# Final report

## Acoustic research to evaluate the current distribution of vaquita

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## 1. Introduction

The vaquita porpoise (*Phocoena sinus*) is endemic to the Upper Gulf of California (AGC) and is the most endangered marine mammal in the world (Rojas-Bracho et al., 2006; Jaramillo-Legorreta et al., 2019). Between 1997 and 2016 vaquitas declined by 92% from 567 individuals (Jaramillo-Legorreta et al. 1999) to 59 individuals (Taylor et al. 2016). Since 2005, the Mexican government has implemented different conservation actions to avoid the extinction of the species (DOF, 2005, 2017, 2020). Acoustic monitoring to estimate the population trends has been and continues to be used to evaluate the success of conservation strategies (SEMARNAT, 2008).

The acoustic monitoring program for vaquita funded by CONANP started in 2011 and included sampling through 2018. Data was gathered from June to September in a grid of 46 sampling sites within the Vaquita Protection Refuge Area (DOF, 2005; Figure 1). Analyses estimated that vaquitas decreased at an average rate of 45% annually (Jaramillo-Legorreta et al., 2019). Acoustic monitoring continues annually through 2024, in a smaller area that was primarily in a sampling grid within the Zero Tolerance Area (ZTA) (DOF, 2020; Figure 1). In 2021 the Mexican Navy deployed concrete blocks with hooks to discourage gillnetting within the ZTA. The area with blocks was increased in 2023 to include the adjacent area called the Extension Area (EA). In the ZTA, it was documented that the average rate of change in acoustic detection for the period from 2021 to 2023 was -14.4%. Therefore, if the acoustic detection rate within the ZTA is a proxy of the population trend, the vaquita continued to decline, but at a very reduced rate (from -45% to -14%) (Jaramillo-Legorreta et al., 2019).

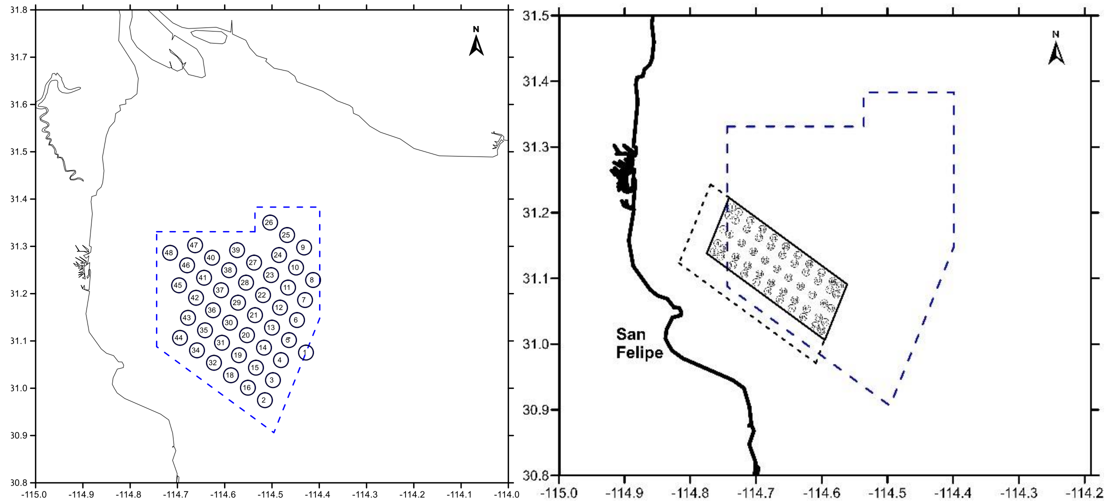


**Figure 1.** The map on the left shows the sampling grid for the acoustic monitoring of vaquita that was carried out between the 2011 to 2018 sampling seasons in the Vaquita Refuge. The map on the right shows the sampling grid for vaquita monitoring which started in 2021 in the ZTA, which is delimited by the polygon with a solid black line and its EA with a dashed black line. Both maps show the Vaquita Refuge polygon with a dashed blue line.

Combined visual and acoustic surveys have also been conducted within the ZTA (jointly supported by CONANP and the Sea Shepherd Conservation Society (SSCS). Using the method called expert elicitation, it was estimated that there was a 75% probability that the total number of different individuals observed in 2024 were between 6 and 8. Since the search focused within the ZTA and the extension area, 6-8 is considered a minimum estimate of the number of vaquitas left. The 2024 estimate is less than the estimated 8-13 seen in 2023 within a similar area. One individual seen on the last survey day in 2024 was seen in 2018 and 2019 but not in 2021, 2022 and 2023, which suggests that vaquitas may be re-occupying areas outside the ZTA. (Cárdenas-Hinojosa *et al.*, 2024). Habitat areas used by vaquitas as recently as 2015 have not been monitored since 2019. To interpret the results of the 2024 survey and provide a more reliable assessment of the conservation status of the vaquita, an acoustic research program in areas outside the ZTA was needed (Cárdenas-Hinojosa et al., 2024).

For this reason, CONANP in collaboration with the Sea Shepherd Conservation Society, and with the scientific advice of the Vaquita Acoustic Expert Panel, completed acoustic research outside the ZTA in the Vaquita Refuge with the goal to determine the current distribution of the vaquita to contribute to the conservation of the vaquita.

## 2. Goal

Passive acoustic research of vaquita outside the ZTA to determine their current distribution.

## 3. Methods

### 3.1. Sampling design

On July 2, 2024, members of the Vaquita Acoustics Expert Panel met to design acoustic research outside the ZTA to determine whether vaquitas were present and to begin to delimit areas of higher vaquita use. Deployment of thirty-five acoustic detectors (F-POD) were to be deployed during two months of the low fishing season in the Upper Gulf of California. To provide the best current information to researchers a summary of vaquita distribution based on both visual and acoustic data obtained in the period from 1993 to 2018 was reviewed.

The panel assumed there were 35 acoustic sensors available and that they will be redeployed at least once. In selecting locations, we used the following guidance: sampling locations should be outside the ZTA but within the Vaquita Refuge area; sampling locations should be very close to places where vaquita have previously been seen (during sightings surveys that took place in 1993, 1997, 2008 and 2015) or heard (during acoustic surveys that took place in 2011-2018); initial sampling locations for each deployment should be distributed as evenly as possible over the area of interest; locations should be chosen objectively using some element of randomization. We decided to place sample locations at randomly selected sites on a 200m grid covering the Vaquita Refuge area, with probability of selecting a grid cell being a function of previous visual and acoustic detections and using a spatially balanced design algorithm. 200m is the approximate distance of vaquitas can be acoustically detected with the passive acoustic detectors.

We used a balanced acceptance sampling (BAS) design (Foster et al. 2017; van DamBates et al. 2018) to select sampling sites. This type of random design allows specification of the target inclusion probability of each potential sample location while also spreading the sampling sites over the study area. Samples sites were generated to achieve the highest chance to detect vaquita. Given the number of F-PODs available (35) for this project, we generated 70 sampling locations and the first 35 were selected for deployment 1 and the second 35 for deployment 2 (Figure 2).

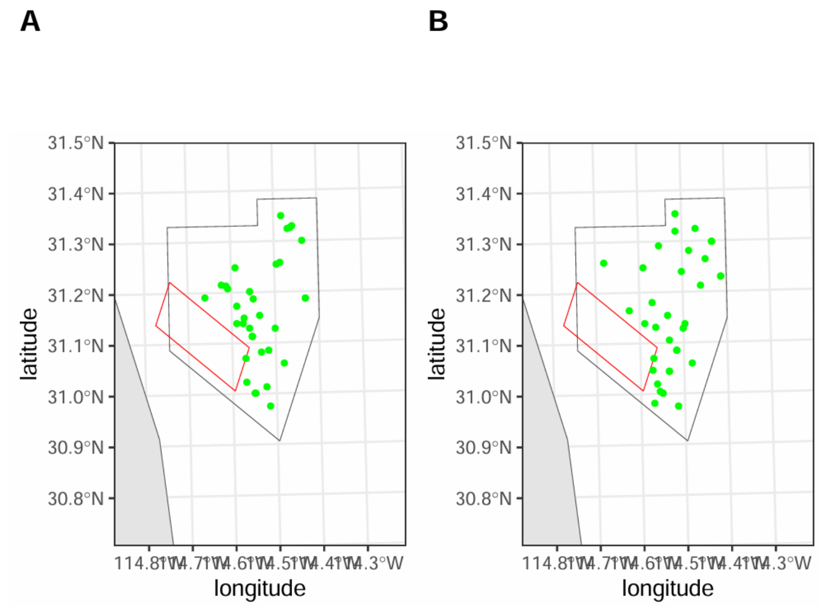


**Figure 2.** Sampling grid including 70 sites proposed to deploy the acoustic detectors (map A shows the first deployment and B the second deployment planned).

The Expert Panel also concluded that the sampling design should involve retrieving acoustic detectors every two weeks (over the two months) to immediately analyze the data and that the results would be used (based on previous acoustic and visual information) to determine the next sampling sites to deploy the F-PODs. More details about the sampling design are attached at Appendix 1.

### 3.2. Moorings, Resqunits devices (pop-ups) and acoustic detectors.

On August 19, 2024, the materials to build the anchors were transported from Ensenada to San Felipe and the fishermen assembled the anchors (Figure 3). The anchors were assembled with the following arrangement: 1) Danforth anchor; 2) shackle; 3) three meters of chain; 4) 35 meters of rope; 5) a handle on the rope to tie the F-POD; 6) Resqunit device (pop-up), and 7) a fishing float buoy. The length of the anchor was different due to the different depth of sampling sites. The objective of the mooring design was to avoid interaction with fishing activities and thus prevent the loss of equipment due to the previously easy detection of the surface buoys. In total, 35 moorings were assembled.

The fishers placed the moorings in the boats in an orderly manner to avoid entanglement during deployments. Each mooring had a label identifying the site where it should be deployed. The arrangement of the moorings in the boats followed the deployment plan previously assigned to each boat. There were three work groups of fishers, to which a similar number of moorings with acoustic detectors were assigned. Each work group had a logbook and a GPS with the geographic location of the sampling sites.

**Figure 3.** Fishers assembling the moorings.

A Resqunit device (https://www.resqunit.com/) was tied to each mooring. The device has an electronic releaser with a timer that allows scheduling the release time of the rigid yellow disk (Figure 4). The Resqunit App was downloaded to a cell phone to connect via NFC (near field communication) with the releaser to schedule the release time at the beginning of the neap tides. This period was selected because the buoy is small and during spring tide conditions the strong currents in the Upper Gulf can sink the disk, preventing work groups of fishermen from finding it. These devices (3) were tested in moorings successfully during the Vaquita Survey 2024.


**Figure 4.** Resqunit devices. The image shows the main components of the device, which are the electronic release timer, buoy disk, and container that holds the buoy.

We used autonomous acoustic detectors called F-PODs (http://www.chelonia.co.uk/) to record the echolocation clicks of vaquita. The preparation and setting up of the 35 acoustic detectors were done one day prior to the deployment of the moorings (Figure 5).

**Figure 5**. Acoustic detectors F-POD ready for the first deployment in the sampling sites.

### 3.3. Deployment and recovery of the moorings with F-PODs.

The first deployment occurred as soon as sea conditions allowed safe navigation and the detectors were recovered during neap tides so that the Resqunit buoy would not be sunk by the strong currents during spring tides. For recovery activities, when the buoy was not found on the surface due to failure of the Resqunit electronic release, the fishermen located the moorings by dragging a grampin-type anchor to hook the main rope of the mooring, to pull it and lift it onto the boat. Fishermen recorded these instances in their logbooks.

**Figure 6**. Moorings placed on pangas ready for deployment and Fisher deploying a mooring with acoustic detector.

**3.4. Data analysis for the identification of acoustic detections of vaquita.**

Once the acoustic detectors were recovered, the data stored in the microSD memory cards were downloaded and analyzed using the software from the F-POD company. The echolocation clicks of vaquita were determined if the pulses were within a frequency range of 130 to 140 kHz with interval between 5 and less than 40 cycles. Additionally, the series of clicks were associated with other series of clicks that are close in time, on a scale of seconds or a few minutes. These characteristics were visualized and inspected using the software from the F-POD company (Figure 7).


**Figure 7**. Valid detection of vaquita based on the review of acoustic parameters of the echolocation clicks.

## 4. Results

### 4.1. Deployment and retrieval of the moorings with F-PODs and Resqunit devices

The first deployment of thirty-five moorings occurred on August 23, 2024 (Table 1). On September 11, 2024, the project fishermen retrieved 28 moorings with acoustic detectors. In four moorings the buoy of Resqunit was not released to the surface, and in another the main rope of the mooring was cut below the Resqunit device and buoy float. The fishers located these five moorings with the grampin anchor. In another seven moorings, the buoy was not released and the fishers were unable to find them.

On the same day, September 11, data from the F-PODs were downloaded and analyzed to determine if there were any acoustic detections of vaquita, and to prepare them for a second deployment. The results were shared via email with some members of the Vaquita Expert Panel to decide where to deploy the acoustic detectors. The next day, the second deployment occurred, but due to lost moorings and acoustic detectors, only 30 moorings were deployed. The moorings were deployed at the sampling sites where vaquitas were detected in the first deployment and four moorings were deployed at a distance of 200 meters at north, east, west and south around these sampling sites. In addition, the rest of the sites were selected from the second set of deployment sites provided by the acoustic sampling design (36 to 70) in numerical order.

**Table 1.** Deployment and recovery of moorings with F-PODs and Resqunits devices.

| Date | Filed activity | Acoustic detectors retrieved | Acoustic detectors lost | Comments |
|---|---|---|---|---|
| 08/23/2024 | Deployment | | | 35 moorings |
| 09/11/2024 | Recovery | 28 | 7 | In 4 moorings the buoy of Resqunit was not released to the surface, and another was cut with knife, but the fishers located with the grampin anchor. |
| 09/12/2024 | Deployment | | | 30 moorings |
| 09/23-24/2024 | Recovery | 24 | 6 | In 10 moorings the buoy of Resqunit was not released to the surface, but the fishers located with the grampin anchor. |
| 09/27/2024 | Recovery | 3 | | The three team of fishers visited the 13 sites with moorings lost to try to locate them with grampin anchor. The buoy of Resqunit was |

| | | | | |
|---|---|---|---|---|
| | | | | not released to the surface on the 3 moorings retrieved. |
| 10/11-12/2024 | Recovery | 2 | | The M/V Sea Horse of Sea Shepherd located and retrieved 2 moorings with detectors. In one mooring, the Resqunit did not release the buoy, and in the other, the buoy was released but probably after the scheduled time. |
| **Total** | | **57** | **8** | A total of 57 F-PODs were retrieved and 8 F-PODs were lost. It was confirmed that the Resqunit devices failed 19 times. |

We retrieved 24 moorings with acoustic detectors on September 23 and 24. Again, some pop-up devices failed. From the moorings retrieved, ten Resqunits devices did not release the buoy to the sea surface and the project fishermen found them with the grampin-type anchor. In another six moorings, the buoy was not released and the fishers were unable to find them (Table 1). Because the shrimp fishing season began on October 2, 2024, it was decided not to continue the sampling of the monitoring program due to the high probability of losing the moorings due to theft or vandalism by fishers.

Efforts to retrieve the 13 lost moorings in the two deployments occurred on September 27 and the 11 and 12 of October 2024, and five moorings with acoustic detectors were found. In summary, eight moorings with acoustic detectors were lost out of a total of 65 moorings deployed for acoustic sampling (Table 1). Furthermore, although three Resqunits devices were successfully tested during the Vaquita Survey 2024, the rate of failure of the pop-up devices in the acoustic monitoring outside the ZTA was high. In total, it was confirmed that 19 devices did not release the buoy. Additionally, other issues were related to Resqunit devices as fragile parts were broken during the first deployment or because the line of the buoy was entangled at spool (Figure 4).

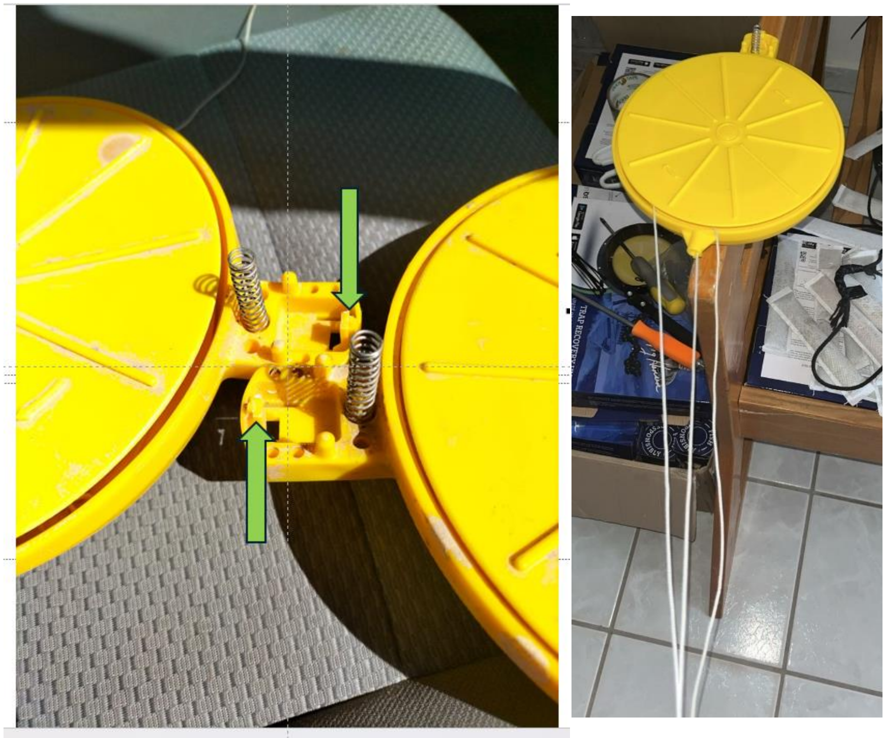

**Figure 4**. The Resqunits had some issues as a broken component that attaches the buoy to the mounting frame (left image) or the line entangled and outside the buoy (right image).

**4.2. Acoustic activity of vaquita outside the ZTA.**

Four acoustic sampling periods over two months of the low fishing season were planned, but only two sampling periods were completed from August 23 to September 11, and between September 12 and September 24, although at some sites the sampling effort was greater since some detectors were recovered on September 27 and others on October 11 and 12 (Table 1). Furthermore, at some sites the effort was greater since moorings were deployed in the same site in both sampling periods (Table 2). A total effort of 991.39 sampling days (23,793.43 hours of recording) were recorded at sixty sampling sites, for an average effort per site of 16.52 days (396.56 hours of recording). In total, 19 acoustic encounters of vaquitas were recorded and distributed in nine sampling sites for an overall average detection rate of 0.02 encounters/day (Tables 2).

**Table 2.** Effort per site, acoustic detections, and detection rate per sampling site outside the ZTA.

| Sampling sites | Longitude | Latitude | Effort (days) | Encounters | Rate (encounters/days) |
|---|---|---|---|---|---|
| 1 | -114.48239 | 31.34973 | 18.96 | 0 | 0.00 |
| 2 | -114.58864 | 31.13892 | 19.05 | 0 | 0.00 |

| Sampling sites | Longitude | Latitude | Effort (days) | Encounters | Rate (encounters/days) |
|---|---|---|---|---|---|
| 3 | -114.51664 | 31.08524 | 19.15 | 0 | 0.00 |
| 4 | -114.55366 | 31.11300 | 19.22 | 0 | 0.00 |
| 5 | -114.61194 | 31.21331 | 19.05 | 0 | 0.00 |
| 6 | -114.57160 | 31.14942 | 19.04 | 0 | 0.00 |
| 7 | -114.48170 | 31.05930 | 32.60 | 3 | **0.09** |
| 7-1 | -114.48163 | 31.06106 | 0.00 | | |
| 7-2 | -114.48177 | 31.05750 | 13.50 | 2 | **0.15** |
| 7-3 | -114.48402 | 31.05941 | 13.47 | 2 | **0.15** |
| 7-4 | -114.47949 | 31.05937 | 13.48 | 0 | 0.00 |
| 8 | -114.46202 | 31.32588 | 32.42 | 2 | **0.06** |
| 8-1 | -114.46203 | 31.32769 | 13.44 | 0 | 0.00 |
| 8-2 | -114.45991 | 31.32586 | 13.44 | 0 | 0.00 |
| 8-3 | -114.46207 | 31.32414 | 13.44 | 0 | 0.00 |
| 8-4 | -114.46416 | 31.32587 | 13.43 | 0 | 0.00 |
| 9 | -114.56943 | 31.07001 | 35.18 | 0 | 0.00 |
| 10 | -114.43008 | 31.18635 | 19.09 | 0 | 0.00 |
| 11 | -114.43540 | 31.30009 | 19.03 | 0 | 0.00 |
| 12 | -114.55953 | 31.12935 | 19.01 | 0 | 0.00 |
| 13 | -114.53350 | 31.08195 | 19.14 | 0 | 0.00 |
| 14 | -114.59005 | 31.24898 | 19.05 | 0 | 0.00 |
| 15 | -114.66077 | 31.19075 | 19.05 | 0 | 0.00 |
| 16 | -114.55024 | 31.00110 | 32.41 | 4 | **0.12** |
| 16-1 | -114.55023 | 31.00290 | 0.00 | | |
| 16-2 | -114.54815 | 31.00111 | 13.43 | 0 | 0.00 |
| 16-3 | -114.55019 | 30.99929 | 28.73 | 0 | 0.00 |
| 16-4 | -114.55231 | 31.00110 | 13.39 | 0 | 0.00 |
| 17 | -114.54966 | 31.18688 | 19.13 | 0 | 0.00 |
| 18 | -114.49543 | 31.25438 | 19.06 | 0 | 0.00 |
| 19 | -114.46836 | 31.32420 | 19.01 | 0 | 0.00 |
| 20 | -114.56853 | 31.02309 | 19.07 | 0 | 0.00 |
| 21 | -114.45772 | 31.32940 | 0.00 | | |
| 22 | -114.58778 | 31.17317 | 19.05 | 0 | 0.00 |

| Sampling sites | Longitude | Latitude | Effort (days) | Encounters | Rate (encounters/days) |
|---|---|---|---|---|---|
| 23 | -114.55366 | 31.11300 | 15.21 | 0 | 0.00 |
| 24 | -114.50085 | 31.12822 | 19.19 | 0 | 0.00 |
| 26 | -114.53582 | 31.15415 | 0.00 | | |
| 27 | -114.55768 | 31.20147 | 19.13 | 0 | 0.00 |
| 28 | -114.54815 | 31.00106 | 0.00 | | |
| 29 | -114.48694 | 31.25782 | 19.05 | 3 | **0.16** |
| 29-1 | -114.48698 | 31.25962 | 13.44 | 0 | 0.00 |
| 29-2 | -114.48485 | 31.25787 | 13.44 | 0 | 0.00 |
| 29-3 | -114.48697 | 31.25599 | 13.44 | 0 | 0.00 |
| 29-4 | -114.48922 | 31.25784 | 13.44 | 0 | 0.00 |
| 30 | -114.52270 | 31.01320 | 0.00 | | |
| 32 | -114.51531 | 30.97518 | 34.99 | 0 | 0.00 |
| 33 | -114.57397 | 31.13864 | 19.03 | 0 | 0.00 |
| 34 | -114.62239 | 31.21531 | 31.36 | 1 | **0.03** |
| 34-1 | -114.62241 | 31.21713 | 12.31 | 0 | 0.00 |
| 34-2 | -114.62025 | 31.21534 | 12.31 | 0 | 0.00 |
| 34-3 | -114.62203 | 31.21354 | 12.31 | 0 | 0.00 |
| 34-4 | -114.62454 | 31.21531 | 12.31 | 0 | 0.00 |
| 35 | -114.60788 | 31.20782 | 19.05 | 0 | 0.00 |
| 36 | -114.53582 | 31.15415 | 29.75 | 1 | **0.03** |
| 37 | -114.56368 | 31.13123 | 19.03 | 0 | 0.00 |
| 38 | -114.51381 | 31.35395 | 0.00 | | |
| 39 | -114.49642 | 31.13715 | 19.19 | 0 | 0.00 |
| 40 | -114.56943 | 31.07001 | 12.30 | 0 | 0.00 |
| 44 | -114.53289 | 31.10539 | 12.30 | 1 | **0.08** |
| 47 | -114.58864 | 31.13892 | 12.32 | | |
| **Total:** | | | **991.39** | **19** | **0.02** |

### 4.3. Distribution of the acoustic activity of vaquita outside the ZTA.

The sampling sites where acoustic encounters of vaquitas were recorded are located mainly towards the southeast area outside the ZTA and a couple of sites located at northeast area of the Vaquita Refuge (Figure 9). The distribution and number of acoustic encounters of vaquita in the two samplings was similar, 10 in the first and 9 in the second sampling (Figure 9).

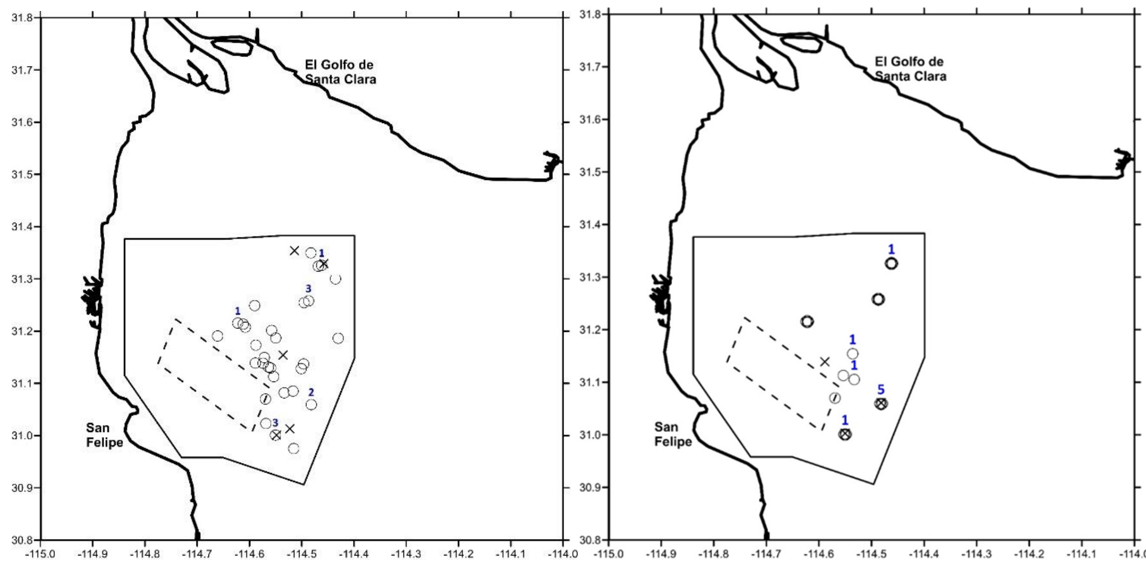


**Figure 9.** Results of the two acoustic sampling periods that occurred between August 23 and September 24, 2024. The symbols on the map show the sixty sites where a mooring with an acoustic detector was deployed. The circles show the sites where the acoustic detector was retrieved, and the "X" symbol where the moorings were lost. The figure on the left shows the sites of the first sampling and the figure on the right the second sampling. In the second sampling, the sites "overlap" on the map due to the proximity of the sites. A number above the symbol indicates the number of vaquita acoustic encounters. The Zero Tolerance Area is delimited by the polygon with a broken line.

Figure 10 shows the acoustic detection rates of vaquita (encounters/total effort per site) obtained in the two sampling periods. The sampling sites with the highest detection rates were obtained at sampling sites 16, and the sampling sites (separated 200 meters) 7, 7-2 and 7-3 towards the southeast area outside the ZTA.

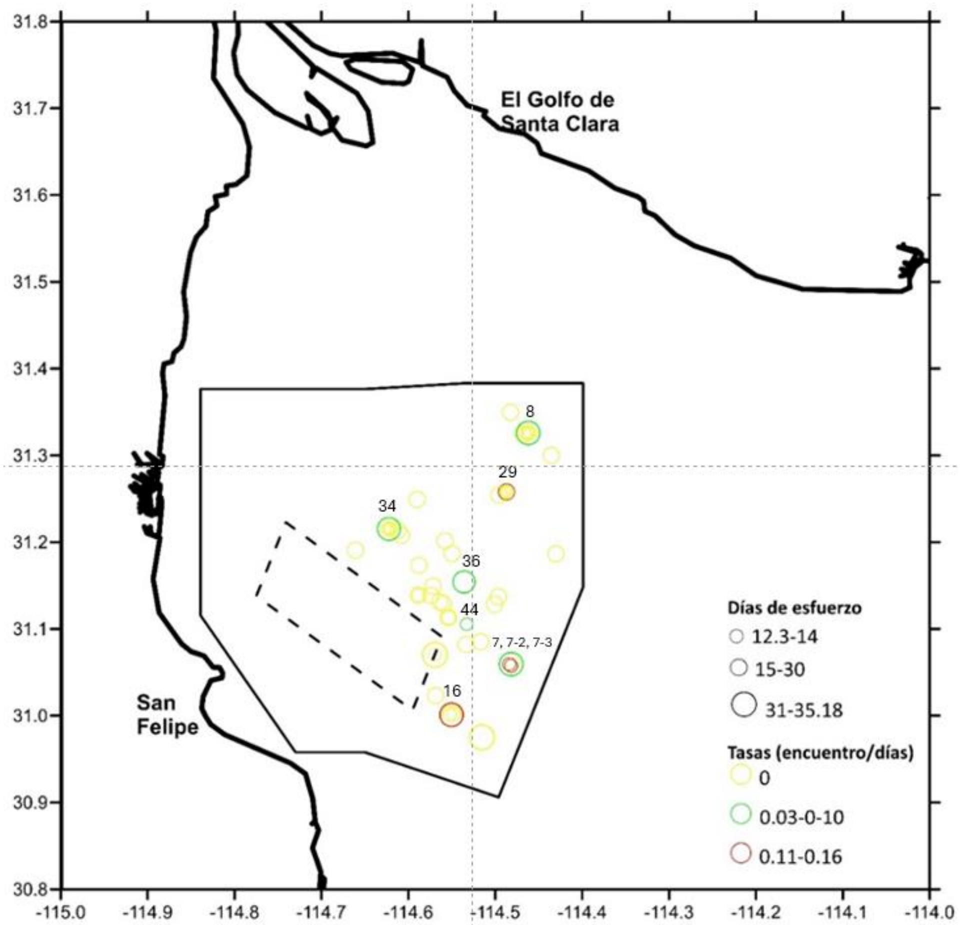


**Figure 10.** Summary of acoustic encounter rates of vaquita recorded outside the ZTA between August 23 and September 24, 2024. Circles indicate the sites with data. The size of the circle indicates the level of effort, in days, at each site. The acoustic encounter rate is indicated by color and shown in three ranges. Sites without acoustic activity of vaquitas are shown in yellow, the detection rates range from 0.03 to 0.10 are in green and from 0.11 to 0.16 in red color. Numbers above the circles indicate the number of sampling site. The Zero Tolerance Area is delimited by the polygon with a broken line.

### 4.4. Simultaneous effort of acoustic monitoring programs at and outside the ZTA and distribution of acoustic activity of vaquita.

We analyzed the data of acoustic detectors deployed at 32 sampling sites from the regular acoustic monitoring within the ZTA that overlapped in the period of monitoring outside of ZTA. The goal of this simple analysis was to show the acoustic encounters of vaquita to determine the distribution of the acoustic presence of vaquita during the study period. Given the sampling of the monitoring inside the ZTA only occurred during the short periods of the spring tides from June to September, the number of days of sampling that the monitoring efforts overlapped was 438.33 days (Table 3). The days of effort outside the ZTA were greater (991.39) because the sampling effort was continuous at the sites. Despite the moorings being deployed at 60 sampling sites, the average effort per site was also greater outside ZTA (Table 3).

**Table 3**. Simultaneous effort of acoustic monitoring and comparison of effort and acoustic encounters per monitoring.

| Study area | Periods | Sampling sites | Days of effort | Average of effort per site | Acoustic encounters | Rate (encounters/days) |
|---|---|---|---|---|---|---|
| ZTA | 1): 08/23-24; 2): 09/02-07; 3): 09/16-21 | 32 | 438.33 | 13.71 | 54 | 0.12 |
| Outside ZTA | 08/23 - 09/24 | 60 | 991.39 | 16.52 | 19 | 0.02 |

In total, 54 acoustic encounters of vaquitas were recorded at ZTA and distributed in thirteen sampling sites for an overall average detection rate of 0.12 encounters/day (Table 4). The detection rate was higher than the obtained outside the ZTA (0.02 encounters/days).

**Table 4**. Effort per site, acoustic detections, and detection rate per sampling site at the ZTA.

| Sampling sites | Effort (days) | Encounters | Rate (encounters/days) |
|---|---|---|---|
| **1** | 11.00 | 0 | 0.00 |
| **2** | 11.01 | 3 | 0.27 |
| **3** | 11.01 | 0 | 0.00 |
| **4** | 11.00 | 0 | 0.00 |
| **5** | 11.01 | 0 | 0.00 |
| **6** | 10.00 | 0 | 0.00 |
| **7** | 11.00 | 2 | 0.18 |
| **8** | 11.00 | 1 | 0.09 |
| **9** | 11.01 | 1 | 0.09 |
| **10** | 11.01 | 1 | 0.09 |
| **11** | 10.99 | 0 | 0.00 |
| **12** | 11.00 | 4 | 0.36 |
| **13** | 10.98 | 7 | 0.64 |

| | | | |
|---|---|---|---|
| **14** | 11.03 | 0 | 0.00 |
| **15** | 10.98 | 0 | 0.00 |
| **16** | 10.99 | 0 | 0.00 |
| **18** | 14.77 | 7 | 0.47 |
| **20** | 33.75 | 0 | 0.00 |
| **22** | 6.01 | 0 | 0.00 |
| **23** | 11.02 | 14 | 1.27 |
| **24** | 25.75 | 1 | 0.04 |
| **26** | 34.18 | 0 | 0.00 |
| **28** | 9.78 | 10 | 1.02 |
| **30** | 11.02 | 0 | 0.00 |
| **32** | 11.09 | 0 | 0.00 |
| **34** | 23.80 | 0 | 0.00 |
| **38** | 14.79 | 1 | 0.07 |
| **42** | 11.06 | 0 | 0.00 |
| **44** | 10.99 | 2 | 0.18 |
| **47** | 24.78 | 0 | 0.00 |
| **48** | 10.04 | 0 | 0.00 |
| **49** | 11.00 | 0 | 0.00 |
| **Total** | **438.83** | **54** | **0.12** |

The acoustic encounters within the ZTA were distributed mainly in the center and towards the northwest portion of the ZTA (Figure 11) as in previous years and as in acoustic efforts for Vaquita Survey 2023 and 2024 (Cárdenas-Hinojosa *et al.*, 2024)

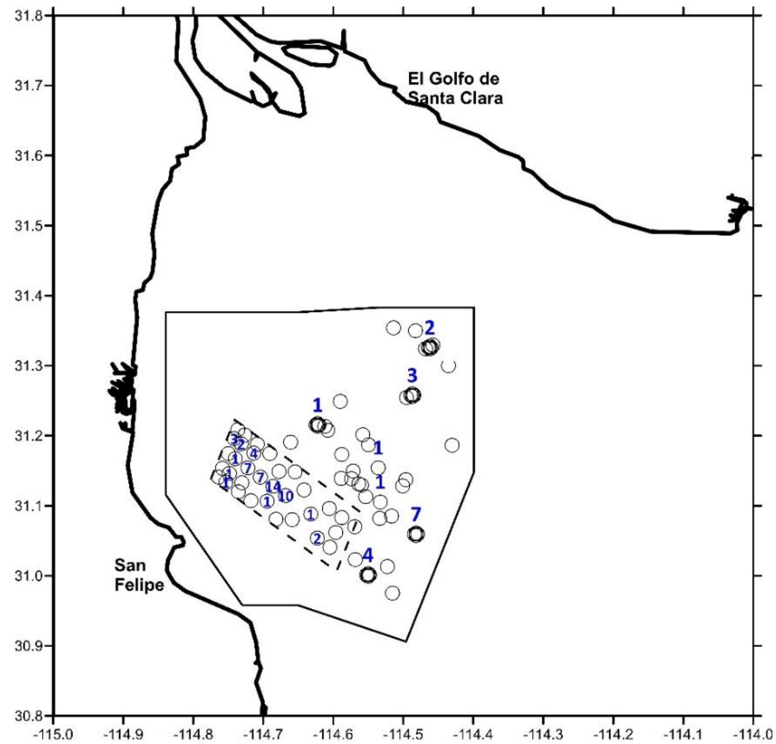


**Figure 11**. Summary of acoustic encounters of vaquita recorded at and outside the ZTA between August 23 and September 24, 2024. Circles indicate the sites with data. A blue number above and in the center of the circle indicates the number of vaquita acoustic encounters per sampling site. The Zero Tolerance Area is delimited by a polygon with a broken line.

Acoustic detection rates of vaquita were higher in the ZTA than outside the ZTA (Figure 12), showing the importance of this area for vaquita habitat. Although vaquita detection rates outside the ZTA were low, the result of detecting vaquitas in these areas allows inferences about the current distribution of vaquitas in the Vaquita Protection Refuge Area.

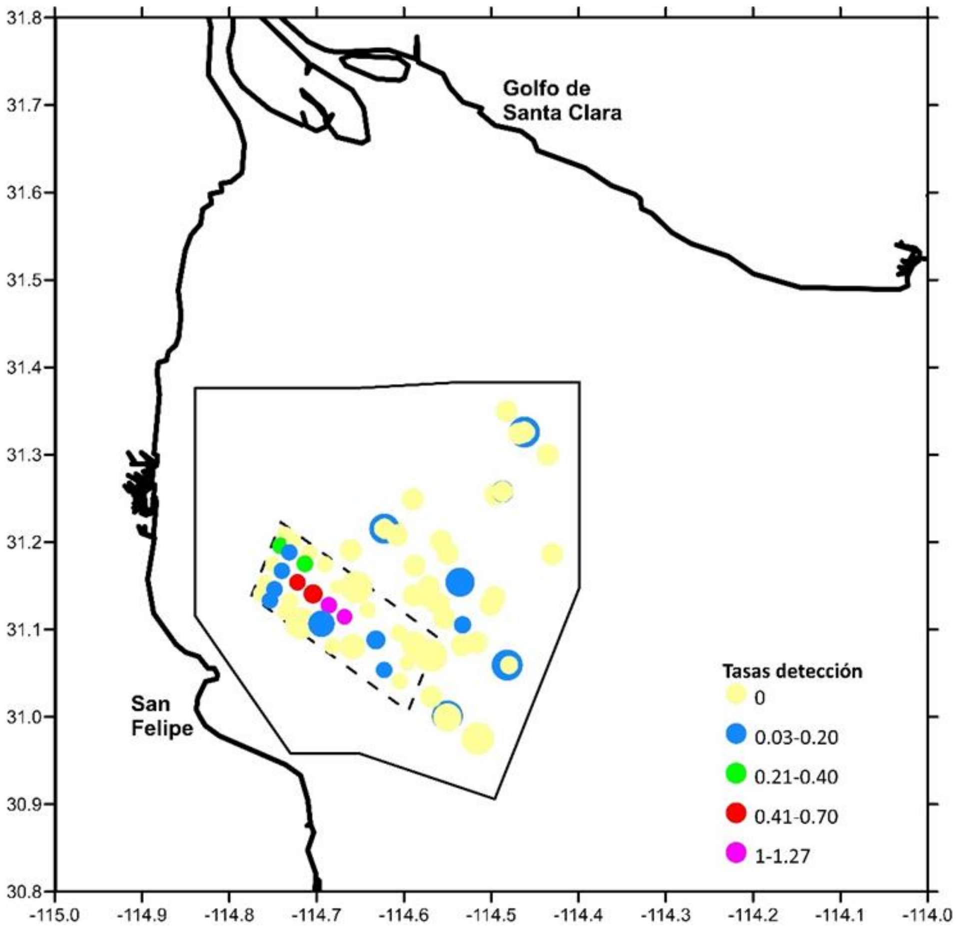


**Figure 12**. Summary of acoustic encounter rates of vaquita recorded at and outside the ZTA between August 23 and September 24, 2024. Circles indicate the sites with data. The size of the circle indicates the level of effort, from 6 to 35 days, at each site. The acoustic encounter rate is indicated by color. The Zero Tolerance Zone is delimited by the polygon with a broken line.

Finally, it is important to mention that no overlap in recording time of acoustic detections of vaquita occurred during the period study. Only in sampling sites 7-2 and 7-3 vaquitas were detected with difference of minutes (around 1 and 9 minutes) in two acoustic encounters. However, no analysis was done to calculate the probability of detecting different groups of vaquitas by analyzing the swimming speed of vaquita and the distance between sampling sites where acoustic encounters were recorded.

### 4.5. Meeting with International Vaquita Acoustic Expert Panel

On October 31, a virtual meeting was held with the International Vaquita Acoustic Panel of Experts. At the meeting, Dr. Gustavo Cárdenas Hinojosa of the CONANP Marine Mammal Research and Conservation Group presented the results obtained from extended acoustic monitoring with the aim of evaluating the implemented sampling design and discussing and reaching consensus on a new sampling design (based on the results) that can be applied in the low fishing season in 2025 to continue collecting scientific data to determine the current distribution of vaquita based on passive acoustic monitoring.

The method used to select the sampling sites based on previous acoustic and visual records of vaquita was considered adequate since the vaquita was successfully detected. The presence of vaquita outside the ZTA was considered very good news because as the population decreased, it was also documented that the distribution of vaquita acoustic activity was shrinking to the area currently known as ZTA (Jaramillo-Legorreta et. al., 2019). In order to continue collecting acoustic data to determine whether vaquitas are reoccupying their range in the Vaquita Refuge, it is considered crucial that extended acoustic monitoring continue into the following sampling season. In this regard, the members of the Expert Panel agreed that the same sampling design be implemented in 2025 but for a longer sampling period with more effort than was done in 2024 to obtain more information on the current distribution of the vaquita and the areas it frequents most regularly in the Vaquita Refuge. However, it was considered that alternatives to the Resqunit devices need to be found since their release mechanism failed on multiple occasions and it is very important to have a device that allows the deployment of moorings with detectors without a buoy on the surface outside the ZTA. Therefore, at the meeting Dr. Barbara Taylor and Dr. Jay Barlow presented an alternative to the Resqunit releasers. They indicated that in San Diego there is the company Subseasonics that manufactures inexpensive acoustic releasers that are used in fisheries. In summary the devices consist mainly of a computer connected to a cable with a transducer to emit the acoustic signal to the receiver (with buoys) on the seabed to release a small buoy. In this way, the anchor line of the detector could be tied to the receiver to recover it. Dr. Nick Tregenza also indicated his company, Chelonia Limited, are developing an inexpensive acoustic releaser that could be adapted to the F-POD acoustic detector that would have the function of releasing itself at a scheduled time. Because the F-POD has positive buoyancy it could be recovered together with the mooring on the sea surface.

The members of the Expert Panel suggested that any type of release device would have to be tested before being implemented in extended acoustic monitoring and it was also agreed that external funding could be obtained to purchase these devices in case they worked correctly in the tests. For the above, Dr. Taylor indicated that the Subseasonics company was immediately making its release systems available free of charge to be tested in the conditions of the Upper Gulf of California.

### 4.6 Conclusions and research recommendations.

1. Results of acoustic research.

In the last sampling carried out in 2018 by the Vaquita Acoustic Monitoring Program within the Vaquita Refuge, individuals were detected only in the southwestern portion, in the area currently known as the Zero Tolerance Area. However, the acoustic detection of vaquitas outside the ZTA in 2024, despite the sampling effort being limited to a single month and the low population density, demonstrates the success of extended acoustic research. These results provide valuable evidence on the current distribution of the species within the Vaquita Refuge.

2. Recommendations for acoustic research

Expansion of acoustic research. It is essential to continue extended acoustic research during the low fishing season. This will allow additional data to be collected to determine with greater precision and scientific robustness the current distribution of the vaquita and the areas it frequents most regularly, key information for designing protection and conservation strategies.

2025 Sampling Planning. It is recommended to start the acoustic research season in May 2025, both inside and outside the ZTA. This month offers optimal weather conditions to carry out both acoustic research and visual observation cruises in an integrated manner. The results of the acoustic research in May would contribute to the sampling design of the cruises to increase the probability of detecting, sighting and photographing vaquitas in areas outside the ZTA, providing crucial information to estimate the minimum population size in the Vaquita Refuge.

3. Alternatives for release devices.

It is suggested to look for an alternative to the Resqunit releasers, which had multiple failures. It is crucial to have a solution that allows the installation of submerged moorings without a buoy on the surface, outside the ZTA, to minimize interaction with fishing activities to avoid the loss of acoustic detectors.

These recommendations seek to optimize monitoring and conservation efforts, improving the quality of scientific information available to support the recovery of this critically endangered species.

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# Vaquita acoustic survey 2024 - proposed survey design v3

Len Thomas + Vaquita Expert Panel

2024-08-14

## History

- v1 12th July 2024. Initial balanced acceptance sampling design on a 1x1km grid, with 30 locations per deployment.
- v2 17th July 2024. Switched to a 200m grid on suggestion from Barb Taylor.
- v3 14th August 2024. Final version for deployment - went to 35 locations per deployment.

## Introduction

This design arises from a planning meeting held on 2nd July 2024, and subsequent discussions. The objective of the passive acoustic monitoring (PAM) survey is to determine whether vaquita may be present outside the area of intensive visual surveying in 2024, and also outside of the zero tolerance area (ZTA) which will be subject to a separate acoustic survey.

For design purposes, we assume there are 35 acoustic sensors available and that they will be redeployed at least once. In reality there may be more than 35 sensors available and they may be redeployed up to 4 times - however the sampling locations of the 3rd and 4th deployment will certainly be dependent on the findings of the earlier deployments (and adaptive sampling design). It may be that the location of the 2nd deployment is also dependent on the 1st, but for the purposes of this document we will produce a set of 70 sample locations that can be used to make two deployments of 35 sample locations.

In selecting locations, we use the following guidance: - sampling locations should be outside the ZTA but within the vaquita refuge area; - sampling locations should be very close to places where vaquita have previously been seen (during sightings surveys that took place in 1993, 1997, 2008 and 2015) or heard (during acoustic surveys that took place in 2011-2018) ; - sampling locations for each deployment should be distributed as evenly as possible over the area of interest - locations should be chosen objectively using some element of randomization

After a second round of consultation, we decided to place sample locations at randomly selected sites on a 200m grid covering the refuge area, with probability of selecting a grid cell being a function of previous visual and acoustic detections and using a spatially balanced design algorithm. The grid spacing is a compromize between wanting to have sample locations close to previous detections (because we suspect habitat preference of vaquita varies strongly over small spatial scales) vs wanting to have sensors far enough apart that they are not redundant. The computer code (in R) that produced this design is fully automated and other spacings could readily be used if desired.

## Sightings

We read in the locations of all sightings from the 1993, 1997, 2008 and 2015 surveys and created a 1x1 km raster covering these. (One exception was that we removed the first sighting from 1993 since it was very far away from the refuge and from any subsequent sighting.) We calculated the number of sightings in each grid cell – this ranged from 0 to 5. We set counts for any rasters inside the ZTA or outside the refuge to 0, because this survey will not cover those areas. A map showing the sighting locations and the raster grid cell counts is given in Figure 1.

## Acoustic detections

The number of acoustic detections declined greatly during the years of the PAM surveys, and also largely contracted into the area now covered by the ZTA (see Figure 4 of Jaramillo-Legorreta et al. 2019 and note the values there are on a logarithmic scale). Our interest here is in determining whether vaquita are once again occurring outside the ZTA, so we base sampling probabilities for the new design on the sum of detections accross all years of the acoustic survey. Specifically, we calculated acoustic encounter rate for each sample location as the total number of clicks detected at that location across all years of monitoring divided by the total number of days of monitoring. We refer to this metric as clicks per day, and the values are shown on Figure 2.

The pattern is dominated by one site that had a high acoustic encounter rate, so we show the same data in Figure 3 on the log scale (natural log of the clicks per day + 1).

## Sampling design

We elected to use a balanced acceptance sampling (BAS) design (Foster et al. 2017; van Dam-Bates et al. 2018). This class of random design allows specification of the target inclusion probability of each potential sample location while also spreading the sampling over the study area. Samples are generated in order and any sequential subset is spatially balanced. Hence if we generate 60 sampling locations and then take the first 30 for deployment 1 and the second

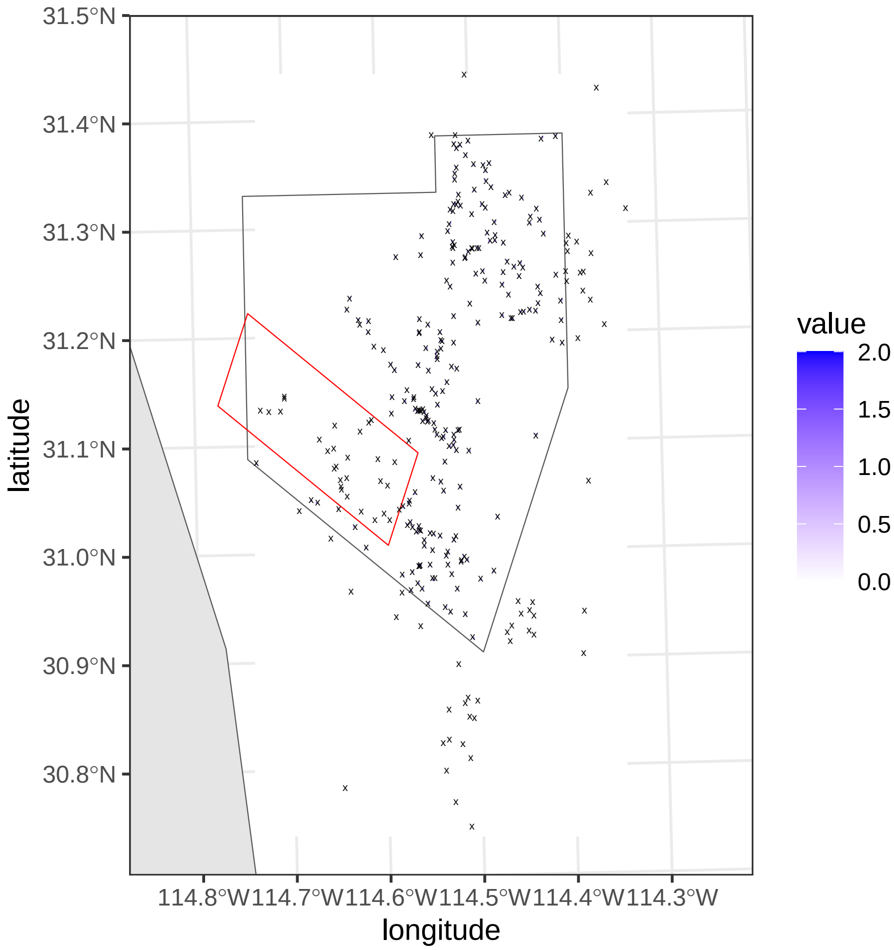


Figure 1: Sighting locations (crosses) and counts of number of sightings per raster grid square (colors) Note that only sightings within the vaquita refuge but outside the ZTA contributed to the counts.

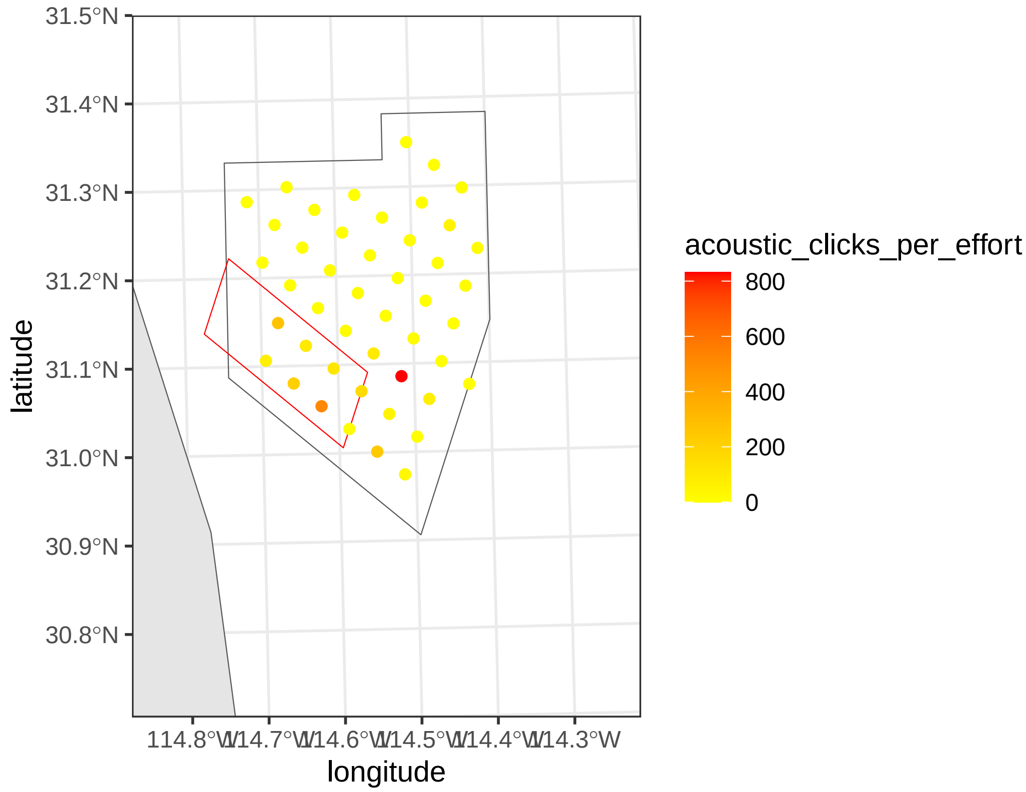


Figure 2: Acoustic click detections per day at the PAM sampling locations.

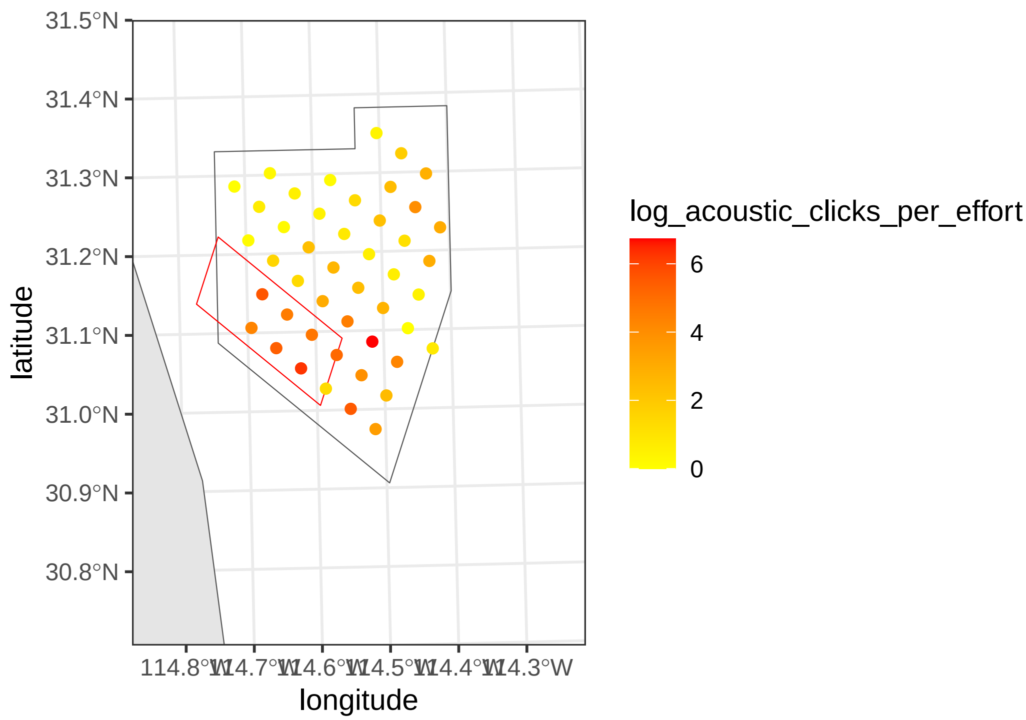


Figure 3: Log of acoustic click detections per day at the PAM sampling locations.

30 for deployment 2 we have 2 spatially balanced samples. If deployment 2 uses an adaptive design instead then we still had a spatially balanced sample for deployment 1.

For the visual detections we set the inclusion probabilities as proportional to the number of detections per raster cell. For the acoustic detections, it would not be practical to set the inclusion probability as directly proportional to the acoustic encounter rate as 2 of the 46 locations accounted for almost half of all detections and so the inclusion probabilities would be too unbalanced to generate a valid design realization. Instead we elected to use the natural log of the (clicks per day + 1) – this still gave higher inclusion probability to sites with more detections and gave an inclusion probability of 0 for sites with no detections.

One remaining decision is the relative weight to allocate to the visual vs acoustic detection locations. Here, we elected to allocate equal weight to each.

A single random realization of the proposed sample scheme, with 70 samples, is shown in Figure 4, together with information used to inform the inclusion probabilities. The sample locations alone for the first 35 samples (deployment 1) and second 35 samples (deployment 2) are shown in Figure 5. The locations are also saved in the file sample_locations.csv.

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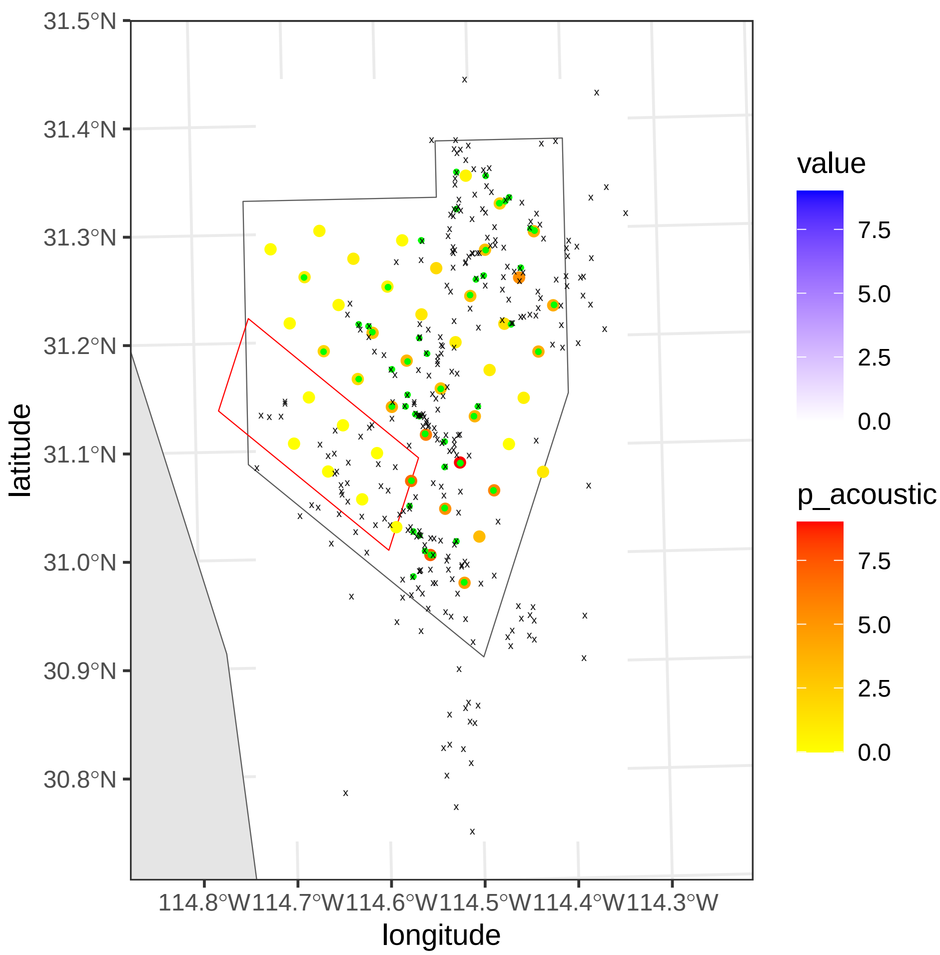


Figure 4: Proposed sample locations (green dots). Also shown is the logged acoustic detection rates (yellow-orange dots), the sighting locations (crosses) and number of visual detections per raster cell (white to blue).

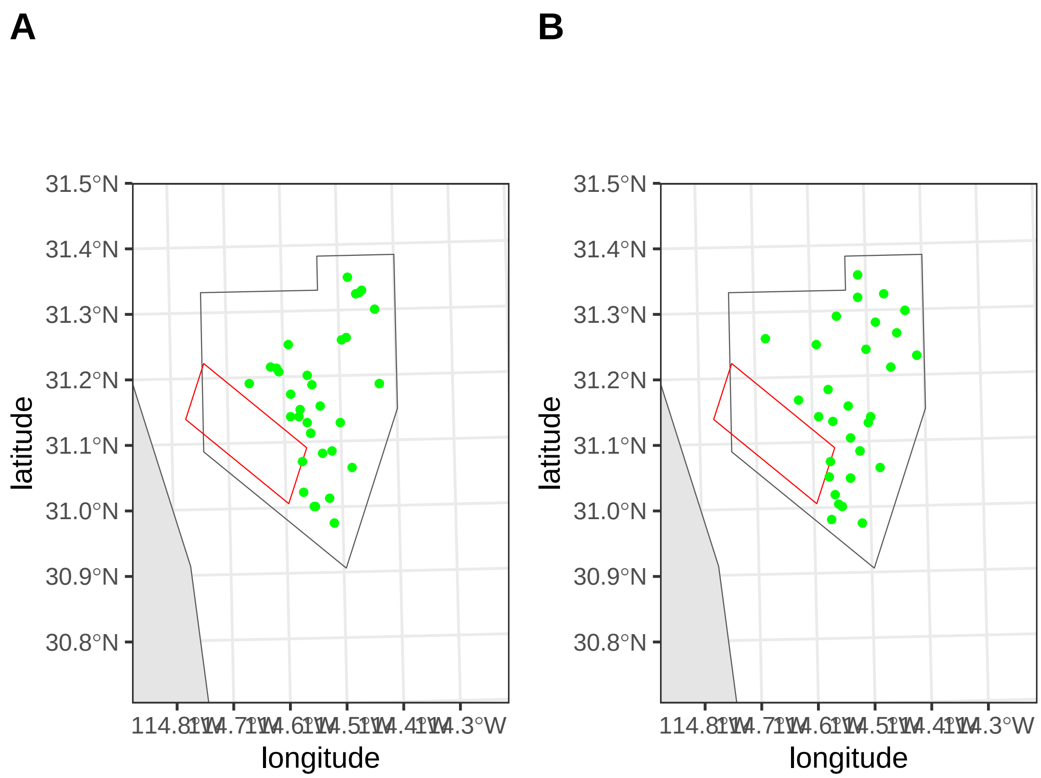


Figure 5: Proposed sample locations (green dots) for (A) deployment 1 and (B) deployment 2.