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ACOUSTIC MONITORING AND STATUS OF VAQUITA POPULATION IN 2022

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ACOUSTIC MONITORING AND STATUS OF VAQUITA POPULATION IN 2022

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ABSTRACT

The population of vaquita has been declining since many years ago, as estimated by several works with data gathered since 1993. It is the key factor considering the species as critically endangered. By 2018 it was estimated that population was composed out of less than 20 individuals, using acoustic data to extrapolate from an estimate of abundance in 2015. Along abundance decreasing, it was also noted that distribution area was also shrinking progressively, with acoustic activity now restricted to the Zero Tolerance Area (ZTA). Given the importance of information about vaquita status, acoustic monitoring was implemented in 2022 season in the ZTA sampling during neap tide periods between April and December. The sampling protocol included a 55 sites grid, from which some sites were selected to sample along eight neap tide periods. A total of 13,964 hours of effort were applied in 42 sites and identifying 77 acoustic encounters of vaquitas in 17 of the sites. The distribution of encounters shows that the most used area is the western portion of the ZTA, with very low activity towards east. Using data of 21 of the sampling sites between October and November, that coincide with 2021, it was estimated that acoustic detection rate decreased at a rate of 11.99% (95% C.I. -38.45% to 21.13%), with 79.64% probabilities of actual decreasing. If detection rate change is a proxy of population trend, vaquita population keep decreasing. Encounters dataset allowed to calculate that, at least for periods, more than one group of vaquitas use the ZTA at the same time. The acoustic monitoring program for 2023 is already funded and will occur between July and November. Also, other survey to observe vaquitas will occur in May, with the aim to use expert elicitation techniques to estimate minimum abundance of vaquita population.

INTRODUCTION

The population of vaquita has been declining since many years ago, as estimated by several works with data gathered since 1993 (Barlow *et al*., 1997; Jaramillo Legorreta, 2008; Gerrodette *et al*., 2011; Taylor *et al*., 2016; Jaramillo Legorreta *et al*., 2019). It is the key factor considering the species as critically endangered (Rojas Bracho, *et al*., 2022).

By 2018 it was estimated that population was composed out of less than 20 individuals, as estimated with acoustic detection rates accounting for population trend, and an extrapolation from an estimate of abundance in 2015 (Taylor *et al*., 2016; Jaramillo Legorreta *et al*., 2019). Along abundance decreasing, it was also noted that distribution area was also shrinking progressively. Since about 2016 it was found that vaquita acoustic activity was vanishing in regular sampling sites where acoustic activity was common (Jaramillo Legorreta *et al*., 2022). By 2018, it was observed that acoustic activity was restricted to the so called Zero Tolerance Area (ZTA), a 22.5 x 10.0 Km zone devoted to the protection of the species.

Since 2011 acoustic monitoring of vaquita, intended to estimate population trend, was implemented using autonomous acoustic detectors (C-POD) to gather data in 46 fixed and systematic sampling sites inside Vaquita Refuge (Jaramillo Legorreta *et al*., 2016). The Vaquita Monitoring Program has gathered data, annually, since then, with just a small sample in 2020 due to the Covid19 pandemic. Along years, moorings and acoustic detectors have been lost due to fishing activities. However, during seasons 2019 and 2021 the loses increased at very high and intolerable levels, totaling over 117 moorings and acoustic detectors lost (Rojas Bracho *et al*., 2021; Jaramillo Legorreta *et al*., 2022).

Despite of the massive loses of equipment, during 2019 and 2021 monitoring seasons, it was possible to document the existence of the species and describe the distribution patterns of acoustic activity inside the ZTA (Jaramillo Legorreta *et al*., 2022). During both years also occurred surveys to sight vaquitas, although no methods were applied to estimate abundance. Instead, expert elicitation methods were used to estimate the number of different individuals sighted during each survey which, in fact, became an estimate of minimum population abundance for every year (Rojas Bracho *et al*., 2022). In 2019 the maximum probability was that 3 calves were sighted, while one or two with similar probabilities in 2021. Regarding all individuals sighted, in 2019 more probable number of different individuals was 11, but with similar probabilities for 10 or 12. For 2021, seven and eight different animals were favored with same probabilities. These estimates indicate a continued reduction of population numbers, although at lower rates as expected according to acoustic monitoring in previous years (Rojas Bracho *et al*., 2022).

Given the importance to keep generating information of vaquita population status, acoustic monitoring was implemented in 2022 season. Considering the shrinkage of vaquita acoustic activity area, now restricted to the ZTA, for this year the previous sampling scheme in 46 sites in the Vaquita Refuge was abandoned, and sampling was focused to the ZTA only, using the previously described 55 sites sampling grid (Jaramillo Legorreta *et al*., 2022; Figure 1). Also, in trying to avoid further loses of equipment, sampling was implemented during neap tide periods as essayed in 2021. In this document we report the results of acoustic monitoring implemented along eight neap tide periods that occurred between April and December 2022.

SAMPLING EFFORT AND DATA

Field methods used to deploy and retrieve moorings were the same described in previous documents presented to SC since 2011. Moorings composed out of a 60 meters long rope, with anchors in one extreme and a rigid buoy in the other were used. Acoustic detectors were fixed in the rope, with auxiliary weight, to hold them at approximately 10 meters below the surface.

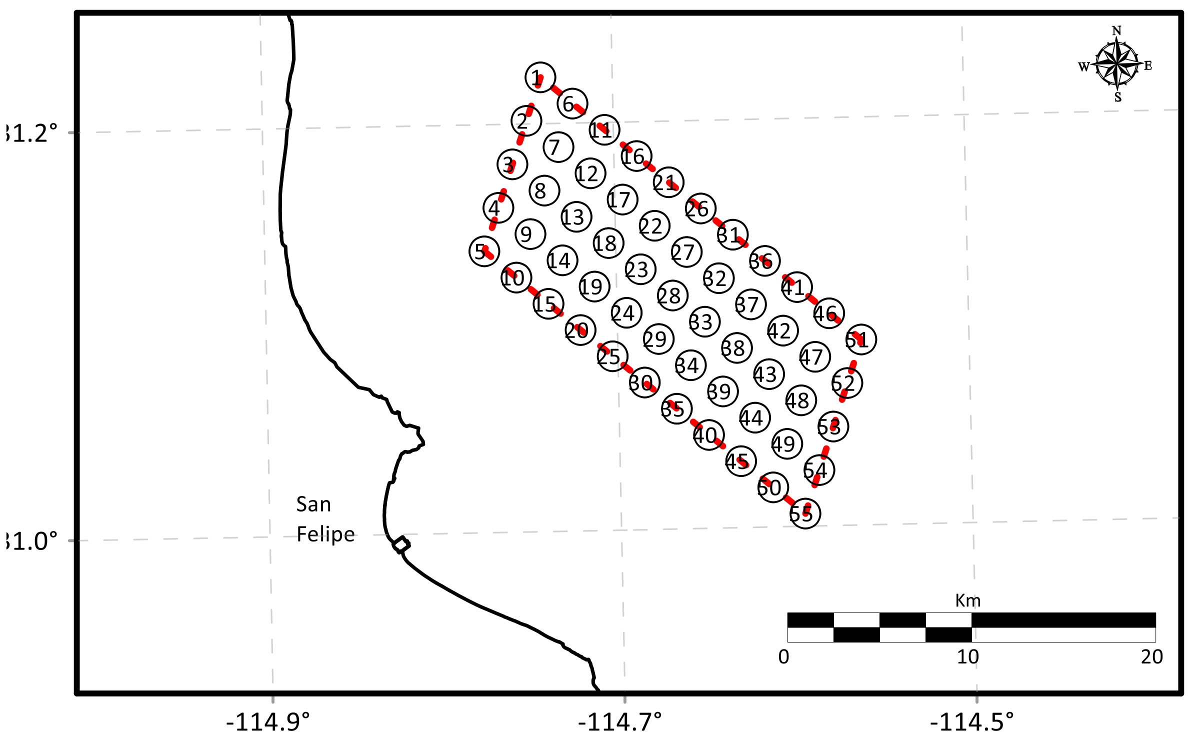

Figure 1. Zero Tolerance Area (red broken polygon) for vaquita protection in the Upper Gulf of California, Mexico. The numbered circles are the sampling sites of the grid used for acoustic monitoring.

During every sampling period, given weather conditions allowed, acoustic detectors were deployed few hours before the start of the neap tide period, and retrieved some hours before the end. Neap tide periods are defined as days when, in average, the difference between consecutive high tide and low tide peaks is equal or lower than 2 meters. It has been observed that, under this metric, most of the fishing fleet avoids performing fishing activities. Tide charts, provided by CICESE, were used to define neap tide periods on every sampling period (http://predmar.cicese.mx/). We used tide charts for San Felipe, the harbor closest to the study area, the ZTA.

Sampling periods

As a prospective effort, sampling was done early in 2022 between April 7 and 10. Only three acoustic detectors were deployed at sites 8, 12 and 28. All detectors were retrieved (Figure 2, Table I). A second prospective effort was done in July, before the start of the regular effort for the year. It occurred between July 5 and 8 again in three sites, 1, 18 and 44. One of the moorings got lost (Figure 2, Table I).

The reminder of the six sampling periods occurred in the second neap tide period of July, using 16 detectors, second neap tide period of September using 30 detectors and both neap tide periods of October using 35 and 30 detectors respectively (Figure 2, Table I). During November and December occurred just one neap tide period strong enough to sample, hence just one sample occurred on every month, using 28 and 29 detectors respectively (Figure 2, Table I).

Moorings got lost on every sampling period, except the first prospective in April, for a total of 23 moorings and detectors lost out of 174 deployed. It accounts for 13.2% of moorings lost, which is a good figure as compared to 21.8% and 40.7% of loses in Vaquita Refuge during 2019 and 2021 seasons respectively, and 44.4% in ZTA during spring tides in 2021. The figure is comparable with 15.3% in ZTA during experimental neap tide conditions in 2019 and the 23.5% in the same area during neap tide trials in 2021. Loses during neap tide periods are associated to fishing activity by the artisanal fleet of clam fishery, that use diving to forest for clams, hence needing lower intensity tidal currents for safety.

Data

Overall, in 2022, sampling was done in 42 sites for a total of 13,964 hours, averaging 332 hours per sampled site (minimum 96 and maximum 686 hours; Figure 3, Table II). Vaquita acoustic activity was found in 17 out of the 42 sampled sites, for a total of 77 acoustic encounters (periods of time when click trains are separated by a maximum of half an hour), for an average of 4.5 encounters per site with acoustic activity (minimum 1 and maximum 13; Table II, Figure 3).

Acoustic encounter rate was in average 0.092 encounters/day, with a minimum rate of 0.062 and maximum of 0.526 encounters per day in sites with acoustic activity (Table II, Figure 3). These results translate into average expectations to encounter acoustic activity of vaquita, in any given site, every 160 hours (minimum 46 and maximum 388 hours; Table II).

VAQUITA ACOUSTIC ACTIVITY IN THE ZTA

From the inspection of Figure 3 it becomes clear that vaquita acoustic activity is more intense in the western portion of the ZTA. In fact, the acoustic presence of vaquitas in the eastern portion appears to be very rare. The first three formal sampling periods, in July, September and October (Figure 2), tend to be homogeneous around the ZTA, and vaquitas were detected in higher numbers in the western portion. As such and given the restricted number of moorings available by then, it was decided to intensify the sampling effort in the western portion of ZTA in the reminder three sampling periods, leaving just few sampling sites towards the eastern portion (Figure 2).

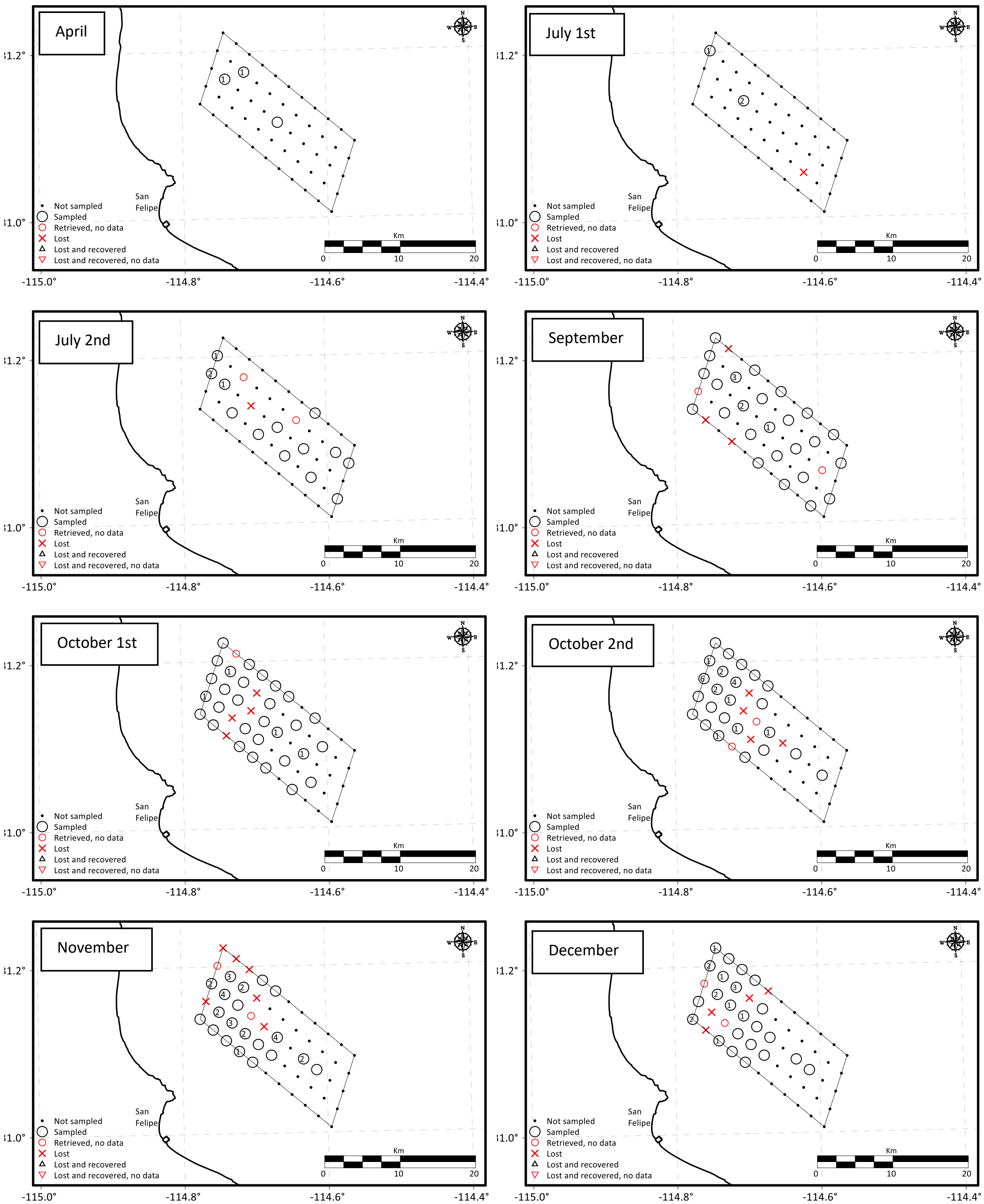

Figure 2. Maps of acoustic sampling schemes on every sampling period between April and December.

The acoustic activity distribution is not, necessarily, representative of the distribution of individuals. Hence, the lower acoustic activity in the eastern portion of the ZTA does not indicate the absence of vaquitas there. It is recommended to keep taking care of the entire ZTA. Aside, visual surveys are required to observe the distribution of vaquitas in the ZTA. Some visual surveys have been done, the last ones in 2019 and 2021 (Rojas Bracho *et al*., 2022). Government of Mexico, in collaboration with Sea Shepherd Conservation Society and US National Oceanic and Atmospheric Administration, are organizing other visual survey for May 2022.

Table I. Sampling effort, acoustic detections, and detection rate per sampling period.

Period	Sampled Sites	Effort Hours	Acoustic Encounters	Detection rate (enc/h)
April	3	176.9	2	0.0113
July 1st	2	139.8	3	0.0215
July 2nd	13	1251.2	4	0.0032
September	25	2527.2	6	0.0024
October 1st	30	2157.6	4	0.0019
October 2nd	24	2626.9	19	0.0072
November	20	2326.4	25	0.0107
December	23	2758.4	14	0.0051

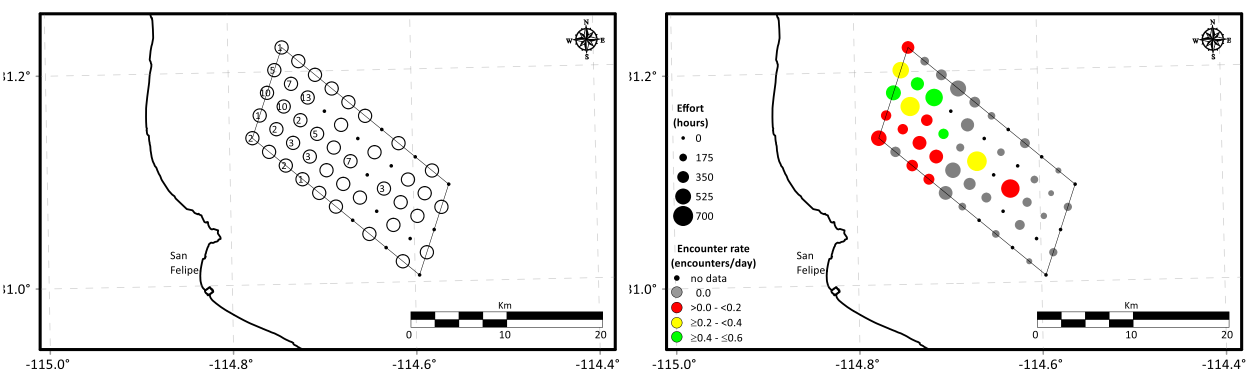

Figure 3. Overall results of the vaquita acoustic monitoring program in 2022. Left map shows the sampling sites included in the dataset (circles), indicating the number of acoustic encounters gathered in every site. Right map shows acoustic encounter rates per site, calculated as encounters per day (see the legend to the left).

Table II. Overall sampling effort, acoustic detections, and detection rate per sampling site.

Site	# of periods with sample	Effort hours	Acoustic encounters	Detection rate (encounters / hour)
1	4	387.65	1	0.0026
2	6	553.62	5	0.0090
3	5	485.00	10	0.0206
4	3	288.68	1	0.0035
5	5	509.83	2	0.0039
6	2	217.08	0	0.0000
7	4	409.00	7	0.0171
8	7	667.07	10	0.0150
9	3	290.08	2	0.0069
10	3	290.83	0	0.0000
11	3	309.58	0	0.0000
12	6	592.60	13	0.0219
13	4	339.85	2	0.0059
14	4	438.80	3	0.0068
15	3	338.35	2	0.0059
16	5	531.57	0	0.0000
17	0	0.00	0	
18	3	289.45	5	0.0173
19	4	434.67	3	0.0069
20	3	315.27	1	0.0032
21	3	310.33	0	0.0000
22	4	410.78	0	0.0000
23	2	192.23	0	0.0000
24	5	507.93	0	0.0000
25	4	434.02	0	0.0000
26	2	171.10	0	0.0000
27	0	0.00	0	
28	7	685.73	7	0.0102
29	3	361.98	0	0.0000
30	2	175.07	0	0.0000
31	0	0.00	0	
32	2	171.42	0	0.0000
33	0	0.00	0	
34	3	270.13	0	0.0000
35	0	0.00	0	
36	3	270.40	0	0.0000
37	0	0.00	0	
38	6	634.02	3	0.0047
39	0	0.00	0	
40	2	174.92	0	0.0000
41	0	0.00	0	
42	2	173.80	0	0.0000
43	2	241.58	0	0.0000
44	3	271.13	0	0.0000
45	0	0.00	0	
46	1	101.78	0	0.0000
47	1	96.43	0	0.0000
48	1	122.30	0	0.0000
49	0	0.00	0	
50	1	102.12	0	0.0000
51	0	0.00	0	
52	2	198.15	0	0.0000
53	0	0.00	0	
54	2	198.07	0	0.0000
55	0	0.00	0	
		42 sites sampled	17 sites with encounters	0.0038 average detection rate
		13,964.42 hours of effort	77 total encounters	

VAQUITA POPULATION TREND 2021 - 2022

In 2021 acoustic sampling in the ZTA occurred between October 10 and November 29 (Jaramillo Legorreta *et al.*, 2022). A first sampling period occurred between October 11 to 24. A second period occurred between October 25 and November 2. A final period occurred during a neap tide period, as applied in 2022, between November 23 to 28. Overall, 5,151 hours of effort were applied in 23 sampling sites and 49 acoustic encounters with vaquitas were identified.

To estimate the change of acoustic detection rate from 2021 to 2022 (as a proxy to population trend; Jaramillo Legorreta *et al*., 2016), it was applied a simple approach to compare datasets composed of sampling sites occurring in both years in the same period. For the period between October and November (which occurred in 2021), a set of 21 sampling sites coincided in both years (Figure 4, Table III).

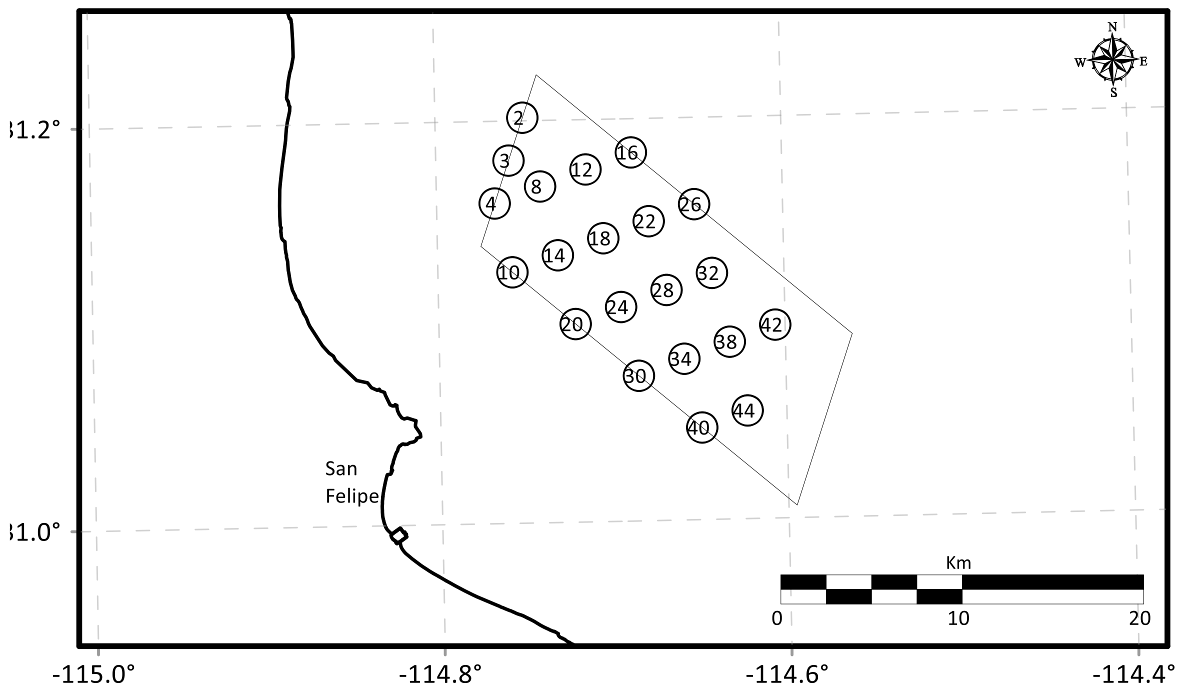

Figure 4. Sampling sites used to estimate acoustic detection rate between 2021 and 2022.

This dataset appears to cover the ZTA in a quasi-homogeneous coverage, with a small portion in the east border uncovered (Figure 4). This portion, in fact, seems to be acoustically used very unfrequently by vaquitas (Figure 3; Figure 6 in Jaramillo Legorreta *et al*., 2022), hence no biases are expected resulting from the analysis of the 21 sampling sites dataset. On the other hand, in the analysis period an additional 19 sites were sampled in 2022, almost the same quantity as the sampled on both years. Despite of this, the effort applied was 53.4% of that in the included sites, gathering only 19.1% of the total acoustic encounters, for an encounter rate that was 44.2% of the rate calculated for the 21 sampling sites in the analysis dataset. As such, it is considered that the information loss in the dataset is not a matter of extreme concern. Other modelling approaches could be considered, as the spatial model used to analyze the population trend between 2011 and 2018 (Jaramillo Legorreta *et al*., 2019).

The dataset in Table III shows how the sampling effort is different among sampling sites in both years, as well as detection rates. Given the heterogeneity of sampling effort, the estimate aproach was to obtain average detection rates, per year, from the averages per site, instead of pooling all the data on every year. It was supposed that every site is independent among sites and between years.

A Bayesian approach was used to model average acoustic detection rates, independently, on every site and year. The acoustic metric was the encounter, wich is a group of click series, separated between consecutive ones by less than half an hour. The time unit is one hour. In 2021 there were identified 44 vaquitas encounters, and 77 in 2022 (including all sampling dates). On every year just one encounter had a duration over one hour (2.3 and 1.3% respectively for 2021 and 2022). Hence, it could be assumed that acoustic detection process on every hour is binomial. The problem turns to estimate the parameter *q* for the case of one trial, so the *q* parameter is equal to detection rate per hour.

AD Model Builder (Fournier *et al*., 2012) was used to implement an MCMC routine to estimate parameter *q* for every site on every year. The implementation consisted out of 500,000 MCMC simulations, which were used to construct the posterior distributions. Prior distribution was a uniform between $1x10^{-7}$ and 0.999999. Later, on every year, average detection rate was calculated as the mean of the 21 sites with every one of the 500,000 simulations. Finally, rate of change, the parameter of interest, was calculated as the ratio of 2022 average rate to 2021 average rate, also on every one of the simulations. Hence it was obtained a posterior distribution composed out of 500,000 simulations for rate of change (Figure 5).

Table III. Dataset to estimate acoustic detection rate trend bewteen 2021 and 2022.

	2021			2022		
Site	**Effort (hours)**	**Acoustic encounters**	**Detection Rate**	**Effort (hours)**	**Acoustic enconters**	**Detection Rate**
2	321	14	0.0436	167	1	0.0060
3	120	1	0.0083	335	10	0.0299
4	183	0	0.0000	167	1	0.0060
8	187	8	0.0428	337	7	0.0208
10	180	0	0.0000	337	0	0.0000
12	523	7	0.0134	311	6	0.0193
14	420	4	0.0095	239	4	0.0167
16	223	0	0.0000	311	0	0.0000
18	350	6	0.0171	24	0	0.0000
20	63	0	0.0000	194	1	0.0052
22	166	0	0.0000	512	0	0.0000
24	278	0	0.0000	216	0	0.0000
26	227	0	0.0000	70	0	0.0000
28	366	7	0.0191	310	6	0.0194
30	386	0	0.0000	76	0	0.0000
32	229	0	0.0000	75	0	0.0000
34	184	0	0.0000	72	0	0.0000
38	67	1	0.0149	314	3	0.0096
40	210	0	0.0000	73	0	0.0000
42	184	0	0.0000	76	0	0.0000
44	100	0	0.0000	76	0	0.0000
Total effort and encounters, and average detection rate						
	4,967	48	0.0097	4,292	39	0.0091

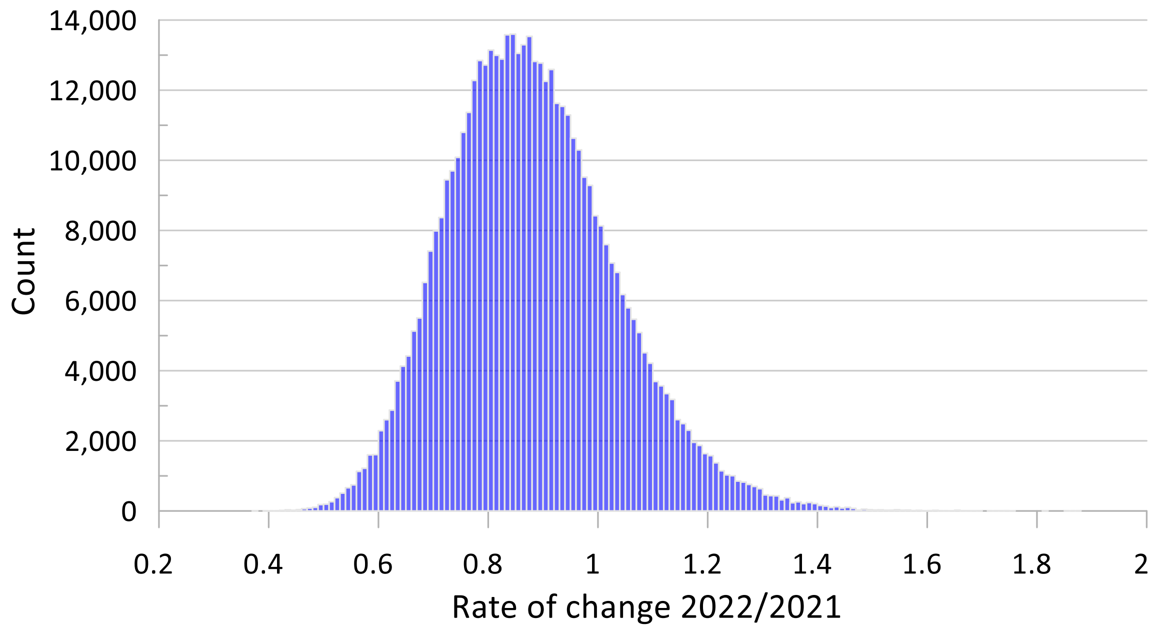

Figure 5. Posterior distribution of rate of change of acoustic detection rate between 2021 and 2022.

The estimate is that acoustic detection rate declined 11.99% between 2021 and 2022 (median 13.12%). With a CV of 0.173 the 95% credible interval is -38.45% to 21.13%. The expectation that the population in fact declined is 79.64%.

Between 2011 and 2018 it was estimated that population declined at an average annual rate of 45% (95% C.I. -53% to -38%) with expectation of declining practically 100% (Jaramillo Legorreta *et al*., 2019). It most be noted that, between 2011 and 2018 the dataset was composed out of the 46 sampling sites grid in the Vaquita Refuge. The estimate presented in this work is for the ZTA, that is a smaller area than the Refuge, but is where vaquitas are inhabiting in the last years.

If the estimate of rate of change in the ZTA is considered as a proxy to whole population trend, as it was for the study in the Vaquita Refuge, then the rate of decline got reduced from 45% to 12%, using point estimates. With data from a couple of visual surveys in 2019 and 2021, using expert elicitation techniques, it was estimated that the minimum population levels were 11 in 2019 and 7 or 8 in 2021 (Rojas Bracho *et al*., 2022). The authors implemented a stochastic projected population trend from 2018 to 2021, supposing population was declining at the rate estimated with acoustic data between 2017 and 2018 (47%; 95% C.I. -80% to +13%; Jaramillo Legorreta *et al*., 2019). The projected population levels were, in general, lower than the estimates of minimum population size. The mean probability that the projected populations were greater than the minimum size was 0.06 in 2019 and 0.07 in 2021.

Hence, there is evidence that population decline rate was, in fact, reduced since 2018. The decline rate estimated in this work seems to agree with this evidence. Is not possible to conclude on the reasons for this but could be associated to the distribution of vaquitas mainly in the ZTA and the protection measures implemented in the area. Or maybe, as proposed by Rojas Bracho *et al*. (2022), survivor vaquitas are better in avoid mortality in fishing nets.

In September 2022 Mexican Navy, in cooperation with the Ministry of Environment, deployed a mesh of 193 concrete blocks with hooks to deter the use of gillnets all over the ZTA. The separation between blocks is about 1 Km. The acoustic detection rates appear to increase in sampling periods after the setting of the blocks, as compared with previous ones, not taking into account the two prospective periods in April and July (Table I). Of course, it does not indicate a change in population levels, but maybe a change in acoustic behavior in response to, maybe, the presence of less fishing boats inside ZTA. As the estimate of rate of change of acoustic detection used data from October and November, detection rates in 2022 could have increased in response to the blocks, which did not occur in 2021. Hence, the estimate of decline (-12%) could have been lower (more negative) in the absence of the deterring blocks. It is a matter of consideration in further modelling.

VAQUITA GROUP STRUCTURE

The 2022 acoustic encounters dataset was used to find events when, probably, more than a group of vaquitas were detected in the ZTA around the same time. For this, the dataset was sorted by date and time, on every sampling period, irrespective of sampling site. With the sorted dataset of 77 encounters it was calculated the distance between sites of encounters and time between events. It was done for consecutive encounters belonging to the same sampling period and that occurred at different sampling sites. A total of 60 of these events occurred. With distance and times between encounters it was calculated the speed of swimming needed, for the group of individuals, to move between sites.

Kastelein *et al*. (2018) measured swimming speeds of harbor porpoises (*Phocoena phocoena*), under controlled conditions in a pool. Under noise-less conditions porpoises swam at an average speed of 4.3 Km/h. Under noisy conditions porpoises were able to keep average speed of 7 Km/h by periods about 30 minutes. Hence, it seems could hold this speed by extended lapses. With measures in the wild Otani *et al*. (2000) report average speeds of 3.24 Km/h and, 90% of the measures, were lower than 5.4 Km/h. Maximum speed found was 15.48 Km/h, although authors mention other reports with up to 22.32 Km/h. However, it seems harbor porpoises spent most of the time swimming at lower speeds.

Supposing vaquitas swim with patterns like harbor porpoises reported above, the movement events in the dataset were considered to be produced by different groups of individuals with certainty when the speed calculated was over 25 Km/h. For speeds over 17 Km/h it was considered that the event was produced by different groups with high probability. Finally, events above 7 Km/h, were considered probable events of different groups.

Five certain events were found in the dataset, two of high probability and other two probable. The reminder 51 events, with speeds under 5 Km/h, were considered probable movements of same group between sites. Sixteen events were consecutive encounters in the same site, which could be an indication of groups spending time around a spot for extended periods of time, but could be the result of different groups visiting the same area with short times of difference.

It seems that, although the abundance of vaquita is at very low levels, individuals are still forming separated groups, instead of a single group unit. However, it could be a dynamic structure, forming separated units in times and a bigger group at other times.

ACOUSTIC MONITORING PROGRAM 2023

The monitoring program has funds already secured for 2023. The sampling protocols will be the same as applied in 2022, deploying moorings only during neap tide periods between July and November. The protocol specifies sampling in at least 30 sites on every tide period, but it will be tried to deploy as much as possible of the 55 sites sampling grid.

The deterring capacity of the blocks deployed in the ZTA will be reviewed, to analyze the possibility to resume sampling during spring tide periods. If fishing effort become effectively deterred, in fact, long lasting deploying could be implemented, which could result in gathering a higher volume of data. Some strategies would need to be used in order to avoid loosing equipment, like to prevent deploying moorings on sampling sites in or near the borders of the ZTA. The position of these sites could be moved inwards to prevent, as much as possible, interaction with fishing activities in the ZTA border areas.

VAQUITA SURVEY 2023

As it happened back in 2019 and 2021, a survey to observe vaquitas is planned for May 2023. Funds are secured and planning, and implementation duties, have been done since late 2022. The aim is to obtain data to apply expert elicitation techniques to estimate minimum vaquita population level, as done with data collected in 2019 and 2021 (Rojas Bracho *et al*., 2022).

As in previous surveys, an acoustic monitoring component will be implemented to assist the visual team to address areas with potential presence of vaquitas. The acoustic monitoring is planned to bring information of vaquita distribution in a near real time way, gathering and analyzing data on a daily basis, as allowed by weather conditions. The same 55 sites sampling grid will be used, deploying as much as possible moorings over the sampling grid.

LITERATURE CITED

Barlow,J., Gerrodette,T., and Silber,G. 1997. First Estimates of Vaquita Abundance. *Marine Mammal Science* 13:44-58. https://doi.org/10.1111/j.1748-7692.1997.tb00611.x

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optim. Methods Softw*. 27:233-249.

Gerrodette T., B.L. Taylor, R. Swift, S. Rankin, A.M. Jaramillo-Legorreta, L. Rojas-Bracho. (2011). A combined visual and acoustic estimate of 2008 abundance, and change in abundance since 1997, for the vaquita, *Phocoena sinus*. *Mar. Mamm. Sci*., 27:79-100. https://doi.org/10.1111/j.1748-7692.2010.00438.x

Jaramillo-Legorreta, A. M. 2008. Estatus actual de una especie en peligro de extinción, la vaquita (*Phocoena sinus*): Una aproximación poblacional con métodos acústicos y bayesianos. Ph.D. thesis, Universidad Autónoma de Baja California. 108 pp.

Jaramillo-Legorreta, A., G. Cárdenas-Hinojosa, E. Nieto-García, 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*. https://doi.org/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 and N. Tregenza. 2019. Decline towards extinction of Mexico's vaquita porpoise (Phocoena sinus). *Royal Society Open Science* 6:190598. http://dx.doi.org/10.1098/rsos.190598

Jaramillo Legorreta, A.M., E. Nieto-García, G. Cárdenas-Hinojosa, D. Arellano, L. Rojas-Bracho, H. de la Cueva. 2022. VAQUITA POPULATION ACOUSTIC MONITORING SEASON 2021. Report presented to the Scientific Committee of the International Whaling Commission Meeting 68D (SC/68D/SM/10).

Kastelein, R.A., S. Van de Voorde and N. Jennings. 2018. Swimming Speed of a Harbor Porpoise (*Phocoena phocoena*) During Playbacks of Offshore Pile Driving Sounds. *Aquatic Mammals* 44(1):92-99. DOI 10.1578/AM.44.1.2018.92

Otani, S., Y. Naito, A. Kato and A. Kawamura. 2000. Diving behavior and swimming speed of a free-ranging harbor porpoise, *Phocoena phocoena*. *Marine Mammal Science* 16(4):811-814.

Rojas-Bracho, L., Taylor, B.L. and Jaramillo-Legorreta, A. 2021. *Phocoena sinus*. The IUCN Red List of Threatened Species 2022: e.T17028A214541137. https://dx.doi.org/10.2305/IUCN.UK.2022-1.RLTS.T17028A214541137.en.

Rojas-Bracho, L. A. Jaramillo-Legorreta, E. Nieto García, G. Cárdenas Hinojosa, E. Hidalgo, E. Vázquez, C. Hoefer and B. Taylor. 2021. VAQUITA UPDATE DURING THE PANDEMIC. Report presented to the Scientific Committee of the International Whaling Commission Meeting 68C (SC/68C/SM/20).

Rojas-Bracho, L., B. Taylor, C. Booth, L. Thomas, A. Jaramillo-Legorreta, E. Nieto-García, G. Cárdenas Hinojosa, J. Barlow, S.L. Mesnick, T. Gerrodette, P. Olson, A. Henry, H. Rizo, E. Hidalgo-Pla, A. Bonilla-Garzón. 2022. More vaquita porpoises survive than expected. *Endangered Species Research* 48:225-234. https://doi.org/10.3354/esr01197

Taylor, B. L., Rojas-Bracho, L., Moore, J., Jaramillo-Legorreta, A., Ver Hoef, J., Cardenas-Hinojosa, G., Nieto-Garcia, E., Barlow, J., Gerrodette, T., Tregenza, N., Thomas, L. and Hammond, P.S. 2016. Extinction is imminent for Mexico's endemic porpoise unless fishery bycatch is eliminated. *Conservation Letters* 10(5), 588–595. https://doi.org/10.1111/conl.12331