Survey report for vaquita research 2023

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Executive Summary

Two ships (*Seahorse* and *Sirena de la Noche*), staffed with scientists whose combined experience studying marine mammals would total around 400 years, surveyed the northern Gulf of California hoping to find and track vaquitas, the rarest marine mammals on earth. The search for these small elusive porpoises was aided by a team of Mexican scientists who used acoustic detectors to determine where vaquitas were spending time. The 17 days of visual search effort between May 10 and May 26, 2023 focused on waters in and around the Zero Tolerance Area (ZTA), which is known to be a stronghold of the last few vaquitas. The team made 16 sightings and had 61 acoustic encounters. Using a method called Expert Elicitation, we estimated that the sightings included 1-2 calves and there was a 76% probability that the total number seen, including calves, was between 10 and 13 individuals. Since the search was in a small portion of the vaquita's historical range, 10-13 is considered a minimum estimate of the number of vaquitas left. That estimate is roughly the same as what was estimated from the last survey in October 2021. All individuals sighted in 2023 appeared to be healthy.

The survey period had been moved from October 2022 to May 2023 because the proportion of windy days was predicted to be less in May. This was the first visual vaquita survey attempted in May. On ten days the winds were considered low enough to sight and track vaquitas; this compares to 4 and 5 days in 2019 and 2021, respectively. Of the 16 sightings over three weeks in 2023, there were 3 photographic matches on 3 consecutive days in which the same mother and calf were seen. For five of the 16 sightings, both photographs and drone footage of vaquitas were obtained.

Calves are assumed to be only a few months old in May. Because we did not see any calves during the first week of survey, effort was shifted to waters north of the ZTA on the reasoning that mothers and calves may shelter in shallower waters there. Moreover, acoustic research had consistently detected vaquitas along the northwestern edge of the ZTA (Figure 1). Autumn surveys in previous years had been hindered by the high number of gillnets deployed in and around the ZTA. Fishing activity tends to be much lower in May, and low numbers of nets were deployed just outside the ZTA and none were seen inside the ZTA. The low fishing effort just northwest of the ZTA meant it was possible to survey this previously unsurveyed area effectively. Figure 2 shows the tracklines of the two ships and the locations where vaquitas were seen. We were able to track 7 groups of vaquitas for more than 30 minutes, and the clusters of yellow dots on the figure likely represent multiple locations of the same groups. The

amount of time it was possible to visually observe and acoustically detect vaquitas was greater than in past years when there were large numbers of gillnetting vessels within the ZTA. No gillnetting activity was observed within the ZTA in 2023, but it was regularly observed in the area northwest of the ZTA where vaquitas were also seen.

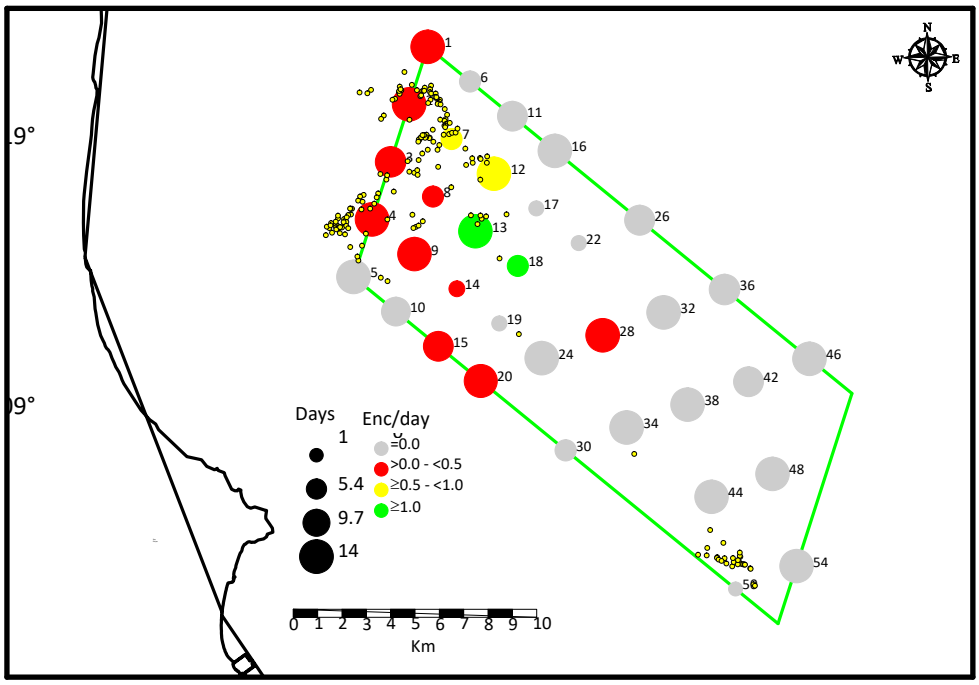

Figure 1. Summary of vaquita acoustic detections during the May survey period with the days of recording depicted by the size of the dots and the color indicating the number of acoustic encounters. The small yellow dots are locations where vaquitas were seen. Clusters of yellow dots represent multiple locations of the same individuals tracked over time. The ZTA is outlined in green and the San Felipe harbor is the small square at the bottom of the figure.

Eight local trainees were introduced to the visual-survey methods and they observed from both ships using handheld binoculars. These trainees were enthusiastic, saw vaquitas, and could make a good future team with further training. We recommended that dedicated efforts be made by an experienced vaquita scientist to train this team using 25-power binoculars. We also note that, due to the rarity of vaquitas, trainees would benefit from training in marine mammal observation and photography in La Paz and also from specific training in sighting porpoises in areas where porpoises are common.

Last August the Mexican Navy deployed 193 concrete blocks with 3m high hooks designed to entangle gillnets. While the exact reason for no gillnet vessels being observed within the ZTA is unknown, the simplest explanation would be that the concrete blocks and hooks, in combination with the collaborative efforts by the Mexican Navy and the Sea Shepherd Conservation Society (SSCS) to remove the few fishermen who were willing to risk their nets by deploying them inside the ZTA, is working. The apparent 90%+ decrease in gillnetting within the last stronghold of vaquitas is probably the most significant step taken to date toward saving the species. It is also important that SSCS has been monitoring the ZTA using state-of-the-art sonar technology to check for nets entangled on the hooks since January (Figure 3) and has found only one net, which SSCS and the Navy partially removed. The

relatively high vaquita presence in unprotected areas just outside the ZTA strongly suggests that the Government of Mexico should consider deploying more concrete blocks in these areas before the next high fishing season begins in September.

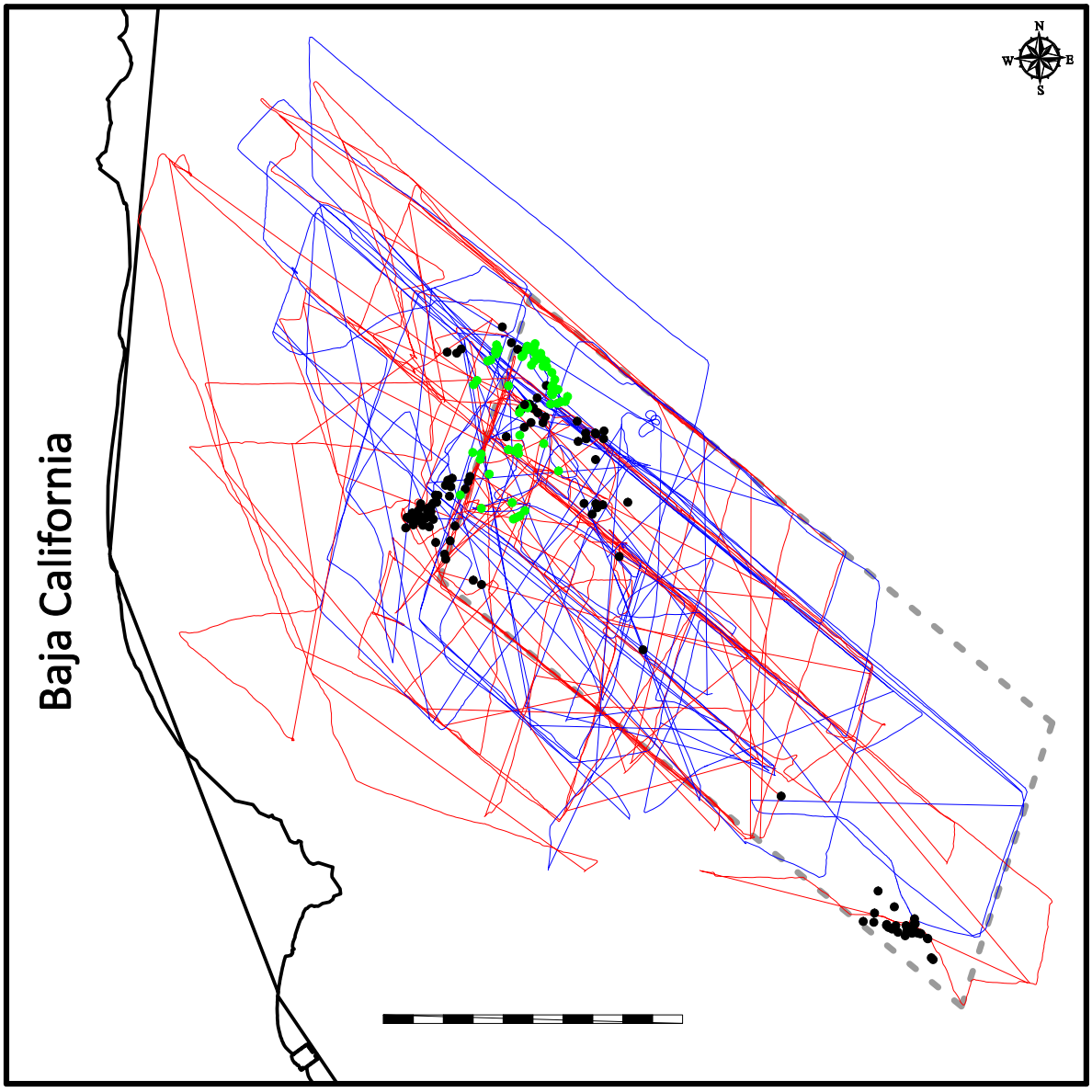

Figure 2. Tracklines followed by *Seahorse* (blue lines) and *Sirena de la Noche* (red lines) during Vaquita Survey 2023. The small dots are locations where vaquitas were seen: green for confirmed cow/calf locations and black for all other vaquita locations. Clusters of dots represent multiple locations of the same individuals tracked over time. The ZTA is outlined with gray dashes and San Felipe harbor is the small square at the bottom of the figure.

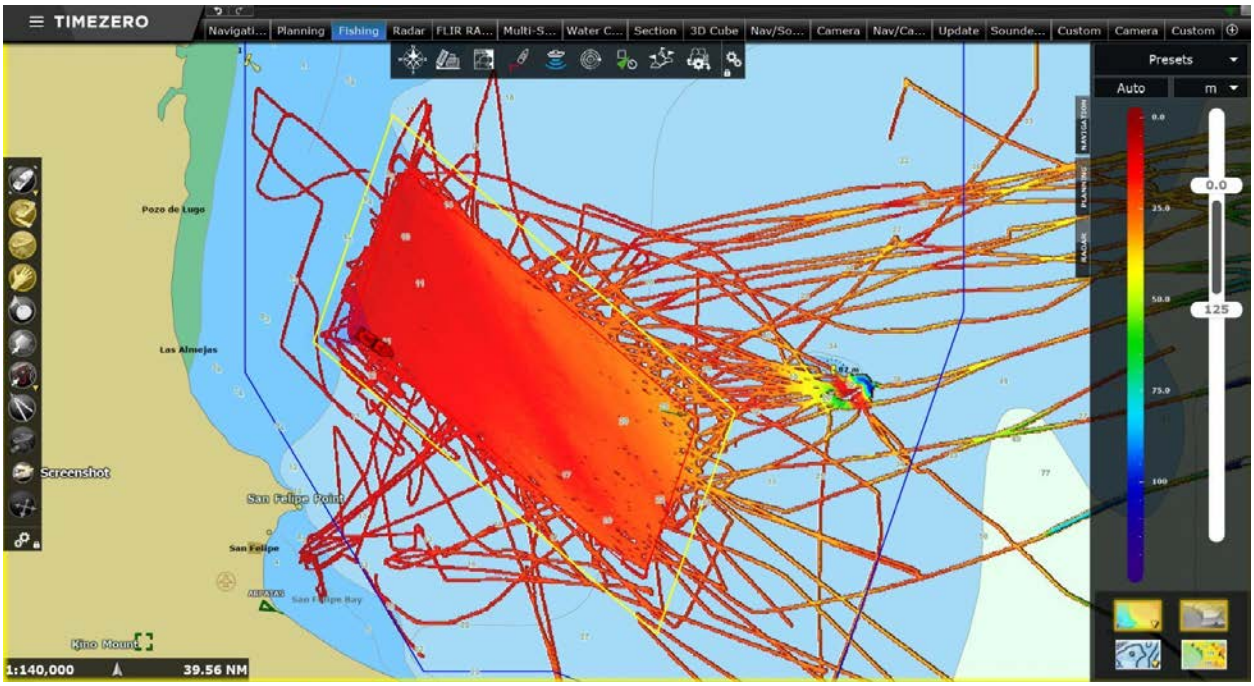

Figure 3. Red lines show where side-scan sonar was used. The area of the ZTA is completely covered because of the focus to search for ghost nets entangled on the concrete block hooks. The yellow rectangle depicts a buffer zone used to quantify fishing effort near the ZTA. The blue line shows the boundary of the Vaquita Refuge.

Main Report

Introduction

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 surfacings 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 45%/year, through 2018 (Jaramillo-Legorreta 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 2023 vaquita population cannot be estimated using line-transect methods.

Faced with these difficulties, vaquita researchers 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).

Surveys focused on photographic identification were conducted in 2019 (see Report here). No within-year photographic matches were made that would allow an abundance estimate. In 2020 an Expert Elicitation (EE) effort was funded to better estimate the numbers of unique individual calves seen (only) and unique individual vaquitas seen (including adults, juveniles and potential calves) during the 2019 survey (Rojas-Bracho et al. 2019c). A similar survey was conducted in 2021 (Rojas-Bracho et al. 2022). The results published from these surveys indicate that vaquitas are no longer declining at 45%/year as estimated earlier but instead may only be declining slightly if at all. Both surveys took place in October and had only 4 to 5 calm days suitable for seeing vaquitas.

The 2023 vaquita survey was moved to May to take advantage of predicted calmer winds. The basic strategy of using acoustics to suggest areas where sighting effort should be focused and EE to interpret sighting data was the same, but 2 large ships were not available. Using one large ship with high-power

binoculars and a smaller ship to aid in tracking vaquitas and to support the photography work had been effective in the past and was the choice for this survey (Figure 4).

Figure 4. The *Seahorse* with crew on the bow and observation team on the bridge deck in the foreground and the *Sirena de la Noche* with the observation team on the bow in the background.

The survey incorporated a training component to introduce interested local young professionals working in fisheries conservation and management to survey methods to detect vaquita (Figure 5). Navy and CONANP personnel observed the survey operations, facilitated communications with Navy vessels in the area and recovered some acoustic detectors that had been cut loose from moorings (Figure 5). During the second week, media representatives joined the survey.

Figure 5. Clockwise from left: SSCS science director Andrea Bonilla (aqua shirt) explaining big-eye binocular use to trainee, Navy and CONANP personnel searching for vaquitas together with big-eye observer Bob Pitman, CONANP vessel *Capitan Paco* searching for lost acoustic equipment. Photo credit: Jesus Zatarain, Director of the Biosphere Reserve of the Upper Gulf of California and Colorado River Delta).

Methods

As in other recent surveys, the locations of acoustic detectors were used to guide visual transect effort (Appendix 1). Acoustic data have suggested that vaquitas are most likely to be found in the ZTA where effort was concentrated in 2019 and 2021. Some search effort was also made in 2023 in areas near but outside the ZTA, where there had been sightings in 2017, but where no acoustic effort had been possible because of theft of acoustic devices. Survey speed was between 4-6 knots. The two vessels followed parallel tracks, staying about 2-4 km apart so that when vaquitas were sighted, the vessels could converge to track and photograph them. Observers were housed on land and transported by small fishing vessels (pangas) to the *Seahorse* or on the *Sirena* itself to each day's survey start position. Vessels left the dock in the San Felipe marina at 04:30.

Because vaquitas are so rare and difficult to detect, it is critical that very experienced scientists carry out the surveys, both acoustic and visual. Acoustic personnel included: Armando Jaramillo-Legorreta, Edwyna Nieto, Gustavo Cardenas and a team of fishermen who deployed acoustic equipment and transported the visual team to the *Seahorse*. Visual personnel included: Andrea Bonilla, Barbara Taylor, Jay Barlow, Robert Pitman, Lisa Ballance, Sarah Mesnick, Ernesto Vazquez, Sergio Martinez, Pamela Martinez, Dawn Breese, Chris Hoefer, Felipe Triana and Anna Hall. Together, the visual team had over 400 years of experience as professional biologists.

The 2023 survey used two ships (the M/V *Seahorse* with an eye height of 7.57m and the M/V *Sirena de la Noche* with an eye height of 4.62m). Eye height is the average eye height above the water that is used to calculate distance to sightings. Unlike the 2019 and 2021 surveys that involved 2 ships with big-eye binoculars (25x), the *Sirena de la Noche* (henceforth called the *Sirena*) was not stable enough for big-eyes and observers used handheld binoculars. The best photographs of vaquitas were taken from a ship similar to the *Sirena* in 2008. The strategy in 2023 was to search from both ships, but once a sighting was made, to rely on the ship with big-eyes and a better capability to track vaquitas to help the smaller and quieter *Sirena* maneuver and attempt to obtain photographs (Figure 6). The Sea Shepherd Conservation Society (SSCS) crew included an expert drone pilot who stood next to observers watching the vaquitas and took directions to obtain video footage.

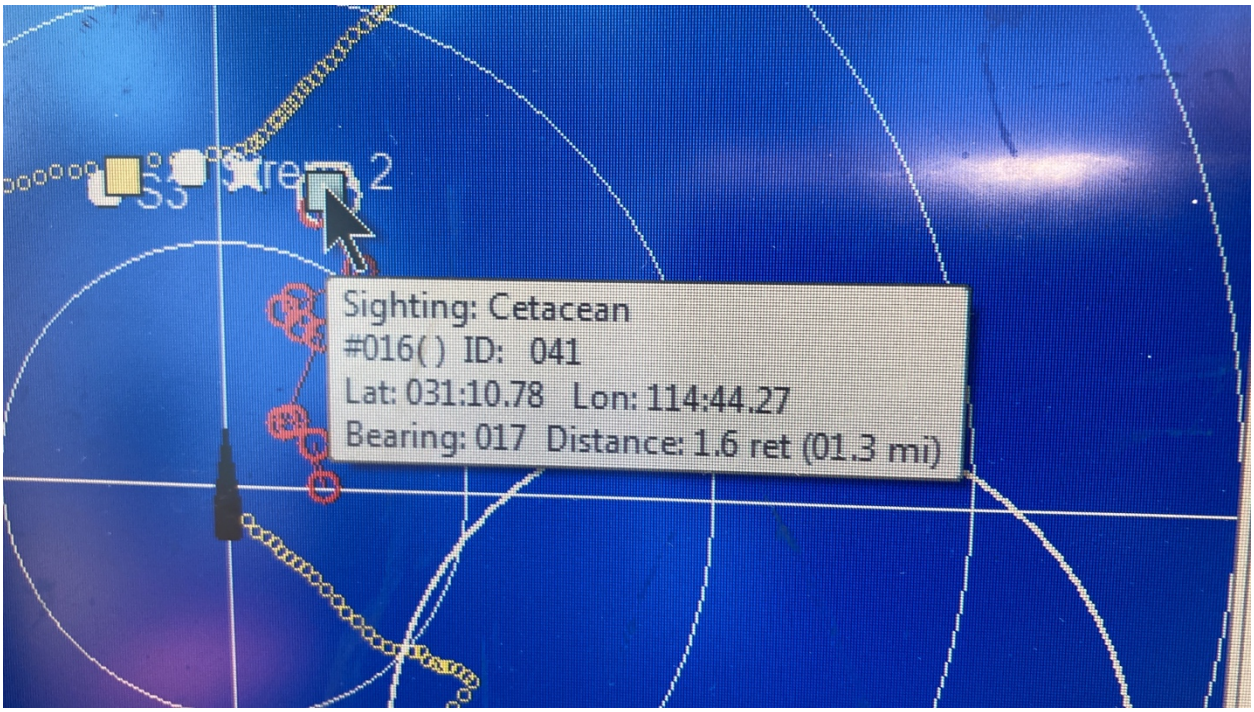

Figure 6. Screenshot of sighting 16. The black ship in the center depicts the position of the *Seahorse* with its path shown by yellow circles. The path of the mother/calf pair of vaquitas is in red open circles with the last position shown where the cursor is pointing and in the text box. The Sirena is located at the yellow box. Each white circle is a nautical mile (1.85 km).

The *Seahorse* was equipped with 3 pairs of big-eye (25-power) Fujinon binoculars on loan from the Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanographic and Atmospheric Administration, U.S. Department of Commerce. Eight scientists staffed the visual effort on this ship, which proved to be a very stable platform for keeping high-power binoculars steady even in 1m of swell, something that is essential for carrying out effective vaquita surveys. Data were recorded in WinCruz software that allowed mapping of the vaquita sightings so that the animals could be tracked and when possible, photographed. The locations of sightings also provided data on swim speeds between within-day sightings. Such data help determine whether sightings could be duplicates of earlier sightings or are 'new' individuals.

Four scientists staffed the *Sirena* and used handheld 7x Fujinon binoculars with built-in compass and reticles to provide angle and distance for sightings. Data were recorded on paper forms and in a sighting record book. In addition, a GPS tracker recorded positions.

Two staff scientists onboard the *Seahorse* recorded the number of fishing vessels inside the ZTA and in a buffer zone around the ZTA every hour using data from radar, binoculars and drone. These data are publicly available on the SSCS's Operation Milagro website.

For the Expert Elicitation (EE) exercise, all experts were required to take 3 hours of online training. During the survey, each sighting was written-up in detail in an Evidence Dossier. Group meetings were held regularly to discuss sightings and verify that the Dossier contained all relevant data. The elicitation was facilitated by experts from St. Andrews University who had also facilitated the elicitations in 2019 and 2021, and it took place on May 31 by Zoom for 4 hours. Experts independently allocated "probs" (likelihood values) for two questions: (i) What is the number of unique calves seen? (ii) What is the total number of unique vaquitas seen (including calves). Each expert was asked to give her or his rationales verbally. They were then allowed to change their 'probs' if the discussion resulted in changing their beliefs. Facilitators then compiled the independent distributions into a single distribution and led a discussion toward a consensus distribution that the group believed could be convincingly argued to a Rational Impartial Observer. A more complete description of this method is given in Rojas-Bracho et al. (2022).

Results

Visual efforts were guided by regular updates provided by acoustic data indicating detection locations of vaquitas (Appendix 2). May 11 was the first day of visual effort and four sightings were made on that day in the northern half of the ZTA. Typically, vaquitas are seen only in very calm conditions (Beaufort 0-2 with winds less than 7 knots). The May weather conditions consisted of calm nights and early mornings followed by increasing winds in the afternoon. On some days, however, winds were low in the morning and late afternoon, but higher in the middle of the day. As a result, given that the visual team was not staying overnight onboard the ships, some surveying was carried out in Beaufort 3 and 4 conditions. Sightings were made in those conditions but tracking the animals was very difficult. Figure 7 shows the survey tracklines coded by Beaufort sea state. Distances surveyed in different sea states are given in Table 1. Raw data files (called DAS files) are available from Armando Jaramillo-Legorreta upon request and are also maintained at the Southwest Fisheries Science Center.

Table 1. Visual survey distances for the two vessels under different Beaufort conditions, in kilometers.

Vessel	Beaufort	Distance (km)
Seahorse	0	42.01
	1	146.53
	2	209.07
	3	157.80
	4	122.00
	5	5.64
	TOTAL	***683.04***
Sirena de la Noche	0	39.48
	1	162.16
	2	232.64
	3	150.22
	4	115.04
	5	3.47
	TOTAL	**703.00**
	TOTAL BOTH VESSELS	***1,386.04***

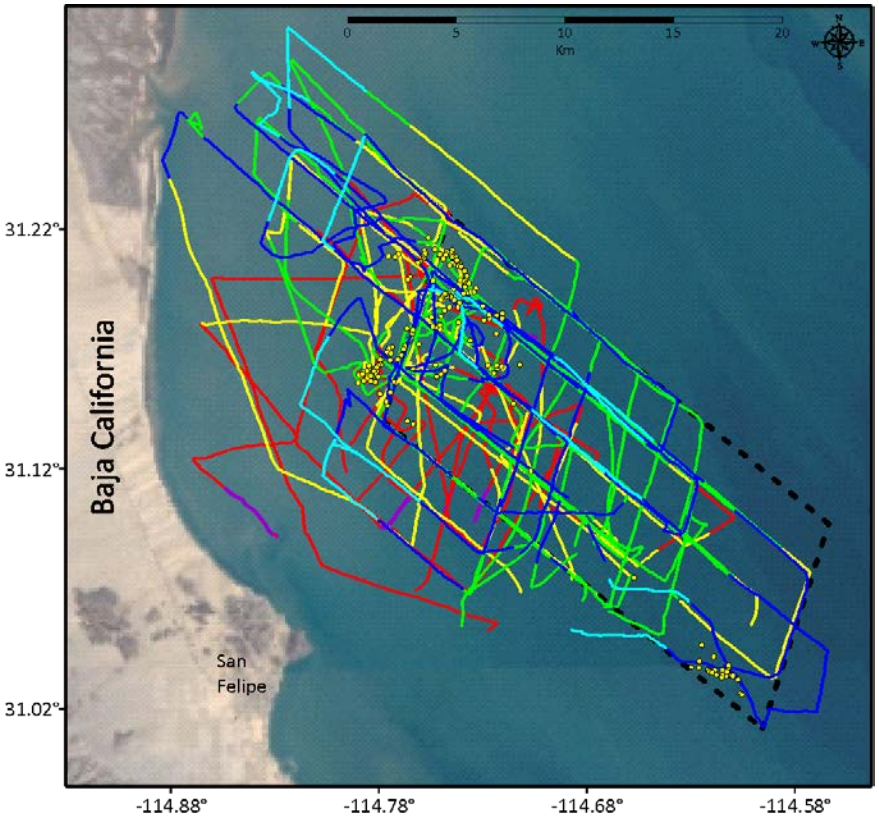

Figure 7. All tracks followed by the *Seahorse* and *Sirena de la Noche* during the 2023 vaquita survey, under different Beaufort sea state conditions (0=cyan, 1=blue, 2=green, 3=yellow, 4=red, 5=purple). All locations where vaquitas were seen are indicated with yellow points. The ZTA is depicted with a black broken line.

Both vessels proved to be very good for sighting vaquitas in good conditions with low swell. Of the 16 sightings (Table 2, Figure 8), 5 were made by both vessels, 4 by the *Sirena* only and 7 by the *Seahorse* only. All 16 sightings are described in detail in the Evidence Dossier (Appendix 3). Experts were provided with the exact information in Appendix 3 and asked to provide their expert opinion on the two questions mentioned above (Appendix 4).

Table 2. Sighting details.

Sighting #	Date in May	Vessel(s)	Duration (minutes)	Photos	Videos
1	11	Sirena	17	N	N
2	11	Both	46	Y	N
3	11	Sirena	1	N	N
4	11	Seahorse	1	N	N
5	15	Sirena	1	N	N
6	16	Both	52	N	N
7	16	Seahorse	101	Y	Y
8	19	Seahorse	1	N	N
9	20	Both	33	Y	Y
10	20	Both	15	Y	Y
11	20	Seahorse	81	Y	Y
12	21	Sirena	1	N	N
13	21	Seahorse	29	Y	Y
14	22	Seahorse	1	N	N
15	22	Seahorse	10	N	N
16	22	Both	89	Y	Y

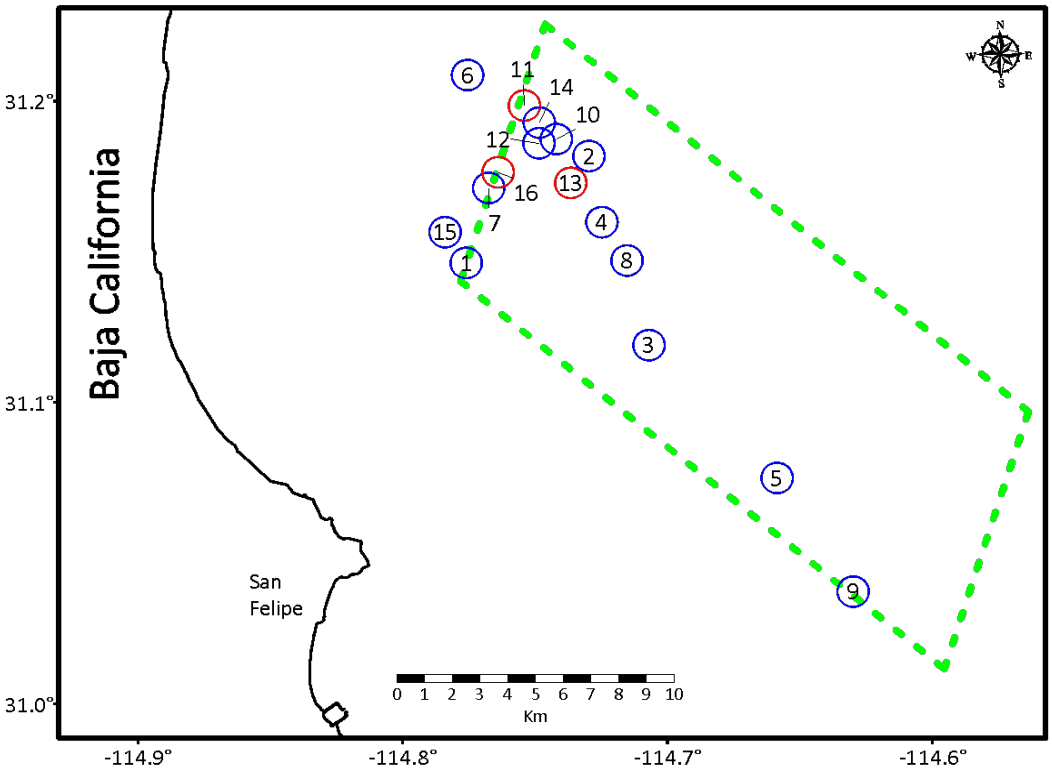

Figure 8. All 16 sightings (colored circles), showing only the initial locations. Red circles indicate that a calf was present. Blue circles are sightings with no confirmed calves seen.

Figure 9 shows the percent experts believed given their observations for the number of calves present for all 16 sightings. There was similar belief that there were one or two calves with a 10% chance there were more than 2 calves seen.

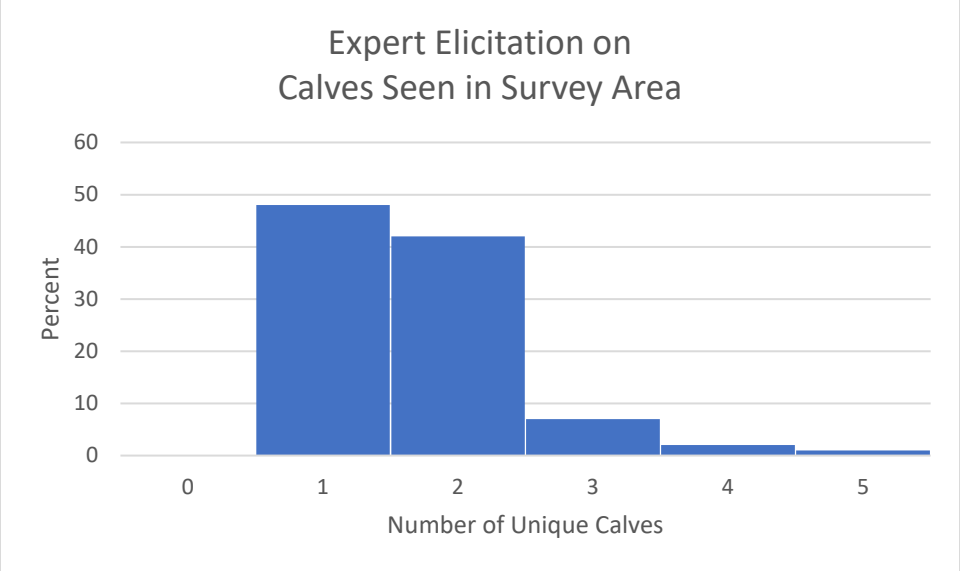

Figure 9. Percent belief for the number of calves in 16 sightings.

The mean estimate for the number of vaquitas seen in all 16 sightings was 10.6 with a 76% belief that there were between 8 and 13 seen and 65% expert confidence that there were at least 10 (Figure 10).

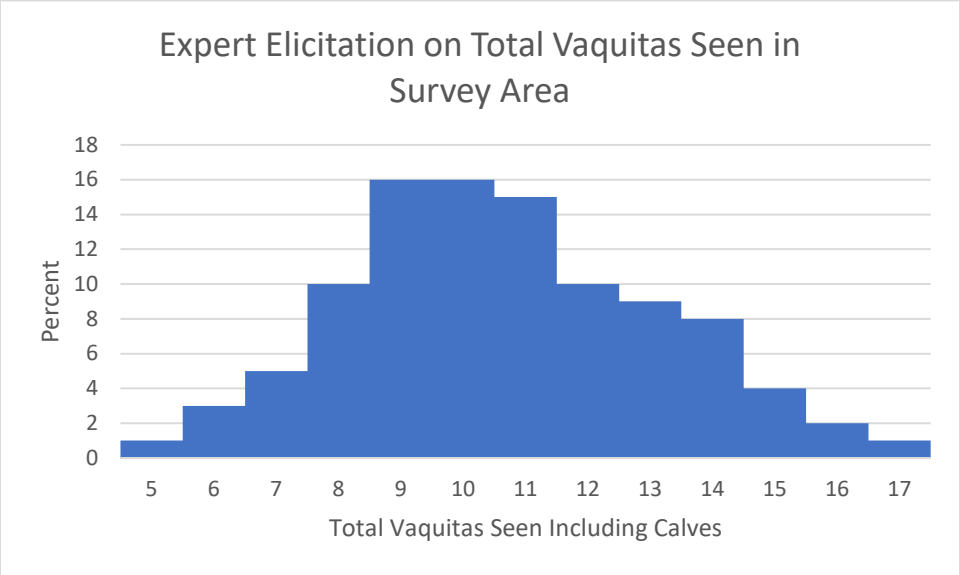

Figure 10. Percent belief from expert elicitation for numbers of unique vaquitas seen in 16 sightings within or near the ZTA.

Discussion

Following the 2021 survey, we published a paper demonstrating that vaquitas were doing better than expected (Rojas-Bracho et al. 2022). The most likely outcome when the decline observed in 2018 was projected forward had been that the vaquita would be extinct by now. Other positive scientific news comes from genetic analysis. Genomic data suggest that vaquitas are less vulnerable to genetic issues known to harm other small populations because they apparently have been rare for over 200,000 years (Robinson et al. 2022). Examining genetic samples from the 1980s to 2017 showed no difference in the level of genetic diversity. Observations since 2018 suggest that at least ten vaquitas remain in the ZTA. Acoustic data also indicate multiple groups of vaquitas detected simultaneously. Vaquitas continue to have robust calves. Observing the lack of gillnets within the ZTA and seeing healthy vaquitas feeding undisturbed makes us optimistic that the species is not bound to continue its decline toward extinction as long as conservation measures can continue to protect the species from gillnets.

The decision to survey in May rather than the fall proved to be a good one. Having 11 survey days compared with only 4 or 5 was likely the biggest factor in going from 7 sightings in 2021 to 16 in 2023. However, interpreting the data from this latest survey is difficult because many factors have changed (for the better). It is hard to say with certainty whether what we observed in 2023 was different because of the season or because real changes have occurred. For example, we were able to observe vaquitas for longer periods in 2023 than in 2021. Is this because the winds were calmer, feeding is more intense in May, the disturbance of vaquitas by fishing activities was less, or we used different vessels that generally moved more slowly and were less disturbing? Similar questions could be asked about why acoustic encounters this May were longer than in past acoustic research. Only after adding more years of research during this season will we be able to address these questions with any confidence. We can certainly say that the animals appeared to be feeding and not disturbed by our presence.

Unlike earlier years, most animals had unmarked dorsal fins, making photographic identification more difficult. Again, this could be the result of several different things. It is plausible that unmarked individuals are newly recruited and have not been as exposed to gillnetting inside the ZTA as was the case a few years ago. Possibly, the older, more heavily scarred individuals seen in 2018 and 2019 are simply elsewhere in May. However, it is also plausible, and concerning, that the well-marked individuals seen in earlier surveys have died. Again, this question can only be resolved through not only more years of survey effort but also by expanding the area surveyed. It would be very valuable to expand acoustic monitoring to areas outside the ZTA, but this can only be done if the problem of equipment theft can be solved.

Our success at tracking animals this year indicates that photographic identification and mark-recapture approaches may prove feasible in the May period. Larger lenses (at least 600mm) with a gimbaled tripod may greatly improve the sharpness of photographs. We recommend a feasibility survey that would use at least one pair of big-eyes to find animals and a stable high-power camera to obtain better photographs. If successful, the new photographic equipment could be used in May. If a good number of photographs are obtained that allow photographic identification, a second effort period a few months later to attempt to 'recapture' identified vaquitas would allow a mark/recapture abundance estimate in the ZTA and nearby waters.

The use of one large, stable ship and one smaller, faster and quieter ship worked very well. We recommend that 3 pairs of big-eyes with experienced observers and the recorder station all be set up in front of the Seahorse bridge. Such an arrangement promotes communication among all members of the team plus the bridge. A team on the deck above the bridge deck could use handheld binoculars on a regular rotation. That deck needs improved safety, both on the ladder and railings, for the front area to be used effectively and safely.

Having trainees see the full operation, including seeing vaquitas themselves, was a good first step (See Appendix 5 for details). All three pairs of big-eyes had to be used by experienced observers in the limited time available for this year's survey. If the *Seahorse* had its own set of big-eyes, new local observers could become proficient at using them on calm days. This would be best if an experienced observer familiar with the visual survey setup and computer program, like Ernesto Vazquez or Juan Carlos Salinas, could be hired as a trainer. Trainees also need to get experience using cameras and acquiring their own marine mammal 'search images'. Such training could be done in La Paz where several experienced observers (Sergio Martinez, Pamela Martinez, and others) reside. The best training for vaquitas, however, would be to spend time observing and photographing harbor porpoises in San Francisco Bay or in British Columbia with Anna Hall.

The biggest improvement in both vaquita conservation and the ability to survey for vaquitas was the greatly decreased amount of fishing activity (Appendix 6). While some of this is due to May being a low fishing month, SSCS data have shown a greater than 90% decline in pangas within the ZTA in recent months. It is likely that this is due to the installation of concrete blocks with hooks that entangle gillnets plus the cooperative arrangement between SSCS and the Navy to enforce the gillnet ban within the ZTA. Although many people were concerned that the hooks would entangle nets that would then potentially entangle vaquitas, SSCS's scrutiny of the ZTA since January with state-of-the-art side-scan sonar has not revealed this to be a problem (Appendix 7). This is the most encouraging news ever of human intervention to save vaquitas. The results of the May 2023 survey provide clear evidence that this type of protection needs to be expanded to cover more of the high-use areas of the remaining vaquitas.

Literature Cited

Jaramillo-Legorreta, A., G. Cardenas-Hinojosa, E. Nieto-Garcia, L. Rojas-Bracho, J. Ver Hoef, J. Moore, N. Tregenza, J. Barlow, T. Gerrodette, L. Thomas, and B. Taylor. 2016. Passive acoustic monitoring of the decline of Mexico's critically endangered vaquita. Conservation Biology 31: 183-191. Doi: 10.1111/cobi.12789

Jaramillo-Legorreta, A.M., G. Cardenas-Hinojosa, E. Nieto-Garcia, L. Rojas-Bracho, L. Thomas, J.M. Ver Hoef, J. Moore, B. Taylor, J. Barlow, N. Tregenza. 2019. Decline towards extinction of Mexico's vaquita porpoise (Phocoena sinus). R. Soc. Open sci. 6: 190598.

Jefferson, T.A., Olson, P.A., Kieckhefer, T.R., and L. Rojas-Bracho. 2009. Photo-identification of the vaquita (*Phocoena sinus*): the world's most endangered cetacean. *Lat. Am. J. Aquat. Mamm.* 7(1-2):53-56.

Rojas-Bracho, L., F.M.D. Gulland, C. Smith, B. Taylor, R.S. Wells, P.O. Thomas, B. Bauer, M.P. Heide-Jørgensen, J. Teilmann, A. Jaramillo-Legorreta, G. Abel, A.J. Read, A. Westgate, K. Colegrove, F. Gomez, K. Martz, R. Rebolledo, S. Ridgway, T. Rowles, C.E. van Elk, J. Boehm, G. Cardenas-Hinojosa, R. Constandse, E. Nieto-Garcia, W. Phillips, D. Sabio, R. Sanchez, J. Sweeney, F. Townsend, S. Walker, J.C. Vivanco. 2019. A field effort to capture critically endangered vaquitas (*Phocoena sinus*) for protection from entanglement in illegal gillnets. Endangered Species Research 38:11-27.

Lorenzo Rojas-Bracho[1*], Barbara Taylor[2], Cormac Booth[3], Len Thomas[4], Armando Jaramillo-Legorreta[5], Edwyna Nieto García[5], Gustavo Cárdenas Hinojosa[5], Jay Barlow[2], Sarah L. Mesnick[2], Tim Gerrodette[2], Paula Olson[2], Annette Henry[2], Henoch Rizo[6], Eva Hidalgo-Pla[7], Andrea Bonilla-Garzón[8] 2022. Benefits of monitoring very small populations: more vaquita porpoises survive than expected. Endangered Species Research 48: 225-234.

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

Taylor, B.L., L. Rojas-Bracho, J. Moore, A. Jaramillo-Legorreta, J. Ver Hoef, G. Cardenas-Hinojosa, E. Nieto-Garcia, J. Barlow, T. Gerrodette, N. Tregenza, L. Thomas, and P.S. Hammond. 2016. Extinction is imminent for Mexico's endemic porpoise unless fishery bycatch is eliminated. Conservation Letters. doi: 10.111/conl.12331

Taylor, B.L., Wells, R.S., Olson, P.A., Brownell, R.L. Jr., Gulland, F.M.D., Read, A.J., Valverde-Esparza, F.J., Ortiz-Garcia, O.H., Ruiz-Sabio, D., Jaramillo-Legorreta, A.M., Nieto-Garcia, E., Cardenas-Hinojosa, G., and Rojas-Bracho, L. 2019. Likely annual calving in the vaquita, Phocoena sinus: A new hope? Marine Mammal Science DOI: 10.111/mms.12595

Thomas, L., Jaramillo-Legorreta, A. G. Cardenas-Hinojosa, E. Nieto-Garcia, L. Rojas-Bracho, J. M. Ver Hoef, J. Moore, B. Taylor, J. Barlow, N. Tregenza. (2017). Last call: Passive acoustic monitoring shows continued rapid decline of critically endangered vaquita. J. Acoust. Soc. Am. 142 (5), November 2017

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Dr. Lorenzo Rojas-Bracho holding vaquita calf model in front of Rocas Consag, near the middle of vaquitas' historical distribution.

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