# Implementation of an acoustic monitoring scheme for vaquita, design and pilot test phases and a review of the Recovery Plan

ARMANDO M. JARAMILLO-LEGORRETA[1], LORENZO ROJAS-BRACHO[1], BARB TAYLOR[2], JAY BARLOW[2], NICK TREGENZA[3]

*(1) Coordinación de Investigación y Conservación de Mamíferos Marinos. Instituto Nacional de Ecología-SEMARNAT c/o CICESE, Km 105 Carretera Tijuana-Ensenada, Camper #6. Ensenada, B.C., 22860 México*

*(2) Southwest Fisheries Science Center, NMFS-NOAA, 3333 N. Torrey Pines Court, La Jolla, CA, 92037 U.S.A.*

*(3) Chelonia Limited, 5 Beach Terrace, Long Rock, Penzance TR20 8JE U.K.*

*ajaramil@cicese.mx*

## INTRODUCTION

This report briefly reviews the rationale for acoustic monitoring of vaquita, describes the design for a monitoring system from a 2009 workshop (Rojas-Bracho *et al.*, 2010) and then focuses on results of the pilot project, the response of the steering committee to those results and recommendations for continued monitoring. This document summarizes the results of a workshop carried out during April 2011 in Mexico to review the information generated on the pilot test.

The vaquita marina (*Phocoena sinus*) is the most endangered species of marine mammal in the world. It occurs only in the northern Gulf of California, Mexico. The species is endangered due to bycatch in fisheries. The abundance of this species has declined from approximately 567 in 1997 (Jaramillo-Legorreta *et al*. 1999) to approximately 245 in 2008 (Gerrodette *et al*. 2011). The Government of Mexico established a Vaquita Refuge in 2005 where vaquitas will be protected from entanglement in fishing nets. By 2008, the Government of Mexico dedicated an unprecedented level of funding in an effort to reverse this decline by banning net fishing within the Refuge and reducing fishing effort throughout the Biosphere Reserve of the Upper Gulf of California by a combination of economic measures (funding fishing permit holders to retire their permits or to switch to other vaquita-safe fishing methods) and enforcement (to eliminate illegal fishing). It is uncertain whether these measures and future measures will be sufficient to reverse the decline in the vaquita population and to allow it to recover. The current level of management actions has likely slowed but not reversed the decline in vaquita abundance (Gerrodette and Rojas-Bracho, 2011). An acoustic monitoring plan was developed to allow managers to determine whether the vaquita population is growing or continuing to decline and the first pilot project of that plan has been completed.

The only available monitoring method that gave the level of precision needed to detect trends in abundance of vaquita in a timely fashion is acoustic monitoring from specialized devices that have been developed in England to detect the echo-location clicks of harbor porpoises and record them over long periods of time. During a vaquita study in 2008 (Rojas-Bracho et al 2010), these devices (called C-PODs) were tested and found to work well at detecting vaquita clicks. The advantages of this method are that these devices can be left in the water to record vaquita clicks for long periods of time and the number of devices can be selected to achieve the desired level of precision. Analyses presented at a 2009 workshop showed that approximately 5,000 C-POD days of sampling per year would be needed to obtain the desired level of precision (CV = 3%; Rojas-Bracho et al 2010).

The 2009 workshop attendees recognized that further research on deployment and retrieval methods was necessary prior to implementation of the full monitoring system. Research was first needed on methods to moor C-PODs to the perimeter buoys of the Refuge and then to develop and test subsurface mooring systems for the C-PODs to be placed inside the Refuge. Data from this pilot study would be analyzed and a report on experimental deployments and the pilot study would be reviewed by a steering committee to make final recommendations on monitoring design.

The steering committee reviewed the work completed on both the attachment to perimeter buoys (Figure 1) and to subsurface mooring systems (Figure 2). The C-PODs worked very well and detected vaquita at expected levels given the locations. Buoy work was highly successful with a depth comparison that led to a recommendation for a mid-water deployment to minimize noise from bottom sediments and noise from surface wave generated bubbles. A satisfactory sub-surface deployment system was created following several important modifications.

## PILOT STUDY C-POD RESULTS

### Data gathered in moorings for Refuge delimiting buoys

Functional C-PODs were used in the pilot tests to develop secure attachment to the Refuge perimeter buoys. Tests were conducted on Buoy G, the closest to San Felipe (Figure 3). The best depth for the C-POD was tested at the same time. Three C-PODs were attached to the same mooring line at different depths (5, 10 and 15 m) to assess possible differences in C-POD performance.

Two tests were carried out: from May 27$^{th}$ to July 15$^{th}$, 2010 and from July 31$^{st}$ to October 9$^{th}$, 2010. C-PODs at 5 and 15 m recorded a higher number of clicks than the one at 10 m. Since most recorded clicks are just noise, this result is consistent with the hypothesis that bubbles from breaking waves and clicks made by sediment particles hitting one another were recorded at every depth but more from the former on the shallow C-POD and more from the latter on the deep C-POD. The best depth to reduce the number of unwanted "noise" clicks being recorded on the C-POD was at the middle (10 m) depth. For that reason, it was decided to deploy the C-POD at 10 m during the pilot test, as there was no effect of the depth on the ability to detect vaquita like signals. During 119 days of testing, 6 detections of vaquitas were confirmed.

On October 10th to November 16th C-PODs were deployed 10 m deep at buoys G and I. Other buoys were not available because authorities were going to remove them for maintenance. During 38 days, two vaquita detections were confirmed at Buoy I and none at Buoy G. Overall, including the testing and pilot periods, a total of 195 days of sampling were completed on both buoys, collecting 8 vaquita detections. Only full sampling days were considered, so the first and last days of effort were removed.

**Data gathered in subsurface moorings**

Two types of trials were conducted on subsurface moorings. The mooring configuration trials focused on design of the mooring set up and retrieval and did not risk use of actual C-PODs. After the configuration had been worked out all subsequent pilot subsurface trials used actual C-PODs. A numbering scheme was developed for the subsurface mooring stations (Figure 3). The pilot study was designed to gain information throughout the Refuge. To obtain representative coverage, the area was divided into six strata using knowledge about vaquita distribution (Figure 4). The pilot study was designed to include one sampling site near the centre of every stratum, and two additional sampling sites selected randomly within each stratum, for a total of 18 sampling sites. Poor weather conditions resulted in only seven moorings being deployed. The first C-POD at site 44 was deployed on October 30th and retrieved on November 15th to check that the anchoring was secure. A fresh C-POD was installed and the one that worked for 16 days was taken to the lab for data analysis. Other three C-PODs were deployed at sites 35, 36 and 43 on November 15th and the remaining three pods were installed at sites 13, 38 and 41 on November 24th.

C-POD retrieval attempts were made between January 29th and 30th, 2011. Moorings at sites 35, 36, 43 and 44 were not recovered after several hours of searching. Moorings and C-PODs at sites 38 and 41 were retrieved on January 29th and the one at site 13 on January 30th. The most likely cause for mooring loss was removal by illegal fishing activities inside the refuge during the shrimp season. Because of the high loss rate, the original planned 18 were not deployed and we continue with the lower number of C-PODs. New C-PODs were deployed at sites 13, 38 and 41 on the same dates they were recovered. Between January 30th and February 1st five more moorings and C-PODs were deployed at sites 2, 4, 25, 32 and 36. Retrieval was attempted for all moorings between March 10th to 23rd. Five moorings were lost and three were recovered at sites 4 (March 10th), 38 and 41 (March 23rd). Overall, 100 vaquita detections were gathered in 345 full days of effort.

**Results summary**

108 vaquita detections were gathered in 540 full sampling days, which included the sampling effort during mooring trials at Buoy G (Table I).

Table I. Results of the vaquita acoustic monitoring pilot project for the buoys and the 5 subsurface moorings that were not lost.

| | Buoy G | Buoy I | S44 | S13 | S38 | S41 | S04 | Overall |
|---|---|---|---|---|---|---|---|---|
| Full days of effort | 157 | 38 | 16 | 66 | 118 | 109 | 36 | 540 |
| Acoustic encounters confirmed | 6 | 2 | 4 | 61 | 18 | 8 | 9 | 108 |
| Average detection rate (detections / day) | 0.04 | 0.05 | 0.25 | 0.92 | 0.15 | 0.07 | 0.25 | 0.20 |
| Standard Error | 0.02 | 0.04 | 0.17 | 0.14 | 0.04 | 0.03 | 0.11 | 0.02 |
| C.V. | 0.40 | 0.70 | 0.68 | 0.15 | 0.24 | 0.34 | 0.43 | 0.12 |

Average detection rates are consistent with results obtained in Vaquita Expedition 2008, which formed the basis for the sampling monitoring grid and therefore supports using the monitoring design. The overall effort is about 10% of the required effort as calculated during the 2009 workshop. Given the coefficient of variation (CV) of 12% observed in this trial, statistical theory indicates that a CV of approximately 4% would be expected given a full season of sampling (approximately 5000 C-POD days per year), which is close to the target CV of 3%. A simulation of 5,000 effort days using Poisson and Negative Binomial distributions, based on data gathered, reached the same conclusion.

The loss of 60% of the moorings installed during the pilot test greatly exceeds the loss rate of 20% that was assumed in the monitoring design. Even with strong enforcement (aircraft, enforcement boats, fishermen fines and penalties including in jail) it's almost impossible to keep out all illegal fishing vessels. This situation means that the only way to obtain the target 5,000 C-POD days within the budget allowed for C-PODs is to avoid monitoring during the shrimp fishing season. Based on the experience of personnel of the Biosphere Reserve Upper Gulf of California, responsible of administering the Recovery Plan funds, a period of very low fishing operations occurs between mid-May and mid-September. On the other hand, after we reported our results at the Ministerial level VMS are being forced to all industrial fisheries vessels. Data will be provided to us by PROFEPA, the environmental watch dog.

## PROBLEMS REMAINING TO BE SOLVED

### Retrieval systems

A suitable reflector that would allow rapid retrieval using a sidescan sonar device to locate the mooring has not yet been found. The steering committee recommended some further research in the very near future to attempt to find a good reflector or transponder design but felt that deployment of the monitoring grid should not be delayed. Should a good reflector not be found prior to deployment, moorings were successfully grappled during the pilot project using exact location but the time to retrieve the mooring can take up to 3 hours, which will make it necessary to allow for more time and work to retrieve the entire grid.

An alternative to reflectors is to modify the mooring design by replacing a heavy and large concrete block instead of the anchor used in the opposite side to the one holding the detector (Figure 2). This kind of blocks are easily detected by side-scan sonar, hence the reflector would not be necessary. An additional benefit of this design is to discourage fishing operations around mooring site, as the block can damage the gear. The blocks can be supplied with pikes, as the ones used in similar structures as trawling deterrents to avoid this kind of fishing. However, fishing with gill and mesh nets would be also discouraged, as these structures can also damage this kind of gear.

### Immediate monitoring reducing C-POD loses

The biggest problem encountered in the pilot project was the complete loss of the mooring and C-PODs most likely due to illegal fishing in the refuge. From April 15 to September 2, the period of lowest fishing effort, one of eight moorings was lost. From October 30 to March 23, a period of intense fishing effort, 9 of 15 moorings were lost. Illegal gillnetting and trawling are known to occur in the refuge (e.g. night time). Therefore we recommend that monitoring occurs in the period of lowest fishing activity from mid-May to mid-September. This period was not recommended in the original workshop design because high unpredictable winds occur in this period. The possibility of illegal fishing even with 24hrs for 365 days enforcement, however, makes this the only viable alternative to be able to monitor vaquita.

The steering committee recognized that stopping illegal fishing was critical to being able to monitor vaquita. Although trawlers do not have such a high direct threat to vaquita, they must be very effective at removing the acoustic detection devices. The preliminary work conducted and the number of fines and penalties clearly demonstrates there is illegal fishing in the Refuge area hard to eliminate.

The steering committee recommended that the full monitoring effort begin in May 2011 with the agreed original deployment design: 48 C-PODs deployed with the sub-surface method and 16 C-PODs deployed on the Vaquita Refuge perimeter buoys (Figure 3). The steering committee recommended deployment of C-PODs on perimeter buoys year-round to obtain data on seasonal movements. Data from this first deployment will be analysed in winter of 2011/12. Because the analysis of acoustic data requires some level of human subjectivity, a training data set will be developed that can be used to test for consistency between analysts. The analysis of this first deployment and all subsequent deployments requires a method of duplicate analysis by different analysts to ensure that subjective differences do not affect the results of the trend analysis.

### Monitoring outside vaquita refuge

About 50% of vaquitas are expected to be within the Vaquita Refuge (Gerrodette *et al*. 2011). The steering committee recognized that even small shifts in vaquita distribution could affect the monitoring program if all monitoring is done inside the Refuge. However, monitoring vaquita abundance with C-PODs would be difficult outside the Vaquita Refuge's no-fishing area because they could be entangled in gillnets and trawl nets. Given the loss of mooring observed in the pilot project inside the Refuge, the steering committee felt deployment of subsurface moorings outside the Refuge where fishing activity is even more intense was unlikely to yield sufficient data at this time. The steering committee recommended that if possible, given the constraints during the first year of deployment, sub-surface moorings with dummy C-PODs should be placed throughout the area of the vaquita distribution outside the Refuge to begin gathering data on loss-rate in the non-fishing season. To gain information on vaquita habitat use the steering committee also recommended an approach that had fishermen deploy C-PODs on their nets (outside of the Vaquita Refuge) and be paid for successful data. Because the season for the grid monitoring is designed to avoid the fishing season, the same C¬PODs could be used to gather data outside the Refuge by fishermen. The data obtained from fishermen could not be used for trend monitoring because the spatial distribution of effort is not systematic and will change from year-to-year.

## RECOVERY PLAN AND MEXICAN GOVERNMENT PROJECTED ACTIONS

Until now, after three periods of fishing effort reduction strategies (2008-2010), the Mexican Government has applied a total of $396 million Mexican pesos (about 33.8 million USD). These public funds have been applied for buy-out, rent-ot and compensations, inspection and surveillance, and research. The initial foreseen universe of 1,200 fishing boats has been reduced to less than 670, nearly half of the original effort. Although some fishermen have been paid to avoid fishing inside vaquita refuge, there is some level of non-fulfilment of the compromise. Juan Manuel García Caudillo (pers. com.), made flights all over vaquita distribution area in order to quantify and describe fishing effort. On each flight, they counted the number of fishing vessels likely fishing inside the refuge and all over the region. His data are being analysed and show a clear decline in number of fishing vessels. However some illegal fishing occurs that affects our monitoring program, which is anticipated to take another 5 years. This is a monumental undertaking which has required substantial investment in infrastructure and personnel and will require further investment to be completed. Because by-catch is a serious problem in many countries, a success story would have a ripple effect for the conservation of porpoises and dolphins with coastal or riverine habitats. The scale of both the monitoring project and the conservation actions are ground-breaking and show Mexico’s serious policy for preventing the extinction of a species.

## ACKNOWLEDGEMENTS

The implementation phase of the Acoustic Monitoring Scheme for Vaquita, described in this document, was possible thanks to the funding and support of The Ocean Foundation, The Cousteau Society and the Mexican Government through the Minister of Environment and Natural Resources and the National Institute of Ecology.

## CITED LITERATURE

Gerrodette, T., B.L. Taylor, R. Swift, S. Rankin, A.M. Jaramillo-Legorreta and L. Rojas-Bracho. 2011. A combined visual and acoustic estimate of 2008 abundance, and change in abundance since 1997, for the vaquita, *Phocoena sinus*. *Marine Mammal Science* DOI: 10.1111/j.1748-7692.2010.00438.x.

Gerrodette, T. and L. Rojas-Bracho. 2011. Estimating the success of protected areas for the vaquita, *Phocoena sinus*. *Marine Mammal Science* DOI: 10.1111/j.1748-7692.2010.00449.x.

Jaramillo-Legorreta, A.M., L. Rojas-Bracho and T. Gerrodette. 1999. A new abundance estimate for vaquitas: First step for recovery. *Marine Mammal Science* 15:957–973.

Rojas-Bracho, L., A. Jaramillo-Legorreta, G. Cárdenas, E. Nieto, P. Ladrón de Guevara, B. Taylor, J. Barlow, T. Gerrodette, A. Henry, N. Tregenza, R. Swift and T. Akamatsu. 2010. Assessing trends in abundance for vaquita using acoustic monitoring: Within refuge plan and outside refuge research needs. NOAA Technical Memorandum, National Marine Fisheries Service, Southwest Fisheries Science Center 459. 39 pp.

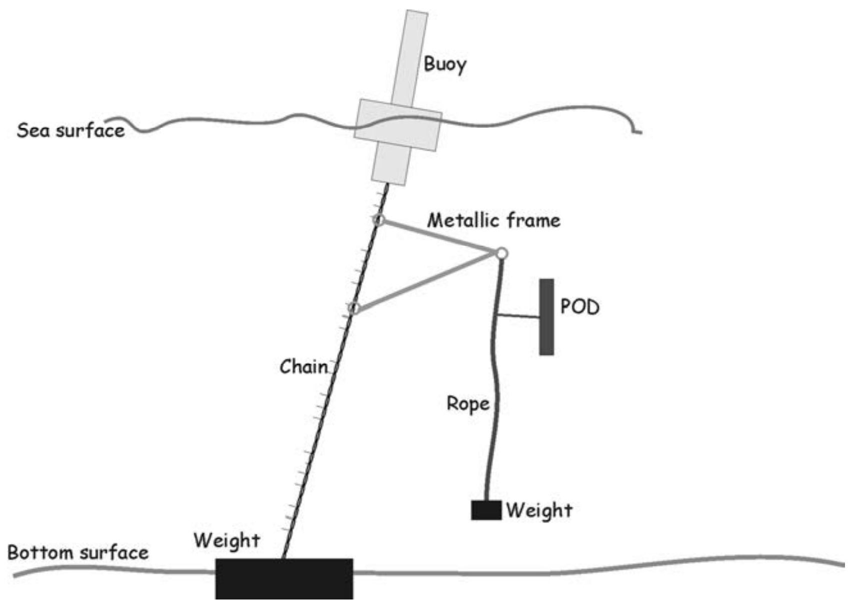


Figure 1. Schematic diagram of the mooring system designed to install acoustic detectors on buoys delimiting the Vaquita Refugee polygon.

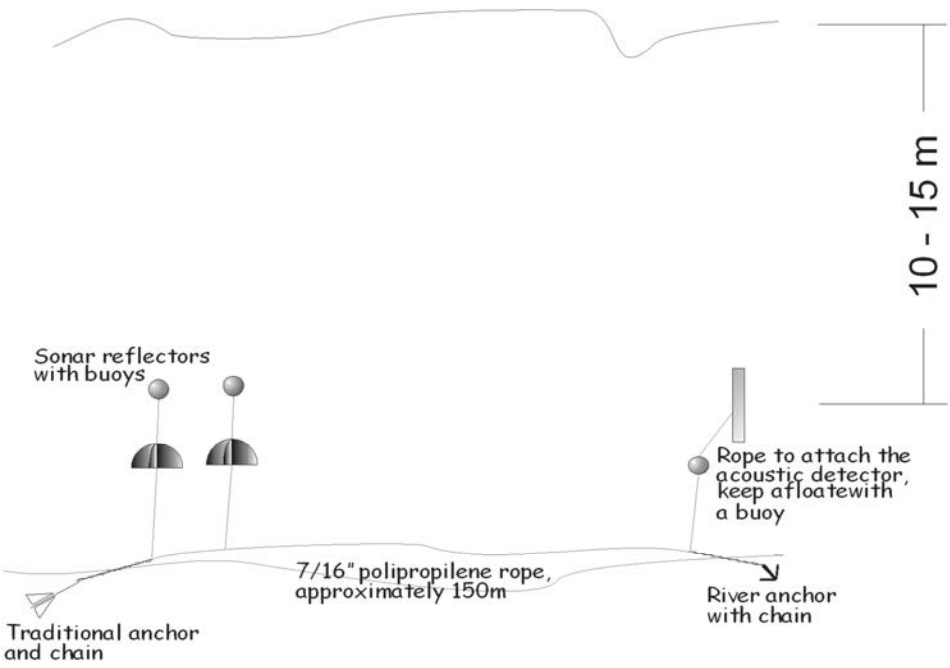


Figure 2. Schematic diagram of the subsurface mooring system designed to install acoustic detectors on sites inside the Vaquita Refugee polygon.

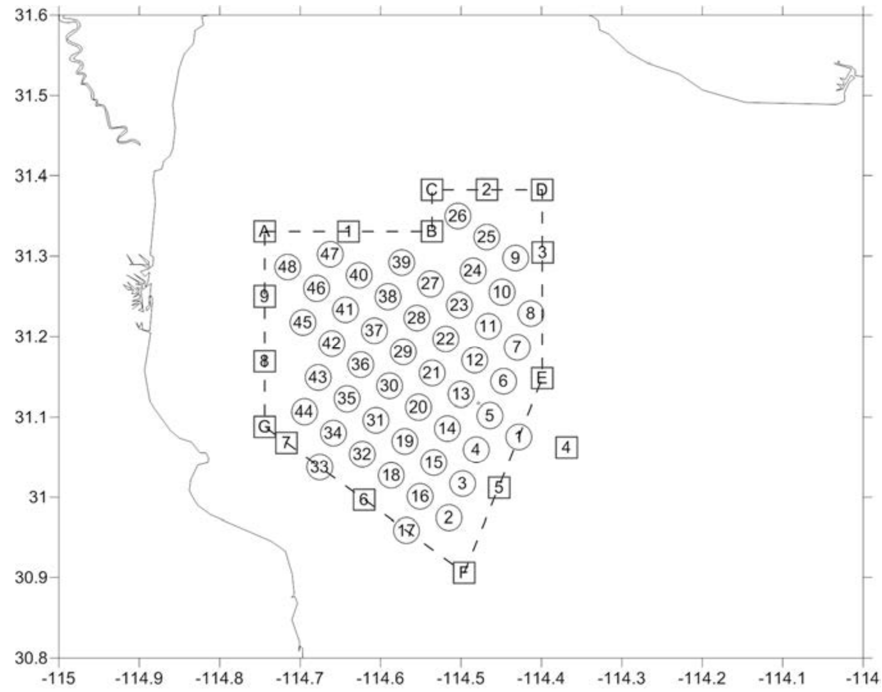

Figure 3. Vaquita Refugee polygon traced with a broken line. Squares mark position of delimiting buoys. Circles mark the sites used in the sampling grid to install acoustic detectors with the subsurface mooring system.

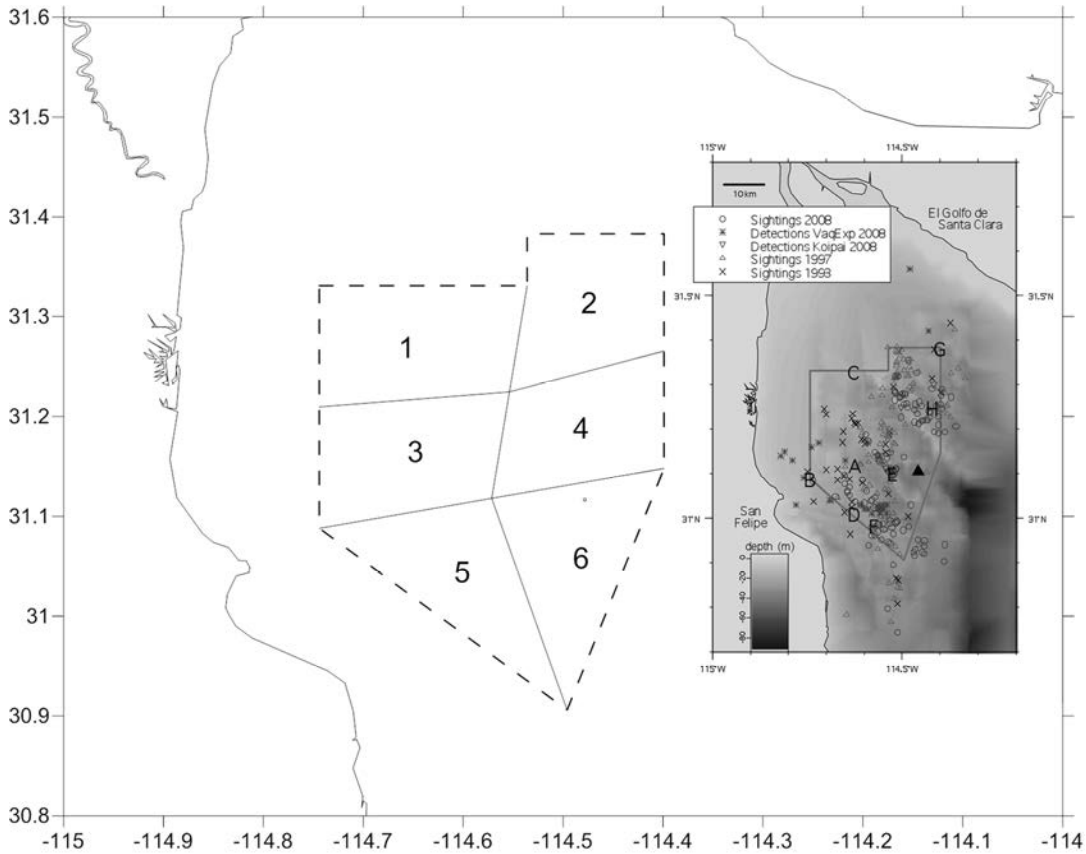


Figure 4. Map showing Vaquita Protection Refuge and stratification design for pilot test. The inset at right shows the knowledge of vaquita distribution from visual data gathered during surveys on 1993, 1997 and 2008 (crosses, circles and triangles) and acoustic data gathered during the 2008 survey (asterisks and inverted triangles).