was possible that the cow/calf pair was part of the group of 4 seen earlier in the morning. What I can say for sure is that the cow calf pair was not the pair of the animals we photographed from the panga in the earlier sighting. My estimate from that group in the bigeyes before I joined the panga was 3/4/3. I did not get a good look at the 4th animal in the group and cannot offer any insight into the size of that individual. So, I suppose if that 4th animal was a calf then the cow/calf observed later in the day may have been part of that group. However, the way the calf was surfacing so close to its mother, I think I would have seen that behavior in the previous sighting as I saw several surfacing sequences from the group of three to four. Despite the odd angle to the surfacings, all of those animals appeared to be the nearly the same size. So, my gut feeling is that the cow/calf were not part of the earlier group.

Appendix 5 Expert Elicitation 1

Observer expert opinion on vaquita sightings on Sept 3, Oct 17, 19, & 27.

The objective of these questions is to quantify expertise on the number of vaquitas seen. Each observer who worked on the October effort should read the Observation document.

1. What is your name?
2. What dates did you work (maximum time is from Oct 14-Oct 28)
3. Assign 10 likelihood points to:
a. Sighting 2 was a mother and calf
b. Sighting 2 is not a mother and calf
4. Assign 10 likelihood points to:
a. Sighting 3 was a mother and calf
b. Sighting 3 is not a mother and calf
5. Assign 10 likelihood points to:
a. Sighting 2 and sighting 3 are separate sightings
b. Sighting 3 is a resight of sighting 2
6. Assign 10 likelihood points to:
a. The small individual in sighting 4 is a calf
b. The small individual in sighting 4 is not a calf
7. Assign 10 likelihood points to:
a. The individual described in sighting 5 is a new sighting
b. Sighting 5 is a resight of sighting 4
8. Assign 10 likelihood points to:
a. The individual in sighting 5 is a calf
b. The individual in sighting 5 is not a calf
9. Assign 10 likelihood points to:
a. The smaller individual in sighting 6 was a calf
b. The smaller individual in sighting 6 was not a calf
10. Assign 10 likelihood points to:
a. The smaller individual in sighting 7 was a calf
b. The smaller individual in sighting 7 was not a calf
11. Assign 10 likelihood points to:
a. Sighting 7 was a new sighting
b. Sighting 7 was a partial resight of sighting 6
12. Assign 100 likelihhood point to the plausible number of calves seen in October
a. 0 calves (none of the sightings included a calf of the year)
b. 1 calves
c. 2 calves
d. 3 calves
e. 4 calves
f. 5 calves
g. 6 calves (all of the putative sightings with calves were unique calves)
13. What is the lowest plausible number of vaquitas you believe were seen? (give a number)
14. What is the highest plausible number of vaquitas you believe were seen? (give a number)

15. Assign 100 likelihood points to the number of unique vaquita individuals you think were seen in this years' effort (both September and all of October through Oct 27) (use all 100 points, your response should range between your answers to question 13 and 14)

a. 4
b. 5
c. 6
d. 7
e. 8
f. 9
g. 10
h. 11
i. 12
j. 13
k. 14
l. 15
m. 16
n. 17
o. 18

16. **Optional question.** Answer if you feel you have a good memory for the 2018 effort. Keep in mind when reading below, that there were 2 ships with big eyes (4 big eyes altogether) in 2019 and 1 ship with bigeyes (2 big eyes) in 2018. In 2018 there were 2 days of good effort with 5 sightings and 2 days of poor to good effort with no sightings. Here is an extract from our Report of the effort to aide your memory:

A field effort to obtain photographs and biopsies from vaquita was held between September 22 and 28, 2018. Vaquita sightings were made on September 26 and photos were obtained. Sighting #001 was a mother and calf that were photographed. The pair was observed surfacing within a body length of one another over 30 times. At one point the pair came close (20m?) to the panga but they were coming directly towards the vessel and so no biopsies could be taken. The mother was photographically matched to the likely mother of V01F from 2017. This pair was tracked from 9:10 until 10:09 (59 minutes). A second pair (#002) was sighted at 10:03 and tracked until 10:26 (23 minutes). Observers thought the second pair were different and of roughly equal size to one another, which was confirmed in photos.

Vaquita sightings were also made on September 27 and both photos and videos were obtained. Sighting #003 was a pair seen between 06:39 and 06:51. Small boats were launched but we were unable to track or photograph this pair. Sighting #004 was also a pair where boats were launched but we were unable to track or photograph. Sizes of the individuals of both #003 and #004 were too distant to determine relative sizes. Sighting #005 was a group of 4 individuals that included a small calf and was tracked for 1 hour and 42 minutes (from 11:06 until 12:48). During this time they got within 50m of various small boats but never within biopsy range. The four vaquitas evidently then split into two pairs (which is consistent with photographs reviewed later). One of the pairs was last sighted at 13:41 for a total tracing period of 2 hours and 35 minutes. Given the timing and spacing of sightings, it was concluded that at least 6 vaquitas were seen during field operations.

September 28th and 29th had marginal conditions for vaquita sightings and there were no further opportunities for either photographs or biopsies.

In 2019 there were 4 days of good conditions with 7 sightings (the equivalent of 8 ship days). There were 2 days of marginal and some relatively good conditions with no vaquita sightings.

Comparing 2019 to 2018 within the Zero Tolerance Area, please distribute 10 likelihood points to:

a. There were less than half the number of vaquitas in 2019 compared with 2018
b. There was between half and the same number of vaquitas in 2019 compared with 2018
c. There were about the same number of vaquitas in 2019 compared with 2018
d. There were more vaquitas in 2019 than in 2018

Appendix 5 Expert elicitation 2

The summary and questions were sent independently to the 9 observer/experts. The probabilities in red differed for each observer (shown is one anonymous observer) and were calculated based on answers given by each observer in elicitation 1.

Short summary of an anonymous expert's responses to sightings

Sept 3
Sighting 001 2 adults

Oct 17
Sighting 002 2 animals (1 possible calf)
Sighting 003 2 animals (1 possible calf)

Your probability that sightings 2 & 3 are separate sightings = .80
Your probabilities for:
0 calves 0
1 calf .28
2 calves .72

Oct 19

Sighting 004 2 animals (1 possible calf)
Sighting 005 1 or 2 animals (could be a calf with adult not seen)

Your probability that 4 and 5 are separate sightings: .70
Your probabilities for:
0 calves 0
1 calf .75
2 calves .25

October 27

Sighting 006 2 animals (1 possible calf)
Sighting 007 2 animals (1 possible calf)

Your probability that 6 and 7 are separate sightings: .8
Your probabilities for:
0 calves 0
1 calf .44
2 calves .56

1. What is the lowest plausible number of calves seen in sightings 2-7? (pick a number)
2. What is the highest plausible number of calves seen in sightings 2-7? (pick a number)
3. What is the median number of calves (you should feel comfortable that if you flipped a coin, the true number would have even chances of being above or below this number)
4. Assign 100 likelihood point to the plausible number of calves seen in October
a. 0 calves (none of the sightings included a calf of the year)
b. 1 calves
c. 2 calves
d. 3 calves
e. 4 calves
f. 5 calves
g. 6 calves (all of the putative sightings with calves were unique calves)
5. What is the lowest plausible number of vaquitas you believe were seen during all 7 sightings? (give a number)
6. What is the highest plausible number of vaquitas you believe were seen during all 7 sightings? (give a number)
7. What is the median number of vaquitas you believe were seen during all 7 sightings (give a number)
8. Assign 100 likelihood points to the number of unique vaquita individuals you think were seen in last year's effort (both September and all of October through Oct 27). Your responses should be assigned to numbers between your answers to questions 2 and 3 above. About half your points should be above the median. The likelihood points that you assign to the numbers below should sum to 100.
a. 4
b. 5
c. 6
d. 7
e. 8
f. 9
g. 10
h. 11
i. 12
j. 13
k. 14
l. 15
m. 16
n. 17
o. 18

Appendix 6 Expert Elicitation results

Question set 1 for individual sightings where 10 points were assigned and individual observers are given anonymous letter 'names':

1. Sighting 2 was a mother and calf
2. Sighting 3 was a mother and calf
3. Sighting 2 and sighting 3 are separate sightings
4. The small individual in sighting 4 is a calf
5. The individual described in sighting 5 is a new sighting
6. The individual in sighting 5 is a calf
7. The smaller individual in sighting 6 was a calf
8. The smaller individual in sighting 7 was a calf
9. Sighting 7 was a new sighting

	Question number								
Expert	1	2	3	4	5	6	7	8	9
A	9	10	8	10	5	5	7	10	8
B	7	8	7	6	2.5	5.5	3	7	8.5
C	8	7	7	9	7	7	2	10	9
D	10	8	9	10	4	5	3	10	8
E	3	6	9	9	8	5	2	10	10
F	7	5.5	6.8	8	5	5.6	5.2	9.5	7.5
G	9	8	7	9	8	5	4	10	10
H	8	7	6	9	5	7	5	9	9
I	7	9	9.5	10	0.3	9.7	2	10	10
Average probability	0.756	0.761	0.770	0.889	0.498	0.609	0.369	0.950	0.889

Responses to the second elicitation given the responses above (see Appendix 5). Experts were asked to assign 100 likelihood points across the range of possible calf numbers

	Number of vaquita calves						
Expert	0	1	2	3	4	5	6
A	0	0	10	40	40	10	0
B	0	10	45	35	10	0	0
C	0	0	0	0	40	60	0
D	0	0	30	40	20	10	0
E	0	21.05	52.6	15.79	10.5	0	0
F	0	15	58	20	4	2	1
G	0	5	10	40	30	10	5
H	0	0	0	44.09	45.2	9.677	1.075
Average probability	0	0.06	0.26	0.29	0.25	0.25	0.01
At least this number	1.0	1.0	0.94	0.68	0.39	0.14	0.01

Responses to experts' estimates of total number of vaquitas seen in all 7 sightings using 100 likelihood points.

Experts	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	0	0	5	5	5	8	20	20	20	9	5	3	0	0	0
B	0	0	10	10	20	20	20	10	10	0	0	0	0	0	0
C															
D	4	10	10	10	30	10	10	6	5	3	2	0	0	0	0
E	0	0	10	20	30	20	10	5	5	0	0	0	0	0	0
F	3	5	16	34	22	14	4	2	0	0	0	0	0	0	0
G	0	0	0	0	0	5	5	5	10	15	20	25	10	5	0
H	0	0	5	12	32	24	16	8	3	0	0	0	0	0	0
I	0	0	3	4	25	35	25	4	4	0	0	0	0	0	0
Average probability	.01	.02	.07	.12	.21	.17	.14	.08	.07	.03	.03	.03	.01	.01	0
At least this number	1	.99	.97	.90	.78	.58	.41	.27	.19	.12	.09	.05	.02	.01	0

Only 6 experts responded to the final question:
Comparing 2019 to 2018 within the Zero Tolerance Area, please distribute 10 likelihood points to:

e. There were less than half the number of vaquitas in 2019 compared with 2018
f. There was between half and the same number of vaquitas in 2019 compared with 2018
g. There were about the same number of vaquitas in 2019 compared with 2018
h. There were more vaquitas in 2019 than in 2018

Expert	16a	16b	16c	16d
A	2	5	3	0
B	1	4	5	0
C	0	2	3	5
D	2	2	5	1
E	1	3	5	1
F	0	8	2	0
Average probability	0.100	0.400	0.383	0.117