Webinar Report: Vaquita Survey Final Design
17 June 2015

Contents

1. INTRODUCTORY ITEMS

A Webinar requested by SEMARNAT (Annex A) took place on 17 June 2015 for the specific purpose of reviewing and reaching final agreement on the design and other aspects of the vaquita abundance survey planned for September-December 2015. The Webinar was hosted by Barbara Taylor at NOAA's Southwest Fisheries Science Center. Greg Donovan, Head of Science, International Whaling Commission, chaired the Webinar and was assisted in preparation of the report by Randall Reeves, Chairman of the SSC/Cetacean Specialist Group of the International Union for Conservation of Nature.

1.1 Chair's opening remarks

After welcoming participants, Donovan emphasised that he would ensure that the primary focus of the Webinar would be to follow the Terms of Reference (ToR) provided by SEMARNAT for the upcoming 2015 survey, the aim of which is to obtain 'the most precise abundance estimate possible given the anticipated low number of [vaquita] encounters'.

In particular, he noted that several of the documents available (see Annex B) addressed, in addition to the primary topic, important issues related, for example, to fishery closures, economic interests etc., that are beyond the ToR, especially given the limited time available. He apologised that the meeting would be held in English and urged participants to speak slowly and to indicate promptly if anything was said that they did not understand or agree with.

Donovan acknowledged the extensive efforts by management authorities and scientists in Mexico, the United States, the United Kingdom and elsewhere to help ensure a successful planning process for the survey. In particular, he thanked the cruise steering committee (Rojas-Bracho, Taylor, Jaramillo-Legorreta, Barlow, Gerrodette, Henry, Nieto-García and Cárdenas-Hinojosa) for their hard work as well as the numerous scientists within Mexico and internationally who have invested their time in providing comments and advice on the various draft planning documents. He particularly thanked those who were unable to participate in the webinar but had sent written comments. The full list of documents that served as background and the basis for discussions is given as Annex B and the documents themselves are given as Annex E, Appendices E1–E11.

In conclusion, he stressed that the discussion would centre on "Responses to reviewers" (Annex E, Appendix E1) and on 'Research design to estimate vaquita abundance**:** with Addendum to optimize design given new results on 2013-2014 rate of decline' (Annex E, Appendix E2). He noted that the report below was not intended to include all of the responses to the reviewers given in Annex E, Appendix E3-E11 but rather those that had been judged by participants to require additional discussion. He explained that at the end of the discussion of each agenda item, he would provide a suggested summary based upon discussions and available documents and invite participants to comment on this. His objective was for the report to contain agreed conclusions or suggestions, and if there were disagreements, a concise summary of the different views expressed.

1.2 Appointment of rapporteur

Reeves was appointed as rapporteur.

1.3 Adoption of agenda

The draft agenda was adopted without change (Annex C).

Participants in the Webinar, including those who were unable to join directly either due to prior commitments or for technical reasons but submitted comments for consideration during the discussions, are listed in Annex D.

1.4 Process for development of report

A full draft of the report was circulated to all participants on 07 July 2015, with a request for responses by 14 July 2015. The report was finalised on 17 July 2015.

2. PRACTICAL SURVEY ISSUES

2.1 Survey areas and timing

2.1.1 Survey areas

The survey area was defined by the cruise steering committee primarily as the known range of the vaquita based on sightings from previous surveys in 1993, 1997 and 2008 plus portions of the northern Gulf of California that are considered to contain potentially suitable habitat for vaquitas based on what is known about their biology and ecology.

The survey area was stratified for practical and safety reasons into two primary strata: an acoustic area (green in Fig. 1) and a visual area (blue in Fig. 1). It was also revised in response to the initial round of reviewers' comments (Annex E, Appendices E1 & E2) especially with respect to the proposed low coverage area outside the believed known area of distribution. The visual area includes a sub-area ('joint visual and acoustic area' used for calibration, red in Fig 1.), whose boundaries include most of the Vaquita Refuge which has been monitored acoustically since 2011. The entire visual area will be covered in one half of the survey period, and a more central 'core' area will be surveyed more intensively ('saturation' sampling is anticipated) in the other. The acoustic area will be monitored acoustically throughout the survey period.

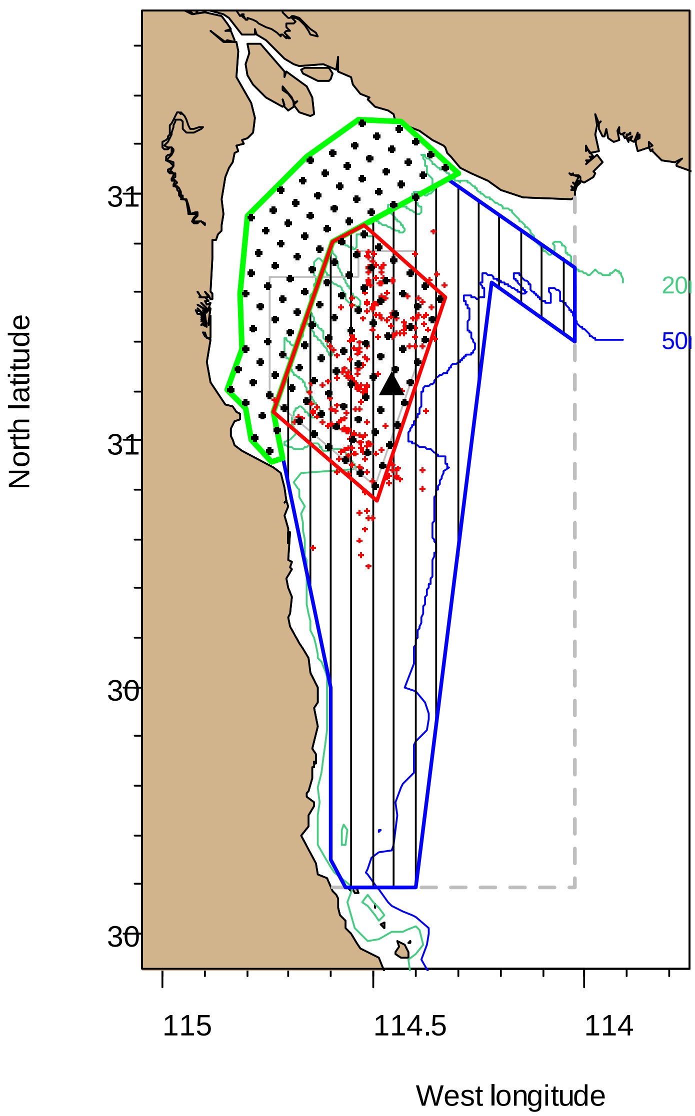


Fig. 1. Survey stratification scheme and suggested tracklines from the Steering Committee after consideration of the initial round of reviewers' comments – see Annex E, Appendix E1.

Key –

Green: acoustic only area

Red: both acoustic and visual area (existing acoustic monitoring zone and Vaquita Refuge – see Annex E, Appendix E1)

Dotted gray line: eastern and southern border of gillnet exclusion zone

Solid gray line: Vaquita Refuge Area

Blue: visual only area

Black crosses: acoustic sampling sites

Red crosses: raw sightings positions from the 1997 and 2008 cruises (information on coverage and tracklines can be found in Jaramillo-Legorreta *et al.* (1999) and Gerodette *et al.* (2011)

Large black triangle: Consag Rocks

There was some discussion about the areas to be covered, including why the visual ship component will not cover the entire gillnet exclusion zone. It was agreed that the boundaries are reasonable, responded to reviewers' comments and had been chosen for both biological and practical reasons, as follows:

(1) based upon sightings and the literature, vaquitas have never been observed in waters deeper than 50m – most sightings from surveys have been in waters 20-35m and there have been acoustic and visual detections in the northern waters shallower than 20m;
(2) the boundaries of the gillnet exclusion zone had been set to follow lines of latitude and longitude to facilitate enforcement even though they covered areas deeper than 50m;
(3) it was not considered appropriate to survey waters deeper than 50m – the level of effort required to obtain an estimate with a reasonable CV (assuming any animals at all were found there) would be far too great and reduce coverage in the primary areas (and see Item 2.2 below);
(4) the *Ocean Starr* (the proposed survey vessel – see Item 2.4.2 below) can navigate safely and effectively only in waters 20m or deeper (during the survey the exact position of that contour line will vary slightly according to tidal phases and states) – hence it was appropriate to cover shallower portions of the vaquita's known or suspected range acoustically;
(5) the overlap zone (i.e. with both acoustic and visual coverage) was appropriate to calibrate the acoustic information (see Item 3.4 below).

2.1.2 Timing of survey

As stated in the Terms of Reference (Annex A), the survey is expected to be conducted as soon as possible i.e. in the second half of 2015. The current plan is for the survey to begin on 15 September and end on 6 December. The visual shipboard component will be conducted as two 32-day legs with one refuelling and re-provisioning stop in Guaymas between them.

It was clarified during the discussion of some reviewers' comments regarding the option of carrying out the survey in spring (when weather may be better) that the steering committee had investigated the available information on prevailing weather conditions throughout the year. In particular, Jaramillo-Legorreta noted that two years ago when the SEMARNAT team had been asked to investigate the design of a vaquita survey, they found that there are, on average, more days with good sighting conditions in the spring than in the autumn but that the difference with autumn was not so great as to preclude the autumn option. Indeed the successful 1997 and 2008 vaquita surveys had been conducted in the autumn and that experience had been used in calculating the number of days that would be required for a successful survey with low CVs. Finally it was concluded that holding the survey in autumn was in accord with the funding body's desire to have it take place as soon as possible.

2.1.3 Summary and conclusions

Participants concurred with the Chair's summary that the steering committee had carefully considered the reviewers' comments and that the revised plans were acceptable with respect to survey area and timing.

2.2 Trackline design for visual survey

The revised survey design includes transects totalling approximately 600n.miles and it is reasonable to expect that this can be covered during the first leg of the survey, assuming an average of around 19n.miles per day; the survey in 1997 covered ~ 17n.miles per day and the survey in 2008, ~ 34n.miles per day. It was also clarified that if conditions were to allow early completion of the full transect grid, the intention would be to attempt to repeat as much of the area as possible in any remaining 'spare' time.

The participants recognised that there are a number of competing factors involved when designing appropriate tracklines e.g. relating to maximising time spent on effort; obtaining equal coverage probability; practical considerations with respect to glare etc. Extensive constructive input had been received from reviewers and the steering committee explained how these had been taken into account in the revised design. Some additional comments had also been received in light of the revised design in written submissions (Annex E, Appendix E4 & E10) as well as during the Webinar discussions, although those making the suggestions had also agreed that the proposed revised design was acceptable.

These comments can be summarised as follows:

(1) given a fixed amount of survey effort, variance estimation is optimised by having more shorter lines rather than fewer longer lines;
(2) running transect lines parallel to the coast is not usually ideal.

It was suggested that consideration be given to modifying the design by running lines at, say, 30-45 degrees SW-NE. This would generate more lines and avoid their being parallel to the coast (and avoid most of the glare). Whilst theoretically more robust, it was also noted that this may (a) conflict with survey logistics and (b) not be important in practice. Determining the best pragmatic approach can also be complex. For example on good weather days, a long S to N line that can be surveyed in a single day maximises the use of those good conditions (although it may be problematic when there are two good weather days in a row) whereas with shorter lines, more time would be lost moving between the end of one line and the beginning of the next. If lines are mostly broken because of variation in sea conditions then there will effectively be more replicates for variance estimation, which is good, but this contrasts with the advantages of surveying a long line in a single day.

It was confirmed that the steering committee had considered the question of transect line design at some length, recognising that a zigzag design is more efficient in that there is no need to go off-effort in good conditions. However, they stressed that the survey area is a small one and only a small amount of time is required for changing lines. There is also a benefit with parallel lines that they provide equal probability coverage within a non-squared polygon. With respect to glare (experience has shown this to be an important issue), use of N-S lines works best. It was also noted that it has proved relatively rare that long lines are completed at one time. Most of them end up being 'composites' of effort on different days, in addition to being of variable length. For that reason, variance estimation on previous vaquita surveys has not been based on replicate lines**.**

2.2.1 Summary and conclusions

Participants concurred with the Chair's summary that the steering committee had carefully considered the reviewers' comments and that the revised plans were acceptable with respect to trackline design and effort. However, the steering committee was also encouraged to continue to examine the design in light of the considerations above by continued informal discussions with reviewers.

2.3 Placement and number of acoustic sampling sites

Participants were informed that with the funds available, it is possible to establish and maintain a maximum of 136 acoustic sampling sites. There had been a number of valuable suggestions made by reviewers with respect to the acoustic component of the initial plan and these had been taken into account in the revised plans (and see Fig. 1).

The sampling strategy within the calibration area (joint acoustic and visual area, red-bordered polygon in Fig. 1) is unchanged from the long-term grid. A similar design will now be used within the purely acoustic area.

2.3.1 Summary and conclusions

Participants concurred with the Chair's summary that the steering committee had carefully considered the reviewers' comments and that the revised plans were acceptable with respect to placement and number of acoustic buoys within the approved budget.

2.4 Visual methods – personnel, equipment including vessel choice, independent observer mode and tracking

With respect to the practical undertaking of the survey, participants noted that the number of sightings is likely to be small, particularly given the recent acoustic data showing a large decline in vaquita abundance over the last three years. There is thus considerable value in the survey being as similar as possible to the successful surveys in 1997 and 2008 (in terms of vessel, observers, searching strategy and equipment) to allow data from previous surveys to be incorporated into estimation of parameters such as the detection function, thereby reducing an important component of the CV. This general point was relevant to the discussions of the individual factors below.

2.4.1 Personnel

The steering committee had focussed on identifying sufficient, experienced and trained observers to undertake the survey in the proposed Independent Observer (IO) mode allowing for sufficient rest periods. Several reviewers had commented on the excellent team that had been put together. Highest priority had been given to individuals with experience in vessel surveys specifically targeting vaquitas, followed by those with shipboard experience surveying for harbor porpoises. The rationale behind this was twofold:

(1) having a 'sighting or search image' enabling the person to detect porpoises that are found in low numbers and often as singles or small school sizes with short periods at the surface; and

(2) ability to reliably identify vaquitas – and especially to distinguish them from bottlenose dolphins, which are encountered relatively frequently in the same waters.

It was noted that two of the best observers in the 2008 survey were Mexican and that they would be present again in 2015. There was agreement on the importance of building up Mexican expertise for vaquita surveys in the future. This had been raised by some reviewers, and there was considerable discussion of how such build-up might best be achieved. Some participants noted that attempts to train new observers during the 2008 vaquita cruise, when the densities of vaquitas were almost certainly higher than is likely for the 2015 survey, had not been particularly successful. In this regard, it was noted that training of observers for harbour porpoise surveys had proved most successful when undertaken in higher-density areas. Others noted that the Mexican tuna-dolphin program has many well-trained and experienced observers with experience in sighting and identifying small cetaceans, even though turbidity, cues and school sizes were often quite different to what is experienced when surveying for vaquitas.

After careful consideration, there was agreement that this pool of observers was a valuable potential source of observers for vaquita surveys and therefore that a concerted effort should be made to enable some of the Mexican tuna-dolphin observers to participate in harbor porpoise surveys in Europe or the United States in order to gain experience detecting porpoises, particularly in highly turbid conditions similar to those of the northern Gulf; whether this is possible before the 2015 survey is unclear at this stage but it will certainly be valuable for the future. There was also agreement that the 2015 survey itself was not an appropriate training opportunity given that the objective was to obtain as precise an estimate as possible.

2.4.2 Equipment including vessel choice

The Terms of Reference (Annex A), indicated that the *Ocean Starr*, that had been used in the two previous surveys, will be used for the visual component of the 2015 survey. It was also noted in the discussion that this could be the last time that this vessel would be available.

Some reviewers had commented on the possibility of using alternative vessels for the 2015 survey, and in particular the new INAPESCA ship (R/v BIPO), which was said to have several good features including a high bridge, ability to sail in shallower waters than the *Ocean Starr* and much quieter engines. The last feature led to discussion of the relatively noisy running of the *Ocean Starr* and the possibility that this could compromise the acoustic data during the survey, especially in the 'calibration' area.

In discussion, it was noted that the noise from the *Ocean Starr* would not mask the vaquita's sounds, given the large mismatch between the peak frequencies of the vessel noise versus vaquita clicks. Indeed, the northern Gulf can be an extremely noisy underwater environment even in the absence of ship noise because of intense biological activity, but the acoustics team stated that they are well-equipped and accustomed to dealing with the implications of this.

This being said, it was agreed that the INAPESCA vessel was certainly a candidate for future surveys.

2.4.3 Independent observer and tracking

Two fully independent teams of observers are part of the basic survey design. The teams will be situated on separate levels of the ship and wear headphones to help ensure their independence. Observer data will be captured by continuous audio recording as a supplement to entry of the data into a computer. This will aid the process of differentiating duplicate from non-duplicate sightings for post-survey analyses.

Participants agreed on the importance of the IO approach and supported it fully as planned.

2.4.4 Summary and conclusions

Participants concurred with the Chair's summary that the steering committee had carefully considered the reviewers' comments. In particular, and taking into account the importance of being able to pool data from previous surveys when estimating parameters such as the detection function, it was agreed that:

(1) all observers should have prior experience in shipboard surveys for porpoises, with priority being given to those that have participated in previous vaquita surveys (the proposed teams are acceptable);
(2) efforts should be made to find opportunities for additional Mexican observers (e.g. those experienced in the tuna-dolphin programme) to participate in harbour porpoise surveys in the U.S. or Europe, particularly in areas with similar conditions (e.g. turbid waters) to increase the pool of Mexican observers, especially for future surveys;
(3) the already-chosen vessel for 2015, the *Ocean Starr* (that had successfully been used before for vaquita surveys), is appropriate for the survey in terms of characteristics and equipment;
(4) for future vaquita surveys beyond 2015, when an alternative platform will probably be necessary, serious consideration should be given to the new INAPESCA ship; and

(5) the IO component of the cruise was well thought out and appropriate.

2.5 Acoustic methods – personnel, equipment

The primary acoustic team for the 2015 survey, led by Jaramillo-Legorreta, involves people who have been part of the acoustic monitoring programme for many years and so are greatly experienced. The primary monitoring tool (the C-POD) was tested in 2008 and has been employed in the acoustic monitoring programme since 2011. Jaramillo-Legorreta reported that the standard monitoring grid of C-PODs was already in place for the 2015 season, and that the primary task for September will be for the grid to be extended into the shallow 'acoustic area' to the north and west. He noted that the existing budget is adequate to cover all anticipated personnel and equipment costs; a total of 136 C-PODs will be deployed. It is planned to retrieve all C-PODs at monthly intervals to ensure that they are functioning properly. In order to accomplish the expanded work in September, three additional acoustic field teams will be hired (making six teams all told). Data are expected to be recovered monthly so that by the end of the survey in December, the initial analyses of 50-70% of the data will be complete and the rest by sometime in January 2016.

There was some discussion about whether the steering committee had adequately considered the possibility of the loss of C-PODS, as had occurred during the existing acoustic monitoring programme, and whether such losses would compromise the acoustic component of the 2015 survey programme.

Jaramillo-Legorreta explained that the greatest loss prior to 2014 was of buoys marking the boundaries of the Vaquita Refuge. Sensors deployed inside the Refuge with unmarked moorings were generally undisturbed. The exceptional loss of detectors in 2014 was thought to have been due to an increase in illegal fishing in the Refuge. There is reason to expect that with the increased surveillance and enforcement as a result of the gillnet ban, there will be less risk of losing acoustic equipment. In fact, if (a) throughout the summer the periodic retrieval of equipment already deployed confirms the expected decline in losses and (b) surveillance and enforcement remain strong through the summer and into September, buoys may be used to mark sampling sites to facilitate retrieval and checking functionality. It was acknowledged, however, that this issue of equipment loss (and damage) is a matter that requires constant attention and monitoring.

2.5.1 Summary and conclusions

Participants concurred with the Chair's summary that the steering committee had carefully considered the reviewers' comments and that the revised plans were acceptable with respect to personnel and equipment. The importance of regular checking of the acoustic equipment to make sure it is present and functioning as intended was emphasised.

2.6 Consideration of supplementary methods e.g. drones, land-based observers, small boats in shallow waters

Several reviewers had commented on the possibility of using different approaches and technologies to those proposed by the steering committee whilst others had expressed their view that the present survey was not the appropriate place to test new methods and equipment. The suggested supplementary methods were considered and are discussed below.

2.6.1 Drones

Barlow noted that the use of aerial surveys for vaquitas had been evaluated several years ago when it had been considered impractical because of the extreme turbidity of the northern Gulf. Under such conditions, vaquitas (which spend only around 2% of their time at the surface) are visible at the surface for only about a second and are not visible at all underwater. He stated that no practical method has been proposed to estimate the fraction of animals missed in such conditions. He noted that no photographs of a vaquita (or other porpoise) have been taken from a drone.

Fleischer acknowledged that the use of drones would require a new experimental design and evaluation of different kinds of high-definition cameras and urged that their potential use in the future not be discouraged. He noted that drones have a number of advantages over aircraft for surveys of marine life, e.g. slower speeds and capability of remaining in one area; they have been used successfully for detecting sharks near public beaches; and the resolution of images has been found to be adequate in certain contexts.

Participants agreed that given the priority of the survey (see Item 1.1), the use of drones should not be integrated into the planning for 2015. However, it was also agreed that experimentation in other contexts (e.g. harbour porpoise surveys) is worth pursuing such that the possibility can be re-evaluated in future years.

2.6.2 Land-based observers
It had been suggested that an observation platform could be constructed on Rocas Consag (see Fig. 1) to allow for land-based observations of vaquitas. Rojas-Bracho noted that he and his team had investigated the possibility some years ago but had found it to be impractical given safety concerns, high cost and uncertainty of obtaining sufficient sightings. With respect to the priority of the 2015 survey, it was agreed that the area that could be effectively searched would be far too small to contribute significantly to obtaining a precise estimate of abundance.

2.6.3 Small boats in shallow waters
Water conditions and the behaviour of vaquitas mean that they present an inconspicuous visual cue (see Item 2.6.1). Previous experience with small-boat surveys of vaquitas has demonstrated the difficulty of detecting and counting them and confirming identification from small boats, probably due to a combination of the relatively low platform height (and thus narrow effective search width), the tendency of the animals to move away from approaching vessels (avoidance), and low density. These factors are not conducive to the objective of obtaining a precise estimate in 2015.

For these reasons the steering committee had decided that acoustic monitoring was the most efficient and practical way to survey shallow (<20m) waters.

2.6.4 Summary and conclusions
Participants concurred with the Chair’s summary that the steering committee had carefully considered the reviewers’ comments and that:

(1) the objective of the 2015 survey meant that in general it was not appropriate for experimental work (and see Item 2.4);
(2) the supplementary methods considered above, either singly or in combination, would not improve the proposed plans for 2015;
(3) additional methodological and technological approaches should continue to be evaluated, including in the broader context of vaquita research (i.e. not simply in terms of obtaining a precise abundance estimate).

2.7 Other
In response to an invitation by the Chair, no other issues were raised by participants.

3. ANALYTICAL APPROACHES

The Chair noted that, particularly given the time available, this section of the agenda was not intended to resolve all analytical issues but rather to ensure that, in terms of potentially productive approaches, none would be precluded by the chosen data collection methods and protocols. Many of the reviewers had made valuable contributions to the discussions of analytical methods and these had been appreciated and taken into account to a large extent in the steering committee’s responses (Annex E, Appendix E1)

3.1 Design-based and model-based
This matter was not discussed in detail during the Webinar although it had been discussed extensively in comments on the proposal. All agreed that there were advantages and disadvantages in both approaches and that both should be considered either individually or in combination in the final analyses and report from the surveys. Most importantly, all agreed with the Chair’s summary that the data collection methods (see Item 2) did not preclude any potentially useful post-survey analytical approaches.

3.2 Biases – availability, detection, responsive movement
3.2.1 Availability and detection bias
Participants agreed that both these types of bias would need to be considered in obtaining a robust and precise abundance estimate. Present data collection methods will allow this to be achieved to the extent possible.

3.2.2 Responsive movement
Vaquitas are known to exhibit responsive movement (avoidance) at the approach of noisy vessels, including the *Ocean Starr.* Again all participants agreed that it will therefore be necessary to account for this in the analysis.

3.2.3 Summary and conclusions
Participants concurred with the Chair's summary that the above biases should and could be addressed in the analysis given sufficient data and that the data collection methods were appropriate. Participants noted that the revised proposal addressed these issues in an adequate manner and also encouraged further collaboration with Mexican and international experts with respect to analytical techniques.

3.3 Acoustics – detection area and calibration
Jaramillo-Legorreta noted that a small-scale playback experiment is planned to determine the variability in acoustic detection between shallow and deep areas, as such variability could bias the extrapolation of densities from one acoustic sampling device to another. In terms of the objectives, the overall intention is to obtain acoustic detection rates at the same time as visual detection rates in the overlap area such that appropriate correction factors can be applied to the acoustic data obtained in shallow areas.

In discussion, reference was made to the recent Static Acoustic Monitoring of the Baltic Sea Harbour Porpoise (SAMBAH). Researchers had calibrated each monitoring site using an artificial playback device. Strong differences in detection probabilities had been obtained for different parts of the Baltic, probably due to the exceptionally stratified water column in that sea. Experience there and in other areas has demonstrated the value of including playbacks at different depths and with different substrates.

Participants recognised that the situation in the much larger Baltic Sea was quite different to that in the portion of the northern Gulf of California to be surveyed for vaquitas. However, it emphasised the importance of carrying out appropriate calibration work under various conditions, especially depth, which might affect detection of vaquita signals.

3.3.1 Summary and conclusions
Participants concurred with the Chair's summary that the steering committee had carefully considered the reviewers' comments and that the existing plans are satisfactory but also that:

(1) the steering committee should continue to work to refine the playback work based on additional input from relevant experts; and

(2) factors to consider should include: the nature of the source (e.g. recorded clicks versus synthesised clicks, use of a directional transducer) and what comprises a sufficient range of depths and habitat types.

3.4 Calibration of acoustic and visual data
The objective of this exercise is to obtain the data needed to develop appropriate correction factors that will allow visual and acoustic data to be combined. This will include estimation of density of vaquitas from sightings and of relative density of vaquitas from daily click rates. The ratio of these will be adjusted in light of the calibration work undertaken described under Item 3.3. Considerable discussion of the approach to be used is contained in the reviewers' comments and the response of the steering committee.

3.4.1 Summary and conclusions
Participants concurred with the Chair's summary that the steering committee had carefully considered the reviewers' comments and that the existing plans are satisfactory but also that the steering committee should continue to consult with outside experts (e.g. L. Thomas, D. Borchers) on the best ways to capture uncertainties associated with the calibration results.

3.5 Accounting for uncertainty
All participants recognised the importance of capturing uncertainty in order to obtain a robust and precise estimate of abundance of vaquitas from the survey. A considerable amount of effort had been expended by the steering committee and reviewers on this topic.

3.5.1 Summary and conclusions
Participants concurred with the Chair's summary that the steering committee had carefully considered the reviewers' comments and that the existing plans, including data collection, are satisfactory. It was stressed that extensive collaboration has taken place among institutions and experts and that this pattern should be maintained through all phases of post-survey analysis and publication of results.

3.6 Other

Partly in response to some of the reviewers' comments with respect to data being available for alternative analyses, the Webinar considered issues related to data availability, reporting of results and ultimate peer-reviewed publication of the abundance estimate. Initial plans for post-survey analysis and presentation of results are specified in the "Research Design to estimate vaquita abundance. With addendum to optimize design given new results on 2013-2014 rate of decline" document (Annex E, Appendix E2).

Participants were informed that the steering committee intends to follow a standard process of scientific peer review and publication, and that in addition, following Mexican policy, data collected at government expense will be made publicly available.

There was considerable discussion of the value of collaboration at all stages of the analytical process and the openness of the steering committee in requesting outside reviews up to the present stage of the project was acknowledged. The pattern, as for previous surveys, was intended to be collaborative in principle and in practice. In addition to the data becoming available, results will be presented for critical review at various fora including the IWC Scientific Committee and CIRVA.

Taylor drew attention to the model provided by the panel of independent international experts used to conduct the analysis of vaquita acoustic monitoring data (see appendix to CIRVA-5 report). Experts from related disciplines met at a workshop at which the data were available, to reach a common understanding of how the data were collected, potential biases etc. and to exchange ideas on approaches to analyse the data and interpret the results.

3.6.1 Summary and conclusions

Participants concurred with the Chair's summary that:

(1) it is important to continue the process of openness and collaboration with respect to data availability, analyses and presentation of results;

(2) the approach outlined by the steering committee, including the need to present initial results in a timely manner, is appropriate; and

(3) the expert panel and workshop approach outlined above should be followed to develop an authoritative final analysis for submission to appropriate fora and ultimately for a peer-reviewed scientific publication.

4. OTHER SCIENTIFIC MATTERS

Following from the above discussions, especially Item 2, the Chair stressed the importance of starting to plan as soon as possible for future vaquita surveys (beyond 2015). Those plans should take into account any lessons learned from the 2015 survey (including the ability to detect trends) as well as being able to evaluate the effectiveness of existing and future protection and mitigation measures.

5. CONCLUSIONS AND RECOMMENDATIONS

The Chair referred to the inclusive nature of the discussions during the Webinar and the constructive approach of all participants to follow the Terms of Reference (Annex A) in trying to ensure that the 2015 survey and subsequent analyses result in the best possible estimate of vaquita abundance.

Whilst each section in the above report includes a summary and conclusions, the following summarises some of the key conclusions and recommendations:

(1) the open approach by the steering committee and the generous allocation of time by reviewers and Webinar participants has resulted in an excellent proposal for the 2015 survey, recognising the Terms of Reference provided – this approach should be extended to the analytical phase;

(2) specific recommendations for additional considerations in experimental design and implementation through collaboration with outside experts have been made in this report, including those related to final tracklines and playback experiments;

(3) it is essential to begin to consider aspects of any future surveys, including the possible use of the new INAPESCA vessel and investigation of ways to expand the pool of trained Mexican observers (e.g. by enabling participation in harbour porpoise surveys in the USA and Europe);

(4) the model of holding an expert workshop at which data are available and alternative analyses can be undertaken is recommended.

Annexes

ANNEX A

SEMARNAT

SECRETARÍA DE MEDIO AMBIENTE Y RECURSOS NATURALES

Subsecretaría de Gestión para la Protección Ambiental

TERMS OF REFERENCE FOR THE VAQUITA SURVEY-2015 WEBINAR

Wednesday 17 June, 2015
8:30 am, Pacific Daylight Time (GMT minus 7 hours)

The Department of the Environment (SEMARNAT) is funding a new vaquita abundance survey in the second half of 2015. The design includes both a traditional line-transect ship-based survey and use of passive acoustics (CPODs) to detect vaquitas in shallow waters that are inaccessible to the ship. Given the dramatic decline in vaquita numbers, which is expected to greatly reduce the frequency of sightings compared to previous surveys, the visual survey component will concentrate effort in areas of known (or expected) relatively high density.

SEMARNAT has concluded that the approach proposed (and as recommended by several experts), using the same vessel as was used in 1997 and 2008 and covering the shallow-water area with a grid of passive acoustic monitoring devices, will provide the most precise abundance estimate possible given the anticipated low number of encounters.

The webinar should focus on the proposal from the survey steering committee and cover the following topics:

(1) Abundance estimation for deep waters (core area)
(2) Abundance estimation for shallow waters using passive acoustic methods
(3) Calibration of acoustic and visual data.

All participants are expected to be familiar with the materials circulated by Annette Henry on 11 June 2015. These include the original proposal, comments from international and Mexican reviewers and the response to those comments by the proposers.

It is the last document, called "Response to reviewers" that will form the primary basis for the discussion.

ANNEX B

WEBINAR DOCUMENTS

Primary Documents (Annex E, Appendices E1 & E2)

Vaquita 2015 Survey Steering Committee. 2015. Responses to reviewers' comments on ¨Research design to estimate vaquita abundance¨. 11th June. 5p (Appendix E1)

Vaquita 2015 Survey Steering Committee. 2015. Research design to estimate vaquita abundance. With Addendum to optimize design given new results on 2013-2014 rate of decline. 15th May. 29p (Appendix E2)

Reviews (Annex E, Appendices E3–E11)

Borchers, D., Hammond, P. and Thomas, L. 2015. Review of Research Design to Estimate Vaquita Abundance. University of St Andrews, St Andrews, UK. 14th May. 5p (Appendix E3)

Borchers, D. email on Jun 17, 2015 at 8:39 AM (Appendix E4)

Cisneros, M.A. 2015. Comments on Research Design to Estimate Vaquita Abundance. Instituto Nacional de la Pesca (INAPESCA). 14th May. 3p (Appendix E5)

Del Monte, P. 2015. Review Observation to the Manuscript ¨Research design to estimate vaquita abundance¨. Instituto Politécnico Nacional – CICIMAR, La Paz, BCS. 11th June. 5p (Appendix E6)

Dawson, S. and Slooten, E. 2015. Review of ¨Research design to estimate vaquita abundance". Marine Science. University of Otago. 15th May. 1p (Appendix E7)

Fleischer, L. 2015. Comments on Research Design to Estimate Vaquita Abundance. Comisión Nacional de Acuacultura y Pesca (CONAPESCA). 14th May. 2p (Appendix E8)

Pérez-Cortés Moreno, H. 2015. Comments to the proposed research to estimate visual and acoustic abundance of the vaquita. Sub-delegación de la SEMARNAT, La Paz, BCS. 14th May. 1p (Appendix E9)

Thomas, L. 2015. Letter to the Vaquita Survey Design Steering Committee. Comments on the document ¨Response to reviewers´comments on research design to estimate vaquita abundance¨. University of St Andrews. 17th June. 3p (Appendix E10)

Ulloa, P. 2015. Comments on Research Design to Estimate Vaquita Abundance. Instituto Nacional de la Pesca (INAPESCA). 14th May. 2p (Appendix E11)

Published Documents

Gerrodette, T., Taylor, B.L., Swift, R., Rankin, Sh., Jaramillo-Legorreta, M.A. 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* 27(2):E79-E100

Jaramillo-Legorreta, M.A., Rojas-Bracho, L. and T. Gerrodette. 1999. A new abundance estimate for vaquitas: first step for recovery. *Marine Mammal Science* 15(4):957-973

Unpublished Background Document

Report on Vaquita Rate of Change Between 2011 and 2013 Using Passive Acoustic Date by the expert Panel on Spatial Models. CIRVA-V: Annex 9. June 24-26, 2014. Meeting held at Southwest Fisheries Science Center, La Jolla, CA, USA. 50p.

Available at:
https://archive.iwc.int/pages/view.php?ref=5461&search=%21collection207&order_by=relevance&sort=DESC&offset=0&archive=0&k=&curpos=24

ANNEX C

AGENDA

1. INTRODUCTORY ITEMS

1.1 Chair's opening remarks

1.2 Appointment of rapporteur

1.3 Adoption of agenda

1.4 Process for development of report

2. PRACTICAL SURVEY ISSUES

2.1 Survey areas and timing

2.2 Trackline design for visual survey

2.3 Placement and number of acoustic sampling sites

2.4 Visual methods – personnel, equipment incl. vessel choice, independent observer and tracking

2.5 Acoustic methods – personnel, equipment

2.6 Consideration of supplementary methods e.g. drones, land-based observers, small boats in shallow water

2.7 Other

3. ANALYTICAL APPROACHES

3.1 Design-based and model-based

3.2 Biases – availability, detection, responsive movement

3.3 Acoustic – detection area and calibration

3.4 Calibration of acoustic and visual data

3.5 Accounting for uncertainty

3.6 Other

4. OTHER SCIENTIFIC MATTERS, IF ANY

5. CONCLUSIONS AND RECOMMENDATIONS

ANNEX D

LIST OF PARTICIPANTS

Name	Institution	Comments
Ballance, Lisa	SWFSC	
Barlow, Jay	SWFSC	
Borchers, David	University of St Andrews	Sent an email with comments
Cárdenas Hinojosa, Gustavo	INECC	
Cisneros Mata, Miguel Ángel	INAPESCA	
Dawson, Stephen	University of Otago	
Del Monte, Pablo	CICIMAR	Sent an email with comments
Donovan, Greg	IWC	
Fleischer, Luis	CONAPESCA	
Gerrodette, Tim	SWFSC	
Hammond, Phillip	University of St Andrews	
Henry, Annette	SWFSC	
Jaramillo Legorreta, Armando	INECC	
Nieto García, Edwyna	INECC	
Pérez-Cortés Moreno Héctor	SEMARNAT	
Reeves, Randall	IUCN SSC	
Rojas Bracho, Lorenzo	INECC	
Slooten, Liz	University of Otago	
Taylor, Barbara	SWFSC	
Thomas, Len	University of St Andrews	Sent an email with comments
Ulloa Ramírez, Pedro	INAPESCA	
Werner, Cisco	SWFSC	

ANNEX E

WEBINAR BACKGROUND DOCUMENTS

APPENDIX E1

Responses to reviewers' comments on "Research design to estimate vaquita abundance" by Rojas-Bracho et al.

The figure below summarizes the revised visual and acoustic sampling design for the 2015 vaquita abundance study. Brief responses to reviewers' comments follow.

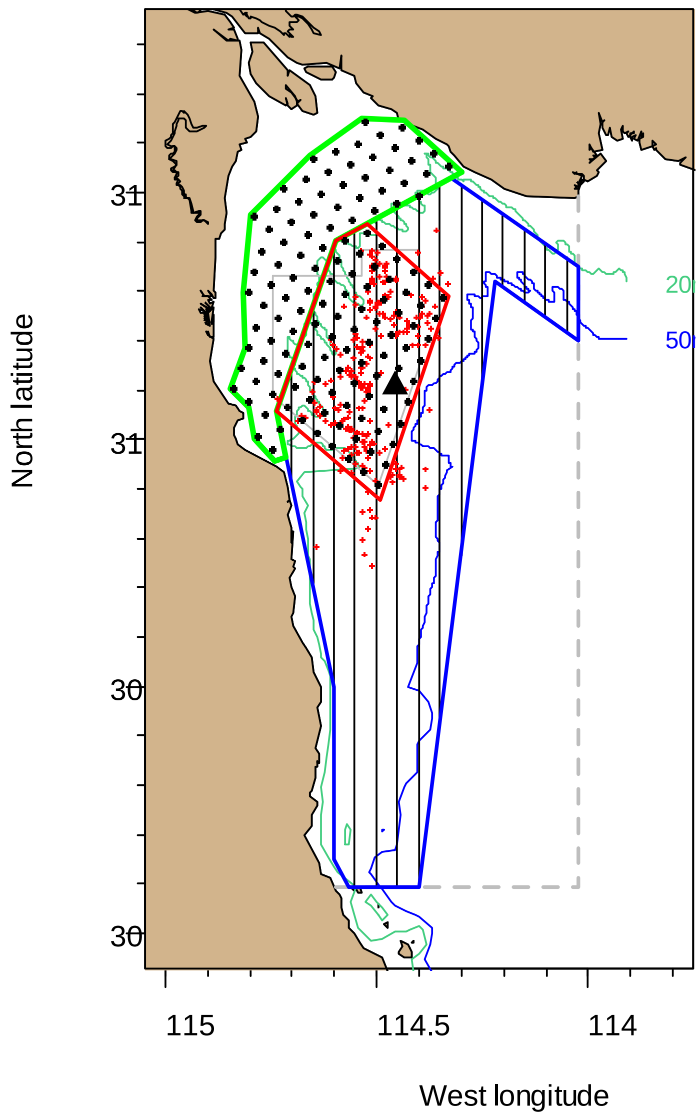


Fig. 1. Research design for the 2015 vaquita abundance study. The area to be sampled visually is outlined in blue, and visual transects are shown as black north-south lines. The area to be sampled acoustically is outlined in green, and acoustic sensor (C-POD) locations are shown as black points. The area to be sampled with both acoustic and visual methods (the calibration area) is outlined in red. Vaquita sightings during the 1997 and 2008 surveys are shown as small red points. The gillnet exclusion area is shown as a dashed gray line, the Vaquita Refuge Area as

a thin gray line, and Consag Rocks as a black triangle. Depth contours of 20m and 50m are shown.

Review from University of St. Andrews (UK):

2a. The revised visual transects sample the area between 20m and 50m within the gillnet exclusion area (Fig. 1). The visual area includes locations of all vaquita sightings and acoustic detections except those in shallow water. The C-PODs sample the area between 10m and 20m in the northeast part of the study area where the ship cannot go. The calibration area has both visual and acoustic sampling.

2b. The north-south transect lines are spaced 0.05° of longitude apart with a random starting point.

2c. The transect lines shown in Fig. 1 have a total distance of about 600nm. Based on past experience, we have a good chance of achieving that amount of transect effort during the first leg. If weather is good, we will complete these lines and begin a secondary series of lines (not shown in the figure) midway between the primary lines. Given the low Beaufort conditions necessary to detect vaquitas, it frequently happens that a transect cannot be completed all at once, and each line ends up being a composite of effort on different days. In addition, transects are of quite different lengths. Under these conditions, what constitutes a replicate for purposes of variance estimation is not so clear. In past analyses for vaquitas and other species, we have used several methods, so we welcome the reviewers' thoughts on this point.

2d. During the second leg of the survey, we plan to sample intensively in the calibration area, where most sightings occurred during surveys in 1997 and 2008 (Fig. 1). Our planned survey is not an adaptive design. Our comment about possible changes was simply meant to cover the remote possibility that we will encounter a significant number of vaquitas outside this core area during leg 1.

2e. The redesigned visual survey area contains only north-south transect lines (Fig. 1). In the southern part of the study area, the lines are parallel rather than perpendicular to depth contours. This is not ideal, but is logistically easier and allows even spatial coverage. The probability of encountering vaquitas south of 30.7N is low, so we think this is a minor issue.

2f. The pre-existing acoustic sensors are laid out in a regular grid. For the 2015 vaquita abundance study, the existing grid will be augmented by additional sensors at the same density in shallow water (Fig. 1). There are 136 acoustic sensors (C-PODs), which is our financial and logistical limit. The sensors are in 2 groups: (1) in shallow water where the ship cannot survey, approximately between the 10m and 20m depth contours in the northwest part of the study area; and (2) in a calibration area where there will be simultaneous visual and acoustic sampling. Data from the calibration area will be used to estimate abundance from click rates in shallow water. As noted previously, dedicated experiments on click detection rates in shallow and deep water will also be conducted as part of the calibration.

2g. The acoustic sensors are evenly spaced within the calibration stratum (Fig. 1), and the level of acoustic sampling will be the same during both legs of the cruise. However, the intensity of visual sampling will be much greater during the second leg, so the 2 periods will be treated separately to allow for possibly different vaquita density within the calibration area.

2h. Stratum boundaries are shown in Fig. 1.

2i. The 8 sparse acoustic sensors in the southern part of the study area have been replaced by visual transects.

3. We agree with the comments about model-based vs design-based analysis. Just for the reasons the reviewers stated, we plan a design-based analysis but may adopt a model-based approach if the data warrant. In a survey of a rare animal like this, the quality and consistency of the data depend on several factors, including the weather, the small number of expected detections, and the clumped distribution of detections.

4. For calibrating visual and acoustic effort, we will only consider data collected in the same area at the same time. There will be 2 separate periods and areas corresponding to the first and second legs of the survey. We expect that most of the data for calibration will come during the second leg when sighting effort is concentrated in the calibration area (Fig. 1).

5. We agree with the comment and do not intend to implement hypothesis testing. On one hand, the experiment to play artificial porpoise clicks is intended to compare the ability to detect, store and identify porpoise-like clicks by C-PODs under different noise conditions (addressed by different sampling depths). With the experiment we can estimate a proportion of the number of porpoise clicks identified in C-PODs in relationship with clicks played. Then the ratio of the proportions between shallow and deep water can be used to correct number of clicks in shallow water. On the other hand, as the reviewers indicate, it is important to determine if the effective detection radial distance changes with depth. A calibration factor can be constructed as explained above using a ratio. To determine effective detection radial distances, we will establish a minimum average SPL of identified clicks as a threshold. This minimum must be enough to identify click series with medium quality according to the C-POD standard. When this minimum is reached the distance will be selected as the effective radial distance. The ratio of radial distances in shallow and deep water will be used as a calibration factor to correct for the number of clicks.

6. Based on past observations, while vaquitas do react to the ship, the response is to move a short distance out of the ship's path. They do not flee the area. Vaquitas live in an area of intense fishing activity and are accustomed to boats and boat noise. If there were a major change in the spatial distribution of vaquitas during the second leg of the cruise, we anticipate that it would be detected by the acoustic array.

7. We appreciate the comments about the dual-team approach. We neglected to mention that audio recordings will be made of all communication between observers on each team and the data recorder, and the audio record will be available for review of ambiguous matches. The "tracker" design was attempted during the 1997 survey and found inappropriate for vaquitas. Recording swim speed and swim direction of animals is part of our regular protocol.

8. We do not believe availability bias is an issue. Given 10-m observer height, 25X binoculars, 6-knot ship speed and harbor porpoise diving intervals, vaquitas will surface at least once, and more probably 2-3 times, while in our search area. We will try to record repeated surfacings of already detected vaquitas and use the methods described in Borchers and Langrock 2015, if this can be done by off-duty observers so that the main search effort is not compromised. Audio recordings will provide a backup if all data cannot be entered in the computer record. On-duty observers will be instructed to call out angle and distance information if resightings are made in

the process of their normal search. We expect a low number of vaquita sightings, but they are likely to be clustered together, so it is critical that observers maintain normal searching after the initial sighting.

9. We agree that aversive movement is a potentially serious issue for any line-transect survey, and that we will have to consider its effect when estimating abundance from the data collected on this project. While we have evidence that vaquitas react at distances up to 1km radial distance, the reaction is not strong. The distribution of perpendicular distances during the 2008 survey did not indicate that reactive movement was an issue for estimating effective strip width (Gerrodette et al, 2011, Fig. 3A).

Reviews from several institutions in Mexico:

Consideration of other vessels, other times of year, and other methods of detecting vaquitas (hand-held binoculars, drones, land-based observations) are topics that may be considered for future studies, but consideration of these issues is not part of this review.

Estimation of vaquita density and absolute abundance will be based on distance sampling methods from the large vessel (see papers for 1997 and 2008 cruises, and references therein). The shallower areas, where the ship is unable to survey, will be covered using passive acoustic detection. This method has been applied since 2011 to estimate vaquita population trend (see document on the analysis of acoustic data 2011-2014, which contains a full description of data and statistical analyses performed). Also, the 2008 estimate was a combination of visual data in deeper areas and acoustic data in shallower ones. The analysis will include all sources of uncertainty, using either bootstrap or Bayesian methods.

Appendix 5 establishes that acoustic detection process could be altered in shallow waters, and describes an experiment to construct calibration factors, and associated variances, to correct acoustic measures in case the effective range of detection is shorter in these waters.

It is necessary to point out clearly that gillnet and long-line fishing is not allowed in the vaquita distribution area for the next two years, according to the agreement published in the *Diario Oficial de la Federación* (DOF), Mexico´s Federal Register. To avoid loss of equipment during the 2015 survey, we are emphasizing that the regulations must be enforced and that there should be no illegal fishing.

One review commented on the level of Mexican participation in vaquita studies. Mexican scientists have been conducting and publishing globally recognized vaquita research for more than 20 years. Previous vaquita surveys in 1997 and 2008 were jointly led by Mexican and US scientists, and the pioneering acoustic monitoring program has been developed and led by Mexican scientists. During the 2008 cruise, special efforts were made to train new observers, including both Mexican students and INAPESCA scientists. Unfortunately, even in 2008 the sightings of vaquitas were so rare that these new observers saw very few vaquitas. Given the short timeframe desired for a new abundance estimate and the anticipated rarity of sightings, the 2015 cruise is not suitable as a training exercise. We agree that Mexican scientists need to be trained, but this training will have to occur on cruises for harbor porpoises. Distance sampling methods are taught at many universities and at regular workshops at the University of St.

Andrews in Scotland. Mexico has an active marine mammal society (SOMEMMA) with many capable scientists, and some of them use line-transect methods in their research.

With regard to publication, CIRVA reports are not suitable for journal publication because the Recovery Team does not conduct original analyses. The exceptional circumstances of the recent decline in vaquitas required a separate Expert Panel of statisticians to carry out the specialized analyses of the C-POD data. Detailed reports of these analyses have been made available to CONAPESCA and INAPESCA scientists, and the Expert Panel has offered to address questions and concerns. The monitoring program was originally designed for a 5-year period. It is only because of the alarming decline in the 3-year period from 2011-2014 that analyses have had to be conducted and publicized more quickly than originally planned. A paper describing this recent research is in preparation and will be submitted for publication this summer.

Reviews from University of Otago (New Zealand):

The zig-zag lines of the proposal have been replaced by a series of north-south visual transects covering all vaquita habitat less than 50m (Fig. 1). The area includes all confirmed vaquita sightings and acoustic detections.

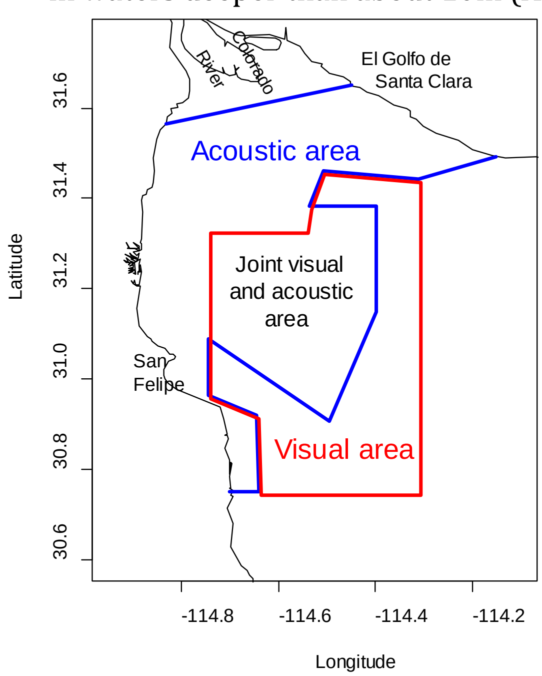
APPENDIX E2
Research design to estimate vaquita abundance
With Addendum to optimize design given new results on 2013-2014 rate of decline

Dr. Lorenzo Rojas-Bracho, Dr. Barbara L. Taylor
Joint cruise leaders
Dr. Armando Jaramillo-Legorreta
Project lead on acoustics
Dr. Jay Barlow, Dr. Tim Gerrodette, Annette Henry,
Edwyna Nieto-García, Gustavo Cárdenas-Hinojosa
Steering Committee

Objective: To provide the Government of Mexico an accurate and precise estimate of current vaquita (*Phocoena sinus*) abundance as soon as possible.
Important times: Survey dates anticipated as September 15-December 6, 2015.
Report with new abundance estimate May 1, 2016.

Estimating the abundance of the most endangered marine mammal in the world is not easy. Vaquitas are notoriously difficult to detect. A complete count (a census) of vaquitas is not possible, so any method of determining vaquita abundance will be based on statistics and will contain some degree of uncertainty. Fortunately there is a history of estimating vaquita abundance, so it is known which methods work and which do not work (Appendix 1). The most accurate and precise estimate of 2015 vaquita abundance will require both visual and acoustic components covering the entire range of the vaquita in the northwestern Gulf of California. No form of aerial survey has been found to be suitable for estimating vaquita abundance, and mark-recapture methods with photo-identification are not feasible (Appendix 1).

The visual component of the vaquita survey utilizes a large ship to conduct transects in waters deeper than about 10m (Appendix 2). The most effective method is to use high power (25x) binoculars at a height of at least 10m above the water. The powerful binoculars allow vaquitas to be detected up to 5km from the ship, which is important because vaquitas react to the ship at distances up to 1km. Accurate estimation of abundance requires detection before the animals react to the ship. For this reason, the visual part of the 2015 vaquita survey should utilize a ship that can support 25X binoculars on a covered observation deck 10m or more above the water (Appendix 3).



The acoustic component of the survey is necessary because part of the vaquita population lives in shallow waters that cannot be visually surveyed by the large ship. The acoustic data will allow the estimate of vaquita density from the visual survey area to be extrapolated into shallow areas (Appendix 4). To increase the precision of the estimate in shallow water areas, we recommend using an array of autonomous acoustic recording devices (CPODs) instead of the single towed hydrophone that was used in 2008. This will require maintaining the grid of 45 CPODs in their current locations throughout the Vaquita Refuge and adding 68 CPODs located evenly throughout the shallow water area (Appendix 4). Shallow-water locations are likely to be noisier than deeper-water areas because the CPOD is necessarily closer to the bottom with noise from snapping shrimp and sediment particle collisions and closer to the surface where breaking waves introduce noise. Dedicated experiments will be carried out to estimate the reduced capacity to detect vaquita clicks to correct for any bias in the abundance estimate (Appendix 5). *To avoid loss of the CPODs, no fishing of any kind (including trawling) can occur during the research period unless coordinated with the survey leaders.* This may require extra enforcement and coordination and potential restrictions on trawling activities. In addition to the staff required to deploy and retrieve this network of CPODs, we recommend hiring 2 additional experienced CPOD analysts from the European Union project on harbor porpoise to augment Mexico's two already experienced staff to analyze the CPOD data as the season progresses. The expected 7,200 days of acoustic data should greatly increase abundance precision for the shallow water area (including 4,350 days within the shallow water area), which was a large contributor to imprecision in past estimates.

Another source of imprecision in past estimates was the estimate of the fraction of vaquitas missed on the trackline (analytically known as g(0)). Due to the turbid waters in the upper Gulf of California and the elusive behavior of vaquitas, a substantial fraction of vaquitas will not be detected even when they are close to the ship. An estimate of this fraction of animals missed is necessary for accurate estimation of abundance. The fraction is specific to the ship and specific to the sighting protocols (number of observers and type of binoculars used). For the *Ocean Starr* and the sighting protocols recommended in this proposal, the fraction missed was estimated to be 0.43. In other words, even with 3 observers searching with 25X binoculars and one observer with hand-held binoculars at a height of 10.2m above the water, only 57% of vaquitas were detected near the trackline. If the fraction of vaquitas missed is not taken into account, the abundance of vaquitas will be underestimated.

Because knowing the fraction of animals missed is so important, the 2015 vaquita cruise will use 2 teams of observers. One team will observe from the flying bridge level and an independent team will search from the bridge level. All observers will use 25X binoculars. This will allow the fraction missed to be estimated. Two specialized data recorders will take data from both teams and determine which vaquitas were seen by both teams in real time. The number of total observers needed is 12, because the 6 observers on watch at any one time need to be rotated regularly to prevent fatigue. It is also critically important that nearly all of the observers have previous experience with vaquita or harbor porpoise. For this very important study, we should use only the most experienced porpoise observers possible. Observers must be able to differentiate between vaquita and bottlenose dolphins (also found in small groups in the area and easily confused with vaquitas). We can obtain enough experienced observers from past vaquita surveys, plus some observers from the EU porpoise efforts to staff the cruise.

To obtain at least 40 vaquita sightings with 95% probability (Appendix 6) requires 64 days in the study area using the same ship (*R/V Ocean Starr*) as past surveys in 1993, 1997 and 2008. An addendum has been added at the conclusion of this document to account for the larger than anticipated decline in vaquita abundance between 2013 and 2014 from analyses done on acoustic monitoring data (completed April 28). Both the visual and acoustic designs were changed to optimize survey precision and also cover areas within the 2-year emergency ban area that were not covered in the 2008 survey. Because the ship survey will use standard software and analytical methods, results from the area surveyed by the ship is anticipated approximately six weeks following the surveys. With acoustic analysts working throughout the survey, it is anticipated that acoustic CPOD data should be processed within six weeks of the end of the survey. Pooling the visual and acoustic data to make a total abundance estimate will take an additional six weeks such that abundance estimates should be ready 3 months after the conclusions of field operations.

One of the important components of a successful survey of this very rare porpoise is using a team of scientists and support staff already experienced in vaquita and porpoise research. A list of staff with brief skill descriptions are given in Appendix 7. Finally, because this work affects the management of a critically endangered species which, in turn, affects the livelihood of thousands of people, we strongly recommended that the survey design be reviewed by the best available experts in marine mammal visual and acoustic surveys. We have requested such a review to both the Society for Marine Mammalogy (the international scientific society for the study of marine mammals) and the International Whaling Commission's Scientific Committee, which developed standards for surveys of marine mammals and expect a review by May 15.

The total estimated costs are: $42,299,439 (MXN). Details of the budget and payment times are given in Appendix 8. Anticipated cruise dates are from September 15 through December 6, 2015 (depending on negotiations for ship time). The report with a new vaquita abundance estimate is anticipated in May 1, 2016.

Appendix 1: An Evaluation of Potential Abundance Estimation Methods for Vaquita

Executive Summary

A wide variety of methods have been developed and used to estimate the abundance of cetaceans (whales, dolphins and porpoises). Methods fall into three general categories: complete enumeration methods (census), density-based survey methods, and mark-recapture methods. Many of these methods have been tried for estimating vaquita abundance in the past. Here we review all available methods and evaluate their utility for estimating vaquita abundance in 2015. We conclude that ship-based visual density estimation complemented by acoustic surveys in shallow waters is the only practical method to obtain a precise estimate of vaquita abundance. Regardless of the method used, survey design and analysis methods should be reviewed by an international team of experts to ensure the credibility of the results. Pilot studies are recommended if new methods are used.

Survey Methods

Complete Enumeration Methods (Census)

The size of human populations in many countries is determined using a census or complete enumeration of all individuals. This works well for humans if the vast majority of individuals can be identified by a permanent address, but even in developed countries some individuals are missed. Outside of zoos and aquaria, the only cetacean population in the world that is censused by complete enumeration is southern resident killer whales in Puget Sound. That method works for them because all individuals are identifiable in a good photograph and because all individuals are seen and photographed every year. Complete enumeration methods will not work for vaquita because the vast majority of animals are not individually identifiable in a good photograph (see mark-recapture methods, below).

All other abundance estimation methods are statistically based and are subject to random sampling variability. For vaquita, there is no method that can estimate abundance without some degree of statistical uncertainty. The best method is one that minimizes this uncertainty for a given survey budget.

Density-based Survey Methods

Density-based survey methods are based on estimating the density of individuals (number of individuals per square kilometer) and then extrapolating that density to a study area. Abundance is estimated as animal density times the size of the study area. This method does not require that all individuals be seen and it doesn't matter if some individuals are seen more than once. Distance-sampling survey methods (Buckland et al, 2001) are a sub-set of density-based methods and require recording the distance between the survey platform (ship or plane) and the animals that are seen. Distance-sampling survey methods include line-transect surveys from boats, ships and aircraft and point-transect surveys from fixed locations. Strip and quadrat surveys are also density-based survey methods but are less efficient and are more typically used for plants and slowly moving animals. Three key requirements for all density-based survey methods are: 1) the survey must be random with respect to the distribution of the animal within the study area, 2) the probability of detection must be estimated (as a function of distance from the survey platform for line- and point-transect surveys), and 3) animals must be detected before they move in reaction to the survey platform.

Visual Line-transect Survey Methods from Boats & Ships

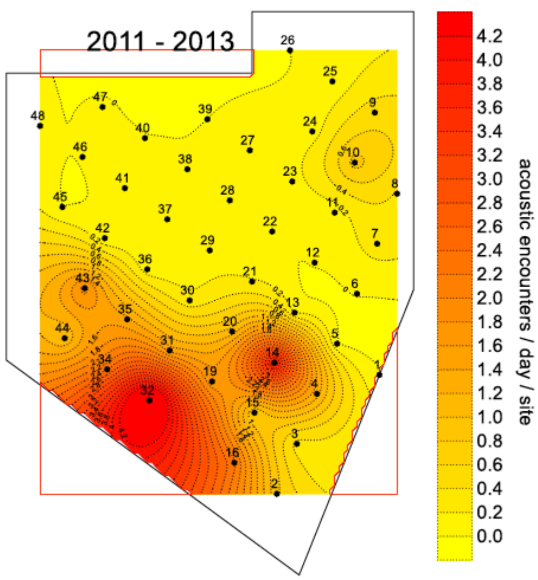
Visual line-transect surveys have been used for many species of cetaceans in many populations around the world. The method has been used successfully on ship-based surveys for vaquita in 1993, 1997, and 2008 and has generated the most precise estimates of vaquita abundance (Barlow et al. 1997; Jaramillo et al. 1999; Gerrodette et al. 2011). Previously, vaquita abundance was crudely estimated from data collected from small boat surveys in 1986-1988 (Barlow et al. 1997), but those estimates were not rigorous because the data were not collected using line-transect methods and because detection probabilities were crudely estimated by guesswork and comparison to other surveys for a different species. The 1997 survey used two independent teams of visual observers on the same ship, and a comparison of data from these two teams showed that vaquita started avoiding the vessel at distances of greater than 1km. High-powered, pedestal-mounted binoculars are required in order to detect vaquita before they move away from the transect line in reaction to the ship. Fujinon 25X150 binoculars were used on each of the three ship-based vaquita surveys. This requirement means that the ship must be large enough (>50 meters length) and stable enough to allow use of such binoculars. The vessel must also be large enough to carry two teams of observers to allow estimation of the probability of detection at zero distance.

One drawback of using a large ship for visual line-transect surveys of vaquita is the need to survey portions of the vaquita distribution that are too shallow to survey by large ship. During the 1997 survey the Mexican research ship BIP XI was used for the shallow water areas. This converted shrimp trawler did not have a configuration (height and stability) suitable for the 25x binoculars, so hand-held binoculars were used. Only 6 sightings were made on-effort in the shallow-water area when the estimated abundance was approximately 600 vaquitas. Because many fewer vaquitas were expected to remain in 2008 (because of ongoing unsustainable deaths in gillnets between 1997 and 2008) a different approach was used: a small sailing vessel towing a hydrophone array (see acoustic line-transect survey methods, below). This was reasonably successful, but again there was sparse sampling and few detections in shallow waters (see below). Because a significant portion of vaquita's range extends into shallow waters, an alternative survey method would be needed to extend the survey into these shallow waters if a ship survey is done in 2015.

Visual Line-transect Survey Methods from Aircraft

Aerial surveys are commonly used to estimate the abundance of harbor porpoise in the U.S. and in Europe. An experimental aerial survey for vaquita was attempted in 1991 (Barlow et al. 1993). Less than two vaquitas were seen on this survey per 1000 km of transect line. Given the extreme turbidity of waters in the upper Gulf of California and the rapid changes in turbidity over short distances (Barlow et al. 1993), no method was found to effectively estimate the probability of detecting vaquitas on the transect line during an aerial survey. The same problem would exist with fixed-wing aircraft, helicopters and drones, so no form of aerial survey will be effective for vaquita abundance estimation.

Land-based surveys
For coastal migrations of gray whales and humpback whales, data are collected from land-based viewing platforms using binocularsObservers change effort to avoid fatigue. Observations are conducted continuously in sea state 2 or less. In 1996 reserachers from the Instituto Nacional de Pesca proposed to build in a viewing platform from Rocas Consag to survey vaquitas. However the project was cancelled after a review with experts and the results of the vaquita 1997 cruise. The cost-benefit ratio is very poor for such a land-based survey because it can only survey from a single point in an area of very low density of vaquitas. Besides, during the 1997 cruise (and subsequent ones) it is clear that the closest vaquitas to these rocks are more than 2 nmi. Low densities near Rocas Consag have been confirmed with the passive acoustic monitoring. The figure below shows vaquita densities using data from 3 years of summer monitoring effort. Rocas Consag lies between CPOD locations 5 and 13, which are near zero in acoustic detections. Vaquitas near the high density site 14 would not be visible from Rocas Consag. Hence the platform has limited value for a proper survey.



Acoustic Line-transect Survey Methods from Boats & Ships
Towed hydrophone arrays have been used in the past to detect the echolocation signals of harbor porpoises, Dall's porpoises, finless porpoises, and vaquitas. Like other porpoises, vaquita produce distinctive echolocation clicks that are easy to distinguish from the lower-frequency clicks made by dolphins in the northern Gulf of California. It is very difficult to estimate porpoise abundance using acoustic methods alone, and this has been done only for harbor porpoises in a few instances and at great expense. One of the difficulties is that hydrophone arrays are towed behind a vessel and porpoises are detected only after they may have reacted to the presence of the vessel. This is a particular problem for vaquita, which respond to ships by moving away from them. Detection probability and avoidance bias are

particularly hard to estimate for vaquita. Acoustic survey data are be more easily used as a measure of relative vaquita density rather than as a measure of absolute density.

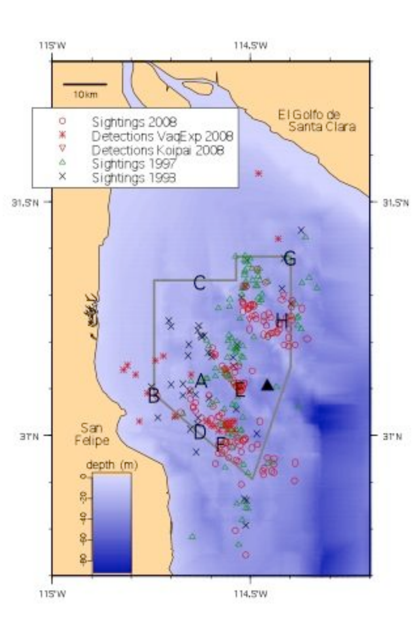
A towed array was used for the 2008 vaquita survey to measure the relative density in a calibration area that overlapped with the visual ship survey and in the shallow water areas where the ship could not survey (Rankin et al. 2009). These data were used as estimates of relative density to extrapolate estimates of absolute density from the calibration area into the shallow-water areas (Gerrodette et al. 2011). A small, 7.3-meter sailing trimaran was used to minimize the avoidance problem and to allow the vessel to survey in very shallow water. There were total of 29 acoustic detections of vaquitas. However, the small sailboat struggled to cover the survey area due to its slow speed, lack of accommodations for multi-day trips, and safety concerns. A larger sailing vessel was recommended for future surveys of this type (Rankin et al. 2009). On the 2008 survey, the acoustic trackline detection probability could only be estimated by comparison with the visual estimates of vaquita density in the area of overlapping survey methods (Gerrodette et al. 2011).

__Acoustic Point-transect Survey Methods from Autonomous Instruments__

In many cases, acoustic data can be collected much more cost-effectively with stationary instruments than with a towed hydrophone array. Instruments (called CPODs) have been developed that can be anchored on the sea floor and collect porpoise acoustic data continuously for 5-6 months. A network of 48 CPODs has been deployed in the vaquita refuge over the past four summers.

A larger network of CPODs have recently been used to estimate the density and abundance of harbor porpoise in the Baltic Sea. The probability of detecting a porpoise as a function of its distance from a CPOD cannot be estimated from a sparse array of single instruments. In the Baltic, a dense array of CPODs was deployed in an area of very high harbor porpoise density, thus allowing CPODs to be used to make absolute estimates of porpoise density. Because there are no areas of high vaquita density, this approach will not work for vaquitas. However, CPODs can be used to estimate relative vaquita density much more precisely than towed hydrophones because many CPODs can be deployed at the same time and collect data day and night for months.

Mark-recapture Methods



Mark-recapture is a commonly used, non-density-based method to estimate wildlife abundance. This method requires that individuals are individually recognized. It is not possible to tag cetaceans in large numbers, so individuals are recognized using distinctive marks seen in high-resolution photographs. This so-called photo-identification method works well with humpback whales and killer whales because every individual in the population has distinctive marks. An intensive photo-identification study was conducted during the 2008 vaquita survey, and only two photographs were obtained of distinctively marked individuals (Jefferson, pers. comm.). No other individuals had marks that were sufficiently distinct to allow them to be recognized if seen at a later date. For this reason, mark-recapture by photo-identification will not work to estimate vaquita abundance. Also, vaquita cannot be physically tagged or genetically tagged (by biopsy) because they cannot be approached. Although Rocas Consag apprears to be in the middle of the vaquita territory (black triangle in the figure), vaquitas appear to avoid this rock and the idea of visual studies from this location, including photographic identification studies, have been abandoned. Mark-recapture methods can be ruled out based on these experiences.

Conclusion

We conclude that visual line-transect surveys from ships are the most robust method to estimate vaquita abundance. The ship must be large enough to accommodate multiple teams of observers and be stable enough to mount 25-power, pedestal mounted binoculars. Such a ship will not be able to survey in shallow-water parts of the vaquita distribution. Acoustic surveys are a cost-effective method to measure relative vaquita density and thereby extrapolate density from the area surveyed by the ship to areas that are too shallow. Autonomous acoustic recorders (CPODs) are much more cost-effective than towed hydrophones for the acoustic component of such a survey.

Pilot Surveys

The use of pilot surveys is strongly recommended whenever an inexperienced team first applies a survey method to estimate cetacean abundance (Dawson et al. 2008).

Expert Peer-review

It is extraordinarily important for a survey plan to be reviewed by a team of experts. No survey plan is perfect and all plans benefit from the careful review by experienced experts in survey design, execution, and analysis. For credibility and transparency, reviews and responses should be in writing.

References

Barlow, J., T. Gerrodette, and G. Silber. 1997. First estimates of vaquita abundance. Mar. Mamm. Sci. 13(1): 44-58.

Barlow, J., L. Fleischer, K. A. Forney, and O. Maravilla-Chavez. 1993. An experimental aerial survey for vaquita (Phocoena sinus) in the northern Gulf of California, Mexico. Mar. Mamm. Sci. 9(1):89-94.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford University Press, Oxford. 432pp.

Dawson, S., P. Wade, E. Slooten, and J. Barlow. 2008. Design and field methods for sighting surveys of cetaceans in coastal and riverine habitats. Mammal Review 38(1):19-49.

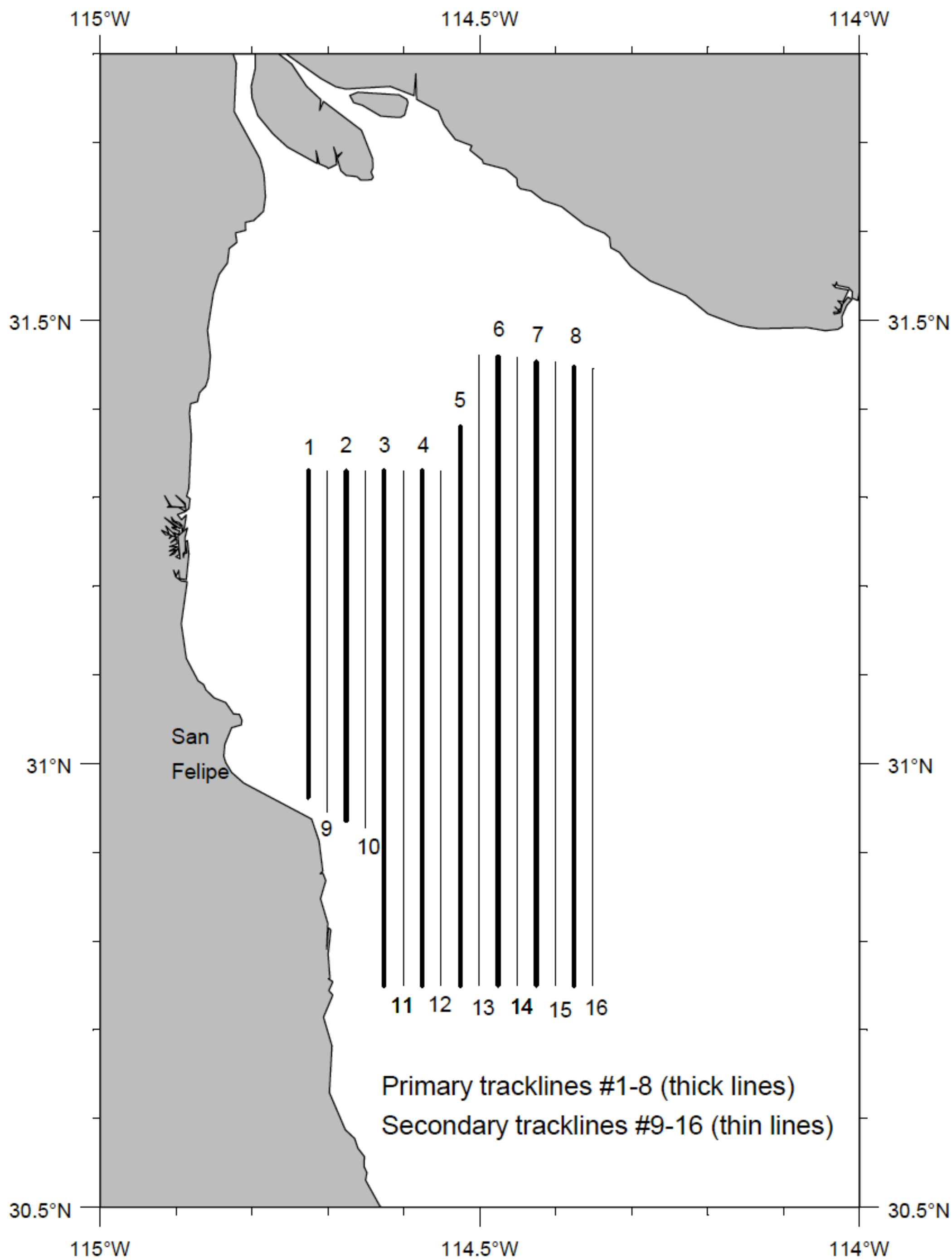
Gerrodette, T., Taylor, B. L., Swift, R., Rankin, S., Jaramillo-Legorreta, A. M., & Rojas-Bracho, L. 2011. A combined visual and acoustic estimate of 2008 abundance, and change in abundance since 1997, for the vaquita, Phocoena sinus. Marine Mammal Science, 27(2), E79-E100.

Jaramillo-Legorreta, A. M., Rojas-Bracho, L., & Gerrodette, T. 1999. A new abundance estimate for vaquitas: first step for recovery. Marine Mammal Science, 15(4), 957-973.

Rankin, S., Swift, R., Risch, D., Taylor, B., Rojas-Bracho, L., Jaramillo-Legorreta, A., & Kimura, S. 2009. Vaquita expedition 2008: Preliminary results from a towed hydrophone survey of the vaquita from the Vaquita Express in the upper Gulf of California.

Appendix 2: Visual survey tracklines and physical setup.

Tracklines would be repeated from the 1997 and 2008 surveys (see Addendum for modified trackline strategy). Tracklines are oriented as in past surveys to be north-south to minimize glare



on the trackline. The configuration of the flying bridge would be similar to that shown below from the 2008 survey, which had 3 full-time 25x binocular observers plus a recorder using the same software (WinCruz) that generates data in the format that can be immediately used in abundance estimation software.

Configuration of the flying bridge with 4 25x binocular positions (photo from 2008 vaquita survey). Two additional pairs of 25x binoculars would be added one deck below (bridge deck) to allow 2 independent teams to estimate the proportion of vaquitas seen on the trackline with greater precision.

Vaquitas can only be seen in the calm conditions shown here and with 25x binoculars at a height above the water of at least 10m.

Appendix 3: Ship requirements

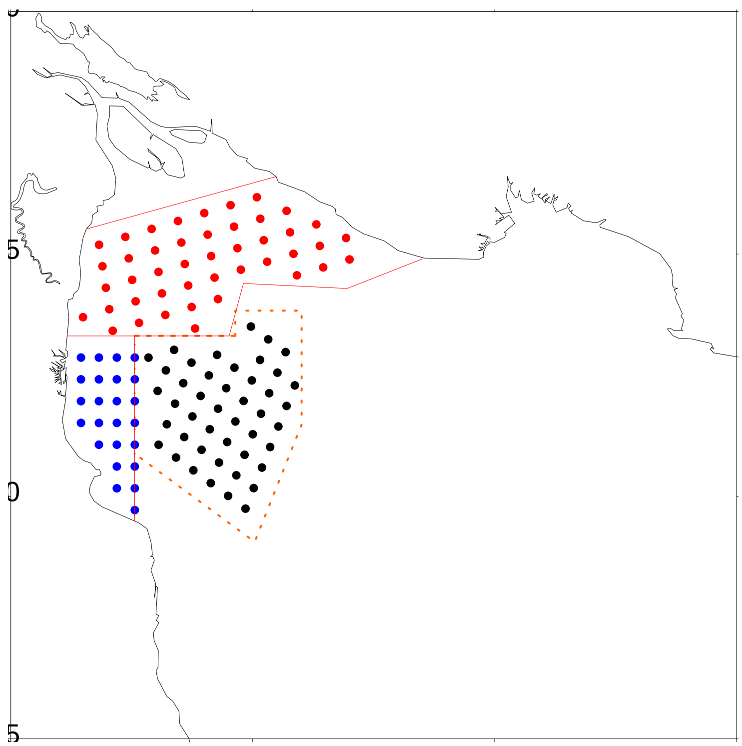
Because vaquitas tend to avoid boats, a ship used for a visual vaquita survey should allow observers to detect vaquitas before they react to the vessel. Based on past experience, this requires 25X binoculars at a height of 10m or more. Hand-held binoculars (7, 8, or 10X) detect fewer vaquitas and are not recommended as the primary method of detecting vaquitas visually.

The minimum ship requirements for conducting a vaquita line-transect survey in 2015 are a ship that has:

(1) at least 15 berths for scientists; and
(2) an observation deck (usually the flying bridge) which:
    (a) is at least 10m above the surface of the water;
    (b) is large enough to accommodate at least 3 25X binoculars at a time and a data recorder position (approximately 10m x 5m);
    (c) has an awning to protect observers from the sun;
    (d) has steel plates with bolts for attaching the 25X- binocular pedestals
(3) an independent deck (likely the bridge) for the independent team with 2 25X binoculars.

Appendix 4: Acoustic component (see Addendum for modification of CPOD grid)

Estimating the density of vaquitas in the shallow-water areas will depend on continued monitoring of the Vaquita Refuge in the grid shown below plus adding CPODs to the shallow water area.



Map showing the sampling grid of acoustic detectors used to estimate vaquita abundance in shallow waters. Black dots inside vaquita refuge will be used to calibrate acoustic data based on visual density estimate in this polygon. Blue and red dots are detectors used to estimate density in shallow water areas. Blue dots correspond to west stratum and red to north stratum after Gerrodette *et al*. (2011).

Vaquita population trend has been estimated using the acoustic grid inside vaquita refuge since 2011, including annual sampling periods (June to September) until 2014 (CICESE, 2010, 2011, 2012, 2014). The estimate using sampling periods from 2011 to 2013 resulted in an annual 18.5% decrease, which addressed to an estimate of abundance of less than 100 individuals (CIRVA, 2014).

The grid inside vaquita refuge lies entirely in waters able to be surveyed by the boat applying visual techniques. Hence, we can use the past experience acoustically sampling this area to calibrate acoustic data to estimate density based on visual data that will be generated at the same time and area.

Inside refuge the density of sampling stations is about 36 sites per 1000 Km^2. Given the absence of previous acoustic data in shallow waters, it is recommended to maintain at least the same density of acoustic sampling sites in this area as inside vaquita refuge. The last has an area of 1262.84 Km^2. For the 1903.61 Km^2 of the shallow area it is required to deploy 68 acoustic detectors (red and blue dots in figure above). With the 45 sites inside refuge, we could be sampling in 113 sites per day, which can result in about 7000 to 10000 days of data depending on the duration of the survey. It must be noted that as contrary to the 2008 abundance estimate, based on a sailboat to obtain acoustic data, the acoustic methods in this proposal will generate data continuously all along shallow area and calibration area all time.

To accomplish this goal it will be required to assure that all acoustic detectors (C-PODs) are operational and with memory available all time. To meet this requirement it is planned to interchange equipment during the survey at least two times. It will allow downloading data, change memory cards and replace batteries. It also will allow having raw data to analyze as survey advance, instead to wait until the end of the whole survey.

Retrieve the acoustic equipment is not a trivial task. Under the methods used inside vaquita refuge it is needed to move a panga to the sites and locate the mooring using a hook trawled behind the boat, as there are no sign of the moorings in surface in order to avoid theft or vandalism. Three methods can be used to retrieve equipment depending on the expectations of fishing activities in the area during the survey:

a) If it can be assured that no fishing will occur, every mooring can be marked in surface with a buoy, which would allow a very fast retrieval of equipment, reducing greatly funds needed to construct more complicated moorings, personnel and fuel.
b) If it is anticipated that fishing could occur, moorings could be deployed using longlines as in the fishing techniques. A boat like Unicap 16, equipped with a stern winch could be used to deploy and retrieve the lines. It could reduce retrieval times, as it will be needed to locate only one extreme of the longline per time.
c) If a boat with a reliable winch is not allocated, the traditional method of individual moorings would be applied, which would require the hiring of several field teams, every one composed out of a panga and three operators. Given past experience, it will be required to have at least 8 teams to assure effective deployment-retrieval operations, but 10 would be better.

Data analysis would occur as data become available after retrieval periods. It is planned to assemble a group of four analysts, composed of two experienced ones of the Mexican team working for the monitoring scheme inside refuge, and other two coming from SAMBAH program (monitoring of harbor porpoises in Baltic Sea, http://www.sambah.org/). As many days of data will be generated in a short time period, analyst will be focused into review a subset of data that can be compared in performance with the GENENC algorithm. It is anticipated from past data that GENENC performs very alike to analysts (CIRVA 2014), which would reduce greatly analysis time and analysts required. It would be required to test GENENC performance over different acoustic conditions, in order to assure reliable analysis. In case GENENC do not perform well under some conditions, analysis will be completed by the analysis team.

CICESE. 2010 (not published). Implementación de un Esquema de Monitorización Acústica para la Vaquita. Reporte para el Instituto Nacional de Ecología, SEMARNAT. Centro de Investigación Científica y de Educación Superior de Ensenada. Ensenada, B.C. 16 de noviembre de 2010.

CICESE. 2011 (not published). Inicio de Operaciones y Calibración del Esquema de Monitorización Acústica para la Población de la Vaquita. Reporte para el Instituto Nacional de Ecología, SEMARNAT. Centro de Investigación Científica y de Educación Superior de Ensenada. Ensenada, B.C. 17 de octubre de 2011.

CICESE. 2012 (not published). Segunda Campaña del Esquema de Monitorización Acústica de la Población de Vaquita. Reporte para el Instituto Nacional de Ecología, SEMARNAT. Centro de Investigación Científica y Educación Superior de Ensenada. Ensenada, B.C., 8 de octubre de 2012.

CICESE. 2014 (not published). Cuarta Campaña de Monitorización Acústica de la Población de Vaquita Marina. Reporte para la Comisión Nacional de Áreas Naturales Protegidas, SEMARNAT. Centro de Investigación Científica y Educación Superior de Ensenada. Ensenada, B.C., 8 de diciembre de 2014.

CIRVA. 2014. Report of the Fifth Meeting of the 'Comité Internacional para la Recuperación de la Vaquita'. Ensenada, B.C., México. July 8-10, 2014. 43 pp.

Gerrodette, T., B. L. Taylor, R. Swift, S. Rankin, A. Jaramillo L, 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 27:E79-E100.

Appendix 5. Acoustic research to estimate detectability of vaquitas by CPODs in shallow and deep waters.

Odontocetes (dolphins, porpoises and river dolphins) have the ability to produce sonar signals. It means that they are able to emit sound pulses in a defined direction and receive the echoes. The analyses of these echoes in the brain allow them to perceive the characteristic of the objects from where sonar signals rebound (Au, 1993; Richardson *et al*., 1995). This ability is commonly known as echolocation, first discovered in bats (Au, 1993).

Echolocation signals are transient pulsed sounds of short duration, typically named “clicks” (Au, 1993; Richardson *et al*., 1995). Acoustic characteristics of clicks vary greatly among odontocete species, ranging from tens to about 160 KHz in predominant frequency, bandwidths (frequency content from predominant one) of few up to about 70 KHz, and durations from about 50 to around 160 μs (Au, 1993). Porpoise (family to which vaquita belongs) clicks are characterized by high frequencies and narrow bands (Kamminga *et al*., 1996; Chappell *et al*. 1996). Vaquita emits clicks with fundamental frequencies around 135 KHz, band with around 17 KHz and duration between 79 and 193 μs (Silber, 1991).

Clicks are not emitted alone by dolphins. Instead, they are produced in series of clicks, separated by regular intervals (Au, 1993; Richardson *et al*., 1995). It is because a click is emitted after the previous one has been received (Au, 1993). Series of clicks are commonly named as click trains.

C-PODs are tonal click loggers, identifying and storing clicks with relatively narrow band (http://www.chelonia.co.uk/downloads/CPOD.pdf, Chelonia Limited, manufacturer of C-PODs). The dedicated program, CPOD.exe, uses a stochastic algorithm named KERNEL, to identify porpoise like click trains based on individual click frequencies, durations, bandwidth, waveform and levels, as well as click intervals, average levels and train envelope form. Hence, a reliable sampling of acoustic detection rates of vaquitas depends on the ability of the C-PODs to identify and store vaquita like click trains, as well as the reliability of KERNEL algorithm to identify trains, under different background noise conditions

The perception of an acoustical signal of interest, in this case vaquita click trains, depends on the levels of background noise, which can be produced by physical or biological sources. Levels of the signal of interest must be higher than the noise levels to be adequately discriminated, a factor known as signal-to-noise ratio (SNR). SNRs could be enhanced by placing acoustic detectors at points where noise level is reduced. After experimentation in sampling sites inside Vaquita Refuge (average depths between 20-30m), this was done by placing C-PODs at middle depth between bottom and surface, which reduces reception levels of sediment knocks on the hydrophone and clicks emitted predominantly by snapping shrimps, as well as clicks emitted by the action of explosion of air microbubbles in the surface by wave forcing (Medwin and Clay, 1998).

In shallower waters, with average depths around 10m, noise levels could prevent reliable performance of C-PODs, as all described noise sources would be closer to the hydrophone. In order to assess this impact, an experiment will be performed to analyze the rate of detection of artificially generated signals under different noise conditions (over the planned sampling area in the Upper Gulf of California, Appendix 4).

A signal generator and a hydrophone with transmission capabilities will be used to generate sinusoidal signals resembling vaquita clicks. In an implementation of a calibration facility in Ensenada, B.C., it was determined that a 10 cycles of a 135 KHz sinusoidal signal is reliably identified as a single click by the C-POD (Oceanides, 2013). It is known that clicks emitted by vaquita contain around this number of cycles (Silber, 1991; Kamminga *et al*., 1996). Noise levels and frequency spectra will be recorded with an oscilloscope.

The harbor in San Felipe will be used to test the signal and determine the voltage required for the C-POD to detect clicks at distances of 100 m and greater. A Reson TC4013 hydrophone is able to emit a 135 KHz signal with a level about 152 dB_{RMS} re 1μPa at 1m, nearly the same emission level reported for harbor porpoise in a tank (162 $dB_{p\text{-}p}$ that converts to 153 dB_{RMS}).

Test sites will be selected from sampling sites depicted in Appendix 4, trying to cover representative portions of all the study area. At every site an array of C-PODs will be deployed, with detectors at different depths and the shallower one at a depth that avoids the C-POD surfacing at low tide. At every depth two C-PODs will be used with different settings. One will have regular settings and the other will be adjusted for high noise settings (use an 80 KHz high pass filter instead the 20 KHz to limit the number of low frequency clicks stored). The array will be deployed from an anchored boat. The arry will have a buoy at the surface and a weight in bottom that will not touch the bottom so it can freely move with currents. Distance from the emitting hydrophone on the anchored boat to the array will be measured with a rope attached to the buoy that is marked at regular intervals.

Trains with 10, 20 and 30 clicks, at click intervals of 0.05 seconds, at the voltage determined in harbor, will be generated with the C-POD array at different distances from the hydrophone. Precise time of signal generation will be recorded and C-PODs will be synchronized with generator time.

Data stored in C-PODs will be downloaded to generate CP1 files (the basic file created by C-POD, containing all clicks identified and stored) and KERNEL algorithm will be applied to generate CP3 files (which contain only click trains identified as porpoises, dolphins or sonar).

The experiment will continue by quantifying the degree to which the proportion of trains stored in CP1 files and the proportion of clicks agree with the number of generated clicks and trains. Also, the proportion of trains stored in CP3 files will be quantified. Finally, the assessment will compare these proportions between distances from hydrophones as well as between sampling sites representing different noise conditions, as determined by spectrograms registered with the oscilloscope.

Significant lower proportions of clicks and trains detected in C-PODs would be an indication of reduced abilities under the prevalent noise conditions. In this case, the proportions measured could be used as a parameter to correct acoustic detection rates, hence avoiding underestimation problems.

Au, W.W.L. 1993. *The Sonar of Dolphins*. Springer-Verlag. New York. U.S.A. 277 pp.

Chappell, O., R. Leaper and J. Gordon. 1996. Development and performance of an automated harbour porpoise click detector. *Rep. Int. Whal. Comm.* 46:587-594.

Kamminga, C., A. Cohen Stuart and G.K. Silber. 1996. Investigations on cetacean sonar XI: Intrinsic comparison of the wave shapes of some members of the *Phocoenidae* family. *Aquatic Mammals* 22(1):45-55.

Medwin, H. and C.S. Caly. 1998. *Fundamentals of Acoustical Oceanography*. Academic Press. San Diego, CA, U.S.A. 712 pp.

Oceanides. 2013 (not published). *Montaje de un Sistema de Recalibración de Equipos de Detección Acústica del Esquema de Monitorización de la Vaquita Marina.* Oceánides Conservación y Desarrollo Marino, A.C. Reporte final del Acuerdo No. OO03 para World Wildlife Fund, Inc. Ensenada, B.C., México. 5 de septiembre de 2013. 22 pp (available with esanjurjo@wwfmex.org).

Richardson, W.J., C.R. Green Jr., C.I. Malme and D.H. Thomson. 1995. *Marine Mammals and Noise*. Academic Press. San Diego, CA, U.S.A. 576 pp.

Silber, G.K. 1991. Acoustic signals of the Vaquita (*Phocoena sinus*). *Aquatic Mammals* 17(3):130-133.

Appendix 6: Number of sea days needed (see Addendum for changes made antipating fewer than 100 vaquitas remaining)

In order to estimate abundance based on line-transect data reliably, a minimum of 60-80 sightings is recommended (Buckland et al, 1993). The number of days of ship survey effort required to obtain 60 vaquita sightings in 2015 cannot be predicted exactly, but it can be estimated probabilistically. We use data from the 2008 vaquita visual survey to estimate the number of vaquita sightings that will occur in 2015, if the same methods are used. This exercise calculates recommended sea days for both the *Ocean Starr* and another comparable ship that has not been used previously for a vaquita survey and would require more sightings to make a reliable estimate. The research design for the main proposal assumes use of the *Ocean Starr* because it is the only ship where a reliable estimate can be obtained even if few vaquita are sighted because numbers have declined further.

We know from past experience that vaquitas can be detected effectively only in calm wind conditions of Beaufort sea states 0-2. We also know that vaquita sightings do not occur evenly, but tend to be highly clustered. Figure 1 shows the daily survey distance on effort and number of sightings during the 1997 and 2008 studies to estimate vaquita abundance. In both years there were many days during which no effective survey effort was possible because of wind (Beaufort>2). On days when effective survey effort was possible, often no vaquitas were seen. The clustered pattern of vaquita sightings was particularly evident in 1997, when 81% of the sightings occurred during the last 5 days of the survey, and 53% of the sightings occurred on a single day.

Another consideration is that the number of vaquitas in 2015 is likely to be substantially less than in 2008. The best estimate of 2008 vaquita abundance, using all available data in a population model, is 214 vaquitas (Gerrodette and Rojas-Bracho, 2011). The best current (2014) estimate of vaquita abundance, using the 2011-2013 acoustic data, is 94 animals (CIRVA, 2014). This means that the number of vaquita sightings per day for a survey in 2015 is likely to be lower than in 2008.

To estimate the number of sightings that could be expected during a survey in 2015, the 2008 data were sampled with replacement by day for various numbers of sea days. The sighting rate was reduced by the ratio 94/214 to account for the estimated decline in vaquita abundance since 2008. It was assumed that wind conditions, vaquita group size, and vaquita spatial distribution in 2015 would be similar to 2008. It was also assumed that the same data-collection methods (ship speed 6 knots, 3 observers with 25X binoculars and one recorder at an observation height of 10m) used on previous vaquita line-transect surveys would be followed.

The results indicate that 85 days in the study area will be required to achieve 60 sightings with 95% probability (dotted line in Figure 2). This means 85 working days in the study area, excluding days in transit and days in port. Similarly, 64 days in the study area will be required to achieve 40 sightings with 95% probability (dashed line in Figure 2).

If the 2015 vaquita cruise uses a vessel that has not been used for previous vaquita surveys, such as *BIPO INAPESCA* or *Ocean Rover*, a target of at least 60 sightings is recommended, which will require 85 days of ship time in the study area. On the other hand, if the 2015 vaquita cruise uses the *Ocean Starr*, the vessel used for vaquita surveys in 1997 and 2008, a target of 40 sightings and 64 sea days would be sufficient. Because the *Ocean Starr* was used for previous studies, some key parameters are already known, and fewer sightings and fewer sea days are necessary. In addition, *BIPO INAPESCA* and *Ocean Rover* are both larger than the *Ocean Starr*, and the draft is greater. In 2008, the *Ocean Starr* was able to carry out transects in 59% of the vaquita range (Gerrodette et al, 2011). The rest of the vaquita range was too shallow, and acoustic sampling from a catamaran was used. If a larger ship is used in 2015, it will be able to cover less than 59% of the vaquita's range. This means that the 2015 vaquita abundance estimate is likely to have greater uncertainty if a larger ship is used.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman & Hall, London.

CIRVA. 2014. Report of the Fifth Meeting of the 'Comité Internacional para la Recuperación de la Vaquita'. Ensenada, B.C., México. July 8-10, 2014. 43 pp.

Gerrodette, T., B. L. Taylor, R. Swift, S. Rankin, A. Jaramillo L, 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 27:E79-E100.

Gerrodette, T. and L. Rojas-Bracho. 2011. Estimating the success of protected areas for the vaquita, *Phocoena sinus*. Marine Mammal Science 27:E101-E125.

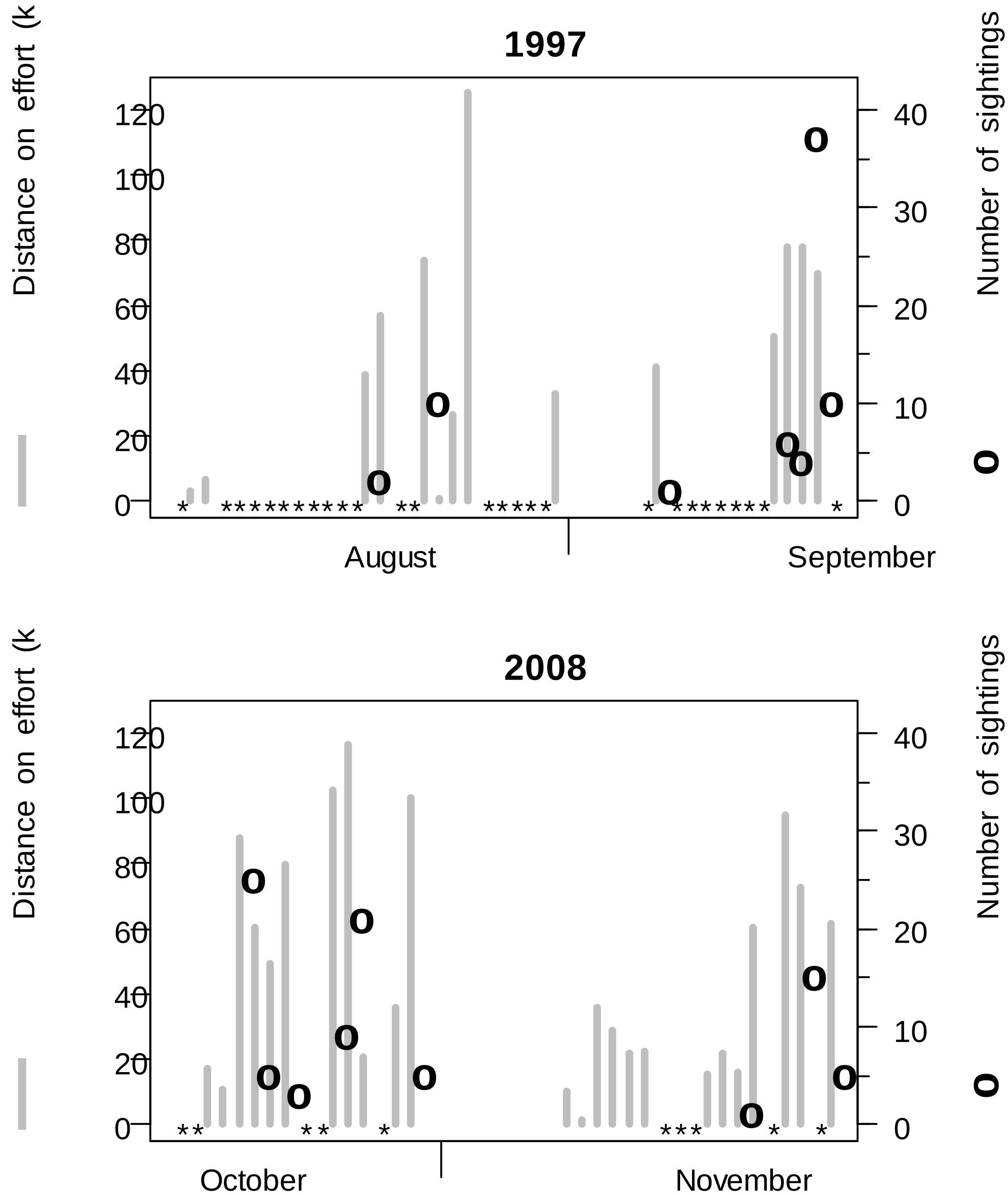


Figure 1. Distance on transect effort in conditions of Beaufort ≤ 2 (gray bars) and number of vaquita sightings (circles) on each day during cruises in 1997 and 2008. An asterisk (*) indicates days when the ship was in the study area, but Beaufort sea state was > 2 for the entire day and no survey effort was possible. In both years the gap in the middle represents time the ship was in port.

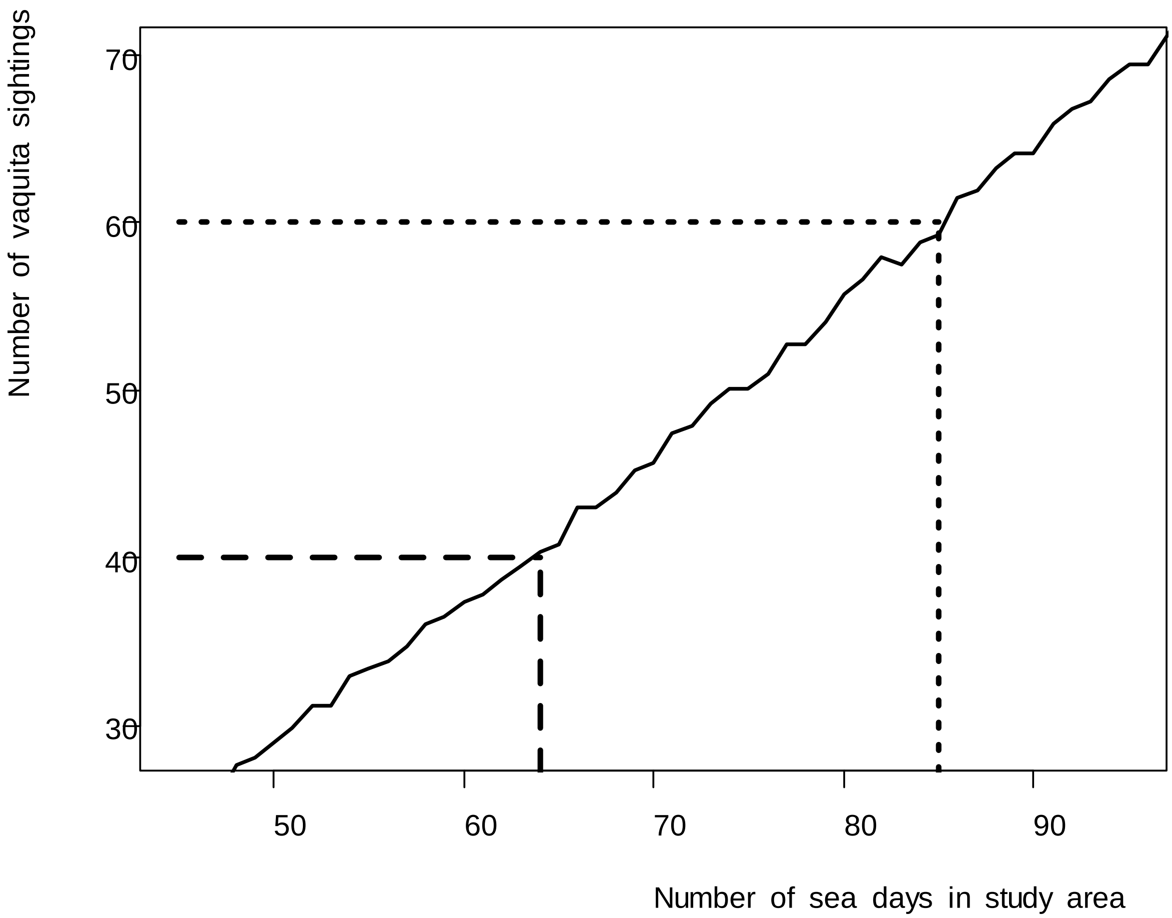


Figure 2. Number of sea days and number of vaquita sightings expected in 2015, using the same methods as surveys in 1997 and 2008. The figure shows the number of vaquita sightings (or more) that is expected with 95% probability for a given number of sea days in the study area. The dotted line shows that 85 days will be required to achieve 60 vaquita sightings with 95% probability. The dashed line shows that 64 days will be required to achieve 40 vaquita sightings with 95% probability.

Appendix 7. Personnel description

With so few vaquita remaining, there will be no opportunity to train observers to be able to identify vaquitas versus other dolphins present in the area. Also, because vaquitas are so hard to see, it is imperative that the very best available observers be used to increase the number of sightings. Similarly, an experienced crew is critical for deployment and retrieval of CPODs and rapid and accurate analysis of the acoustic data. Both teams are listed below with a brief account of their qualifications.

Visual Team (only 12 visual observers needed at one time, but we expect some will be available for only half of the cruise)

Lorenzo Rojas (Mexico) co-cruise leader 1997, 2008
Barb Taylor (USA) observer 1997, co-cruise leader 2008
Tim Gerrodette (USA) co-cruise leader 1997, analyst 1997, 2008
Ernesto Vazquez (Mexico) vaquita observer 1997, 2008
Juan Carlos Salinas (Mexico) vaquita observer 1997, professional observer on many cruises with harbor porpoise
Jay Barlow (USA) vaquita observer 1997, 2008
Robert Pitman (USA) vaquita observer 1997, 2008
Dawn Breese (USA) vaquita observer 1997, 2008
Karin Forney (USA) vaquita observer 1997, professional observer on many cruises with harbor porpoise
Sarah Mesnick (USA) vaquita observer 2008
Paula Olson(USA) vaquita observer 2008, professional observer on many cruises with harbor porpoise
Lisa Ballance (USA) professional observer on many cruises with harbor porpoise
Suzanne Yin (USA) professional observer on many cruises with harbor porpoise, expert data recorder
Jeff Moore (USA) professional observer on many cruises with harbor porpoise, expert panel on acoustic analysis
Anna Hall (Canada) vaquita observer 2008, professional observer on many cruises with harbor porpoise
Chris Hall (Canada) vaquita observer 2008, professional observer on many cruises with harbor porpoise
Per Berggren (Sweden) professional observer on many cruises with harbor porpoise
Susie Calderan (UK) professional observer on many cruises with harbor porpoise
Russell Leaper (UK) professional observer on many cruises with harbor porpoise

Acoustic Team

Armando Jaramillo-Legorreta (Mexico) acoustic lead for vaquitas 1997-2015
Edwyna Nieto-García (México) field researcher and acoustic analyst 2006-2015
Gustavo Cárdenas-Hinojosa (México) field researcher and acoustic analyst 2010-2015.
Francisco Valverde-Esparza (México) field operations manager
Alan Valverde-Esparza (México) field operations
Javier Valverde-Márquez (México) field operations
Rafael Sánchez-Gastelum (México) field operations
Alejandro Sánchez-Gastelum (México) field operations
Ramón Arozamena-Osuna (México) field operations
Juan Osuna-Romo (México) moorings assembly

Appendix 8: Budget

The budget presented here is an approximate estimate based on preliminary data on ship costs, which would need to be negotiated with the company. The costs here are for ships from Stabbart Maritime and were given in USD and converted using 1USD/15.44MXN (conversion on Apr 22, 2015).

Description	Payment Date	Amount (MXN)	Subtotal (MXN)
C-PODs, Moorings, and Batteries	01-May-15	$3,137,640	
Deposit for vessel	01-May-15	$2,871,840	
Storage and Pick-up truck	01-May-15	$524,960	
			$6,534,440
Contracted observers, travel funds, per diems	01-Jun-15	$4,647,440	
Deployment of moorings with C-PODs at 113 sites; fuel, meals and salaries	01-Jun-15	$105,224	
Field coordination, salary, per diem, fuel	01-Jun-15	$62,300	
			$4,814,964
Acoustic data analysis	01-Jul-15	$968,860	
			$968,860
C-POD retrieval, fuel, meals, and salaries	01-Aug-15	$486,978	
			$486,978
Supplies/Equipment/Shipping Expenses	15-Aug-15	$216,160	
Vessel insurance	15-Aug-15	$386,000	
			$602,160
Line-transect communications	01-Sep-15	$30,880	
Acoustic communications	01-Sep-15	$30,880	
Deployment of moorings with C-PODs at 113 sites; fuel, meals and salaries	01-Sep-15	$105,224	
In house observers	01-Sep-15	$404,914	
Modifications to shop to meet survey protocols	01-Sep-15	$46,320	
Travel to/from ship (government vehicles)	01-Sep-15	$30,880	
			$649,098
Field coordination, salary, per diem, fuel	15-Sep-15	$62,300	
			$62,300
1/2 payment for vessel	01-Oct-15	$11,966,000	
Ship/equipment contingency expenses	01-Oct-15	$200,720	
Supplies/Equipment/Shipping Expenses	01-Oct-15	$77,200	
			$12,243,920
C-POD retrieval, fuel, meals, and salaries	15-Oct-15	$487,055	
Final payment for vessel	01-Nov-15	$15,449,665	
Total			$42,299,439

Addendum

Revised Vaquita Visual Survey Design

Appendix 6 assumed that there were 100 vaquitas. Results from the acoustic monitoring effort analyzing data through 2014 indicated that there was a large decline in the past year. Consequently, the steering committee decided that a stratified design should be used to obtain better precision given the expected number of vaquita.

We propose using a stratified systematic survey design to achieve the multiple goals of broad areal coverage, compatibility with previous surveys, and precise abundance estimation. The survey will be conducted as two 32-day legs with a refueling and re-provisioning stop in Guaymas between them. For the visual survey, three strata include the historical survey area, the outlying area, and the core area (see the acoustic survey section for additional stratification). Broad areal coverage will be concentrated in the first leg of survey effort and will include two strata: a historical survey stratum (surveyed in 1997 and 2008) will be covered by 9 north-south transect lines (gray lines, Figure 1) and an outlying stratum (red lines, Fig 1) will be covered by coarse zig-zag of transect lines within the remainder of vaquita habitat in the new gillnet exclusion zone. The outlying stratum will exclude waters deeper than 100m which are not suitable habitat for vaquita. Because vaquita abundance has declined since the last survey in 2008, precise abundance estimation for the remaining population will require a greater concentration of survey effort in the core vaquita habitat than on previous surveys. The third stratum will consist of this vaquita core habitat (green polygon, Figure 1) and will primarily be surveyed on the second leg. Survey effort in the core habitat will consist of a high density of north-south transect lines that complement the 9 survey lines that were covered during Leg 1. The boundary of the core stratum in Fig. 1 was determined *a priori* based on previous fall surveys and will be re-evaluated by the survey design group after the first leg determine if the vaquita distribution has changed appreciably. The *a priori* core area is 8% of the total ban area and 34% of the historical survey area, but contains 96% of vaquita sightings during the 2008 survey. We anticipate that saturation sampling (>100% of surface area surveyed) of the core area can be achieved with a high density of survey effort during the 32 survey days of Leg 2.

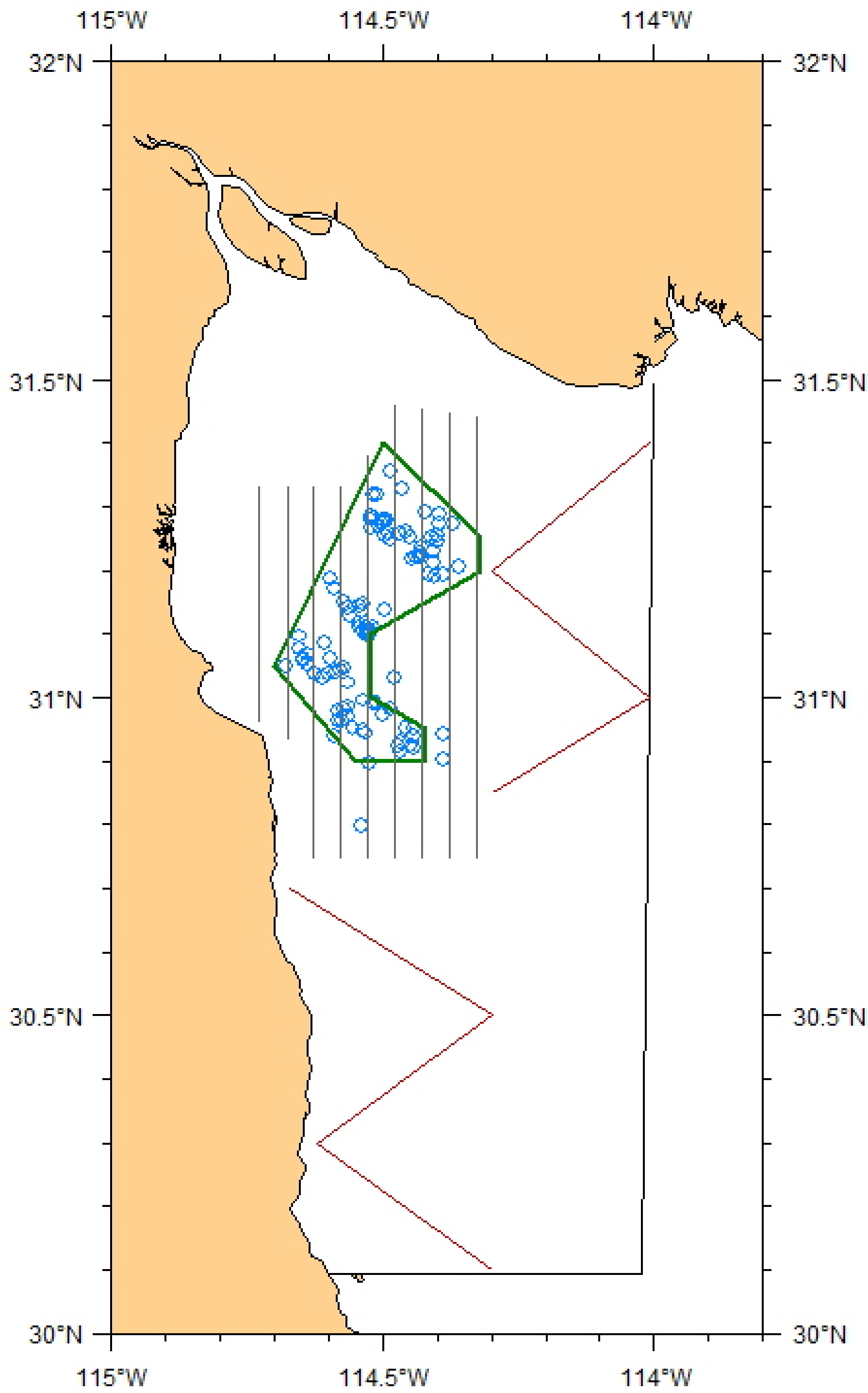
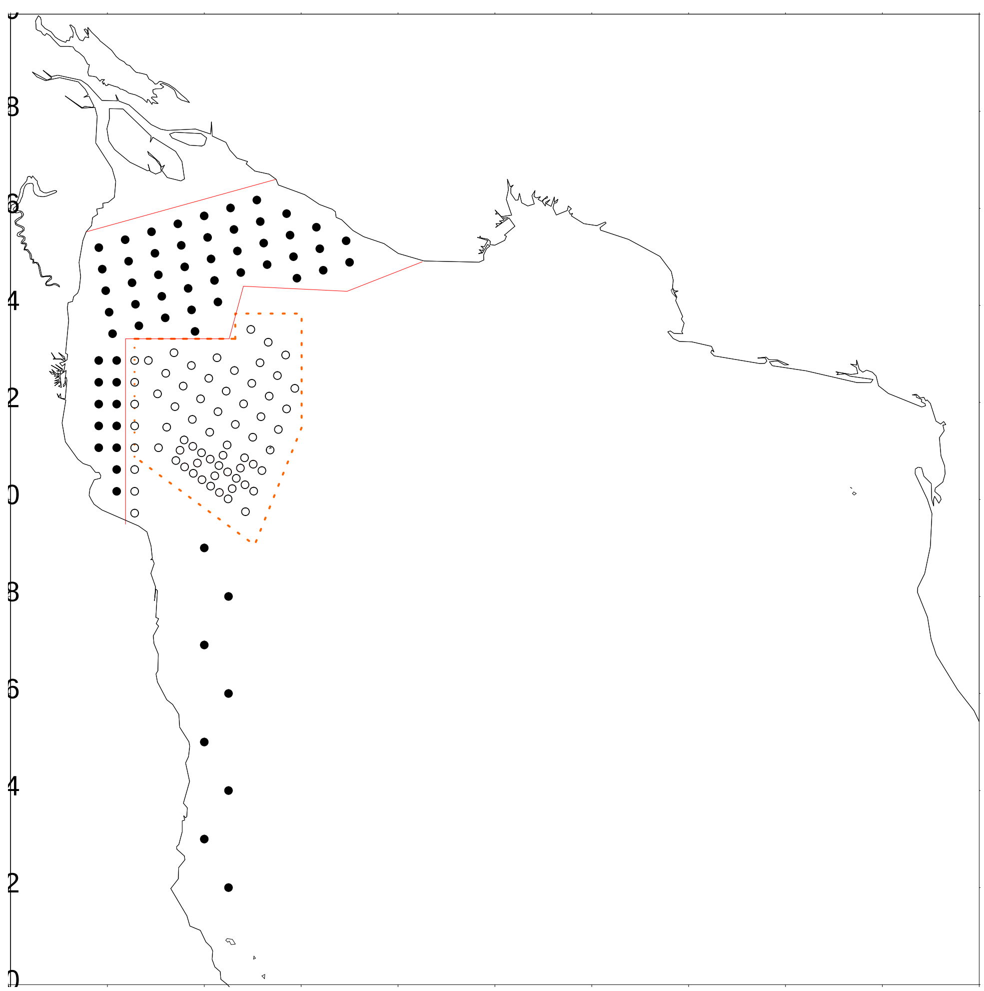


Figure 1. Visual survey transect lines as described above. The southern and eastern boundaries shown by black lines correspond to the boundaries of the 2-year gillnet ban. Although the latitude and longitude roughly correspond to the historical southern and

eastern extent of vaquita distribution, the boundaries of the ban area were made straight to facilitate enforcement. However, vaquitas have not been sighted in waters deeper than 100m and therefore these waters are not surveyed (the southeastern portion of the ban area). Start and end locations for zig-zag outlying transects will be randomly chosen and avoid waters deeper than 100 m and should be considered approximate in this diagram.

Revised Vaquita Acoustic Survey Design



Map of the Upper Gulf of California showing the acoustic sampling grid for 2015 Vaquita Survey. Open circles are sites where acoustic and visual data will be gathered in order to calibrate acoustic information to estimate population density. Closed circles represent sampling sites in shallow areas (west and north of calibration area) and southern portion of vaquita distribution, where acoustic data will be used to estimate abundance in absence or scarce visual data. Polygon with broken line delimits the Vaquita Protection Refuge, where acoustic data has been gathered since 2011. In the southern portion of this area an increased number of sampling sites will be used to increase precision, as is the zone where vaquita acoustic activity is highest. The whole sampling grid has 130 CPOD sites.

Review of Research Design to Estimate Vaquita Abundance

Reviewers: Professor David Borchers, Professor Philip Hammond, Dr. Len Thomas, University of St Andrews, St Andrews, UK.

14th May 2015

This document contains our joint review of the survey and analysis plan for estimating vaquita abundance contained in the document "Research design to estimate vaquita abundance, with Addendum to optimize design given new results on 2013-2014 rate of decline" by Rojas-Brancho et al.

General assessment

Overall, we believe that the proposed methods (a combined shipboard line transect survey and static passive acoustic survey) are the best data collection and analytical design possible to estimate vaquita abundance. All the options have been well reviewed and it is clear that this is the best way to generate a robust estimate of abundance given the range of constraints.

We also believe that the team who have designed the survey, and the list of potential observers and co-workers is exemplary. The level of relevant expertise and experience of the data collection and analytical team is unparalleled. There are potential factors that might affect the success of any cetacean abundance estimation project (e.g., weather, mechanics) but lack of competence of the personnel is definitely not a factor in this project. We have the utmost confidence that this team will ensure as far as humanly possible that the project is a success.

Beyond this general assessment, we have a number of specific, minor comments and suggestions which we detail below. Members of the team have a well-earned reputation for collaboration and we are sure they will discuss any details with other colleagues to maximise the success of the project.

Specific comments

1. As stated above, we support the decision to use a combined visual line transect and fixed passive acoustic survey, for the reasons laid out in the document. Clearly, a visual line transect alone will be ineffective, given the animal density and evasive behaviour; there were problems with the towed survey in the 2008 survey, particularly with sample size, that are likely to be much worse this time. A fixed passive acoustic survey alone could potentially work, but this would require extra measures to estimate detectability (such as a tracking array or and SECR-ready setup), and also quantification of acoustic "cue" production rate (see Marques et al. 2013 for lots of details). Hence, using a "calibration" stratum, where the visual and acoustic surveys are both done in the same time and place, and the former is used to calibrate the latter, seems the best option – this is similar to the previous vaquita cruise of 2008 (analyzed in Gerrodette et al. 2011), but with the towed acoustic survey replaced by a fixed one. One option not mentioned is the use of an underwater glider instead of the fixed acoustic survey, but this has not been proven to work for passive acoustic surveys, while there is plenty of evidence that fixed sensors do, and in particular CPODs have been used for acoustic monitoring of vaquita in this area for several years. In any case, we think this is neither the time nor the place to be trialling

novel technology, given the critical importance of this survey and given also that established methods have been shown to be effective.

2. We had some comments about the spatial design of the survey, focussing on the Addendum containing the optimized survey. For these comments, we assume that standard design-based analysis methods will be used to produce abundance estimates (as was done in Gerrodette et al. 2011).

   Visual

   a. The boundaries of the study area and strata are not shown in Figure 1 of the Addendum; they need to be drawn clearly on the map, and used in defining where the transect lines start and stop. It would also be very useful to see the 100m depth contour, and whatever the shallowest depth contour is where the study area stops.
   b. Relatedly, we believe it is not mentioned how the parallel lines will be laid out spatially – presumably using a random systematic parallel line design – the key is that they must be laid out at random.
   c. We wonder if 9 transect lines is "enough" to get a reliable estimate of variance in the stratum covered by these lines. Actually, it appears these lines will cover two strata, because a subset of this area will be more intensively surveyed, with the aim being complete coverage in the highest density part. For the subset covered twice, variance should not be a problem since you'll likely use an effort-weighted average, so the second intensive survey will dominate. However, for the part not covered twice, the variance may be high, so it may be better to put in more lines if possible.
   d. We believe that the proposed stratification system for the core area, where a part is re-surveyed depending on the findings of the first phase, may lead to an under-estimation of variance. This would happen if the core habitat (green polygon on p27) is adapted on the basis of the first survey, and then survey effort from both surveys are combined to produce an abundance estimate for the core stratum – this is akin to post-stratifying one survey after having seen the survey results. It would not happen if separate estimates are obtained for the initial stratum from the first survey and for the new stratum from the second survey, but then it is difficult to see how to combine them. This may, however, not be a big issue if the core habitat does not change much.
   e. Although the zig-zag lines are only indicative, we see three issues with them as drawn. Firstly, their strata do not seem to join up with the parallel line stratum. Secondly, there are too few legs for reliable variance estimation. WE suggest each of these strata are divided in half vertically, and a separate set of zig zag lines is placed down each side. An equal spacing zig-zag should be used to ensure (almost) even coverage. Thirdly, it is not clear how the area deeper than 100m is to be avoided with these lines – this would be clearer if the 100m contour was shown. However it is done, it needs to be done in such a way that coverage is even in the rest of the stratum.

   Acoustic

   f. It is not clear how the acoustic sensors are to be laid out – we know that there is a fixed grid of pre-existing sensors, but how were they positioned – on a random grid? In general, it is essential to define the survey area boundaries clearly and design the transect lines or CPOD positions within those boundaries to achieve representative coverage so that density can be extrapolated to the whole survey area to obtain a design-based abundance estimate.

g. Given (a), above, it is not clear where the calibration stratum (*sensu* Gerodette et al. 2011) is – but it is clear that distribution of acoustic sensors is not even throughout this stratum. It's essential (in our view) that the acoustic sensors are laid out on a regular (preferably randomly located) grid, covering the whole of the calibration stratum. If there is a desire to survey more intensively with the acoustic sensors in one area than another (higher density of sensors where animal density is higher), there will need to be 2 calibration strata, each with a regular grid of sensors within it.
h. There also seems to be some missing areas with no C-PODs in-between the acoustic strata – again, seeing the study area and stratum boundaries will be useful here.
i. There are only 8 sensors in the far southern stratum. If one expects no detections on any of them, then this is fine; otherwise more sensors might be required to get an accurate variance estimate (and one hopes it's not too high). We would also like to see the survey area boundary for this stratum as there are no sensors on the inshore side, which implies it's not part of the study area.

3. The somewhat variable coverage design proposed and the issue of underestimation of variance due to selection of the area to be re-surveyed on the basis of the outcome of the initial survey could be overcome by fitting a spatial density surface to the survey data rather than using stratified design-based inference (i.e., analysing using a model-based rather than design-based approach). Design-based inference involves fewer assumptions, but a model-based approach does allow for more flexibility in the design and so if equal coverage designs within strata are not feasible and/or an "adaptive" design of the sort proposed is used (defining core habitat stratum on the basis of the first pass survey), it may be worth adopting a model-based approach to estimation. Another potential advantage of a model-based approach is that it may be possible to use covariates to "explain" spatial variation in counts, thereby producing a smaller estimated variance. They key disadvantage of model-based methods is that they require more assumptions and so are intrinsically less robust. For this reason we would caution against not planning for equal coverage probability and relying on a model-based approach to density estimation. One additional assumption of a model-based method is that the range of values of the covariates used in the model are covered representatively. The best way to achieve this is likely to be an equal coverage probability design anyway. A model-based approach can always be implemented in addition to a design-based approach to investigate if the former leads to improved precision.
4. We wanted to confirm that for the calibration stratum, the visual survey and acoustic survey will take place at the same time. This is important if it's to be a correct calibration.
5. It is not clear from the text how the playbacks of artificial vaquita sounds are to be used to correct for any differences in sensitivity between CPODs in the calibration stratum and those in the peripheral strata. It would be useful to give more details there. In the SAMBAH project, the researchers assumed that the ratio of effective surveyed areas (ESAs) between strata calculated from the playback experiments was equal to the ratio of ESAs of real porpoise clicks. Will the same thing be done in this case and, if so, is it justified?
   In any case, one should not do hypothesis testing (as implied in the document), as a null hypothesis of no difference is probably silly and the power of the test may be low. A better approach would be to estimate how the effective detection area of CPODs varies with depth and then use this (with associated uncertainty estimate) to calibrate the extrapolation of vaquita density from the visual survey region to the shallow-water region.

6. We wondered whether there is there any danger that the intensive line transect survey planned for phase 2 will "chase" the vaquita out of the core area.
7. It is not 100% clear in the proposal how the two-team data will be collected and analysed to estimate g(0) but we assume that the two-team configuration will be "IO", in which each team operates independently of the other. The proposal states that there will be independent duplicate identifiers to determine which animals are seen by both teams and which are not. We like this approach (rather than determining duplicates post-survey by comparing time, angle, distance and group size data) because the additional information available to someone in the field helps the determination of duplicates. Nevertheless, there will likely be some duplicate uncertainty and it needs to be considered in analysis how this will be dealt with.
   An alternative could be to use the tracker or "BT" configuration (used on SCANS surveys; Hammond et al. 2013) in which a "Tracker" team searches farther ahead than the "Primary" team and the detections made by the Tracker team are used as trials to be seen or not seen by the Primary team. A theoretical advantage of this approach is that the data can be analysed using so-called full independence models to take account of responsive movement (see below) as well as estimating g(0). However, these models are not robust to unmodelled heterogeneity, which, if present, will cause an underestimation of abundance. Use of point independence models provide robust estimation of g(0) but cannot account for any effects of responsive movement.
   Another option if the IO configuration is used and data are also able to be collected on animal heading at first sighing, could be to consider the methods of Palka & Hammond (2001) to explore and account for any effects of aversive movement in the data.
   We encourage the proposers to consider these (and other) options to maximise the ability to estimate g(0) and deal with any aversive movement in the data in the most robust way.
8. Two teams both searching the same, or very similar distances ahead of the vessel (IO configuration) will allow estimation of perception bias at perpendicular distance zero but not necessarily of availability bias (which arises due to submerged animals not being available to be detected by either observer team). Thus g(0) will only partially be estimated.
   If it is possible to obtain multiple detections of different surfacings of the same vaquita by following it, the methods of Borchers and Langrock (2015) could be used to correct for availability bias and perception bias. The method may need modification if animals respond to the vessel while within detectable range. We would, however, recommend that attempts be made to obtain multiple sightings (of multiple surfacings) of vaquita if possible as such data are informative about the availability (surfacing) process and having these data opens up the possibility of applying (a suitably adapted version of) the method of Borchers and Langrock (2015) to correct for availability bias, as well as perception bias. The cost of collecting such data is primarily that other vaquita might be missed because observers are attempting to follow a previous detection, but with low vaquita densities it seems likely that this cost will be negligible unless vaquita have extremely clustered distributions. If it is unlikely that multiple surfacings from vaquita will be detected even if observers attempt to get them, then the utility of the above method is obviously compromised.
9. A generic problem with surveying vaquita by ship, well-described in the proposal, is that these animals react to an approaching survey ship by moving away from the transect line at distances of up to 1km (p1 of the proposal) or greater than 1km (p5). The solution proposed is to use a survey ship that has an observation platform high enough (10m) that observers with 25x

binoculars can detect animals at distances greater than 1km. This seems appropriate but such a ship (also able to accommodate the required large number of observers) is larger than a typical cetacean survey ship and therefore likely to be noisier. Because the animals are reacting aversively to the noise of the ship, the larger (and noisier) it is the more they may react. We are sure the proposers are well aware of this and that the plan is to use as quiet a ship as possible for the survey.

Notwithstanding the use of a ship that allows detection of vaquita at distances greater than 1km, some first detections will (we assume) still be made at radial distances shorter than 1km and the recorded perpendicular distances of these sightings are likely to be greater than if there were no aversive movement. How to deal with this in analysis needs to be considered. If this does occur and nothing is done in analysis, abundance is likely to be underestimated.

10. The overall cost of the project is high, especially the cost of the ship survey, which is much higher than the equivalent in the budget for survey ships in the proposed SCANS-III survey of European Atlantic waters in 2016. We assume this is primarily because of the need for more observers on a larger ship (higher and larger observation platform, more berths for more observers, etc) than we typically use in Atlantic waters. We do <u>not</u> think the specifications should be changed to enable a cheaper ship to be used; if this is what it costs then this money needs to be found.

Literature cited

Borchers, D.L. and Langrock, R. Double-Observer Line Transect Surveys with Markov-Modulated Poisson Process Models for Overdispersed Animal Availability. Biometrics (Accepted April 2015).

Gerrodette, T., Taylor, B. L., Swift, R., Rankin, S., Jaramillo-Legorreta, A. M., & Rojas-Bracho, L. 2011. A combined visual and acoustic estimate of 2008 abundance, and change in abundance since 1997, for the vaquita, *Phocoena sinus*. Marine Mammal Science, 27(2), E79-E100

Marques, T.A, L. Thomas, S.W. Martin, D.K. Mellinger, J.A. Ward, D.J. Moretti, D. Harris and P.L. Tyack. 2013. Estimating animal population density using passive acoustics. Biological Reviews 88: 287-309.

Hammond, PS, Macleod, K, Berggren, P, Borchers, DL, Burt, ML, Cañadas, A, Desportes, G, Donovan, GP, Gilles, A, Gillespie, D, Gordon, J, Hiby, L, Kuklik, I, Leaper, R, Lehnert, K, Leopold, M, Lovell, P, Øien, N, Paxton, CGM, Ridoux, V, Rogan, E, Samarra, F, Scheidat, M, Sequeira, M, Siebert, U, Skov, H, Swift, R, Tasker, ML, Teilmann, J, Van Canneyt, O and Vázquez, JA. 2013. Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. Biological Conservation 164: 107-122.

Palka, D.L. and P.S. Hammond. 2001. Accounting for responsive animal movement in line transect estimates of abundance. Canadian Journal of Fisheries and Aquatic Sciences 58: 777-787.

APPENDIX E4

From: David Borchers <dlb@st-andrews.ac.uk>

Date: Wed, Jun 17, 2015 at 8:39 AM

Subject: Re: 2015 Vaquita Survey Design: Reviewer Comments and Webinar Information

I'm afraid I can no longer attend the webinar due to a small domestic emergency. One small comment on the response to the reviews, on the issue of availability bias, to supplement Len's comments: The fact that animals will certainly surface one or more times while within detectable range does not mean that there is no availability bias. It is only if animals are continuously on the surface that you can be sure there is no availability bias. (Alternatively, if the search areas of the two observer teams are separated sufficiently that animals are independently available to each observer, then the double-observer estimate of g(0) implicitly accounts for the availability bias.)

I suspect that neither of the above conditions holds on this survey, but that said (and given the clustered distribution of animals and hence need to keep observers on effort rather than trying to get multiple sightings of detected groups), I don't think there is anything about the survey design that should be changed. With some knowledge of the availability process (e.g. likely mean dive cycle length) one can use the forward distances of detections (which are available if detection angle and radial distances are recorded) to get estimates of, or at least investigate the extent of, availability bias.

Apologies for missing the meeting. I hope it is productive and wish you the best for the survey.

David

APPENDIX E5

Comments on Research Design to Estimate Vaquita Abundance

Dr. Miguel Ángel Cisneros, Researcher at INAPESCA, former General Director of INAPESCA, former WWF Coordinator for the Northwest region.

14th May 2015

This document contains comments on the document "Research design to estimate vaquita abundance, with Addendum to optimize design given new results on 2013-2014 rate of decline" by Rojas-Brancho et al.

Technical issues

Aerial surveys. The arguments of the appendix are not convincing to dismiss them. The fact that the previous aerial surveys (1991) have not been successful does not mean they are useless; it depends on the methodology, operating experience of the staff and the weather conditions when the monitoring is being realized. I recommend using drones. There are professional drones in a very good price ($30,000.00 Mexican pesos), which could be operated from a vessel conveniently located (date, time and zone) such as *BIPO*.

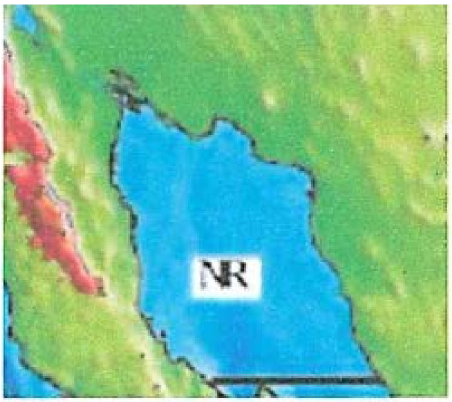
Semi-fixed platform in Consag. The argument to rule it out is that the vaquitas do not get very close to the rock (2km max.); but binoculars can reach up to 5km. If this is about increasing the sample size the semi-fixed platform could be installed. I recommend not discarding it in advance, because the logistics and operational feasibility could be studied, and if deemed necessary, build a mobile one for its installation at a later time, as this should not be a one-time effort. With current technology and resources such as vessels and work helicopters, it could be developed and installed at any needed time.

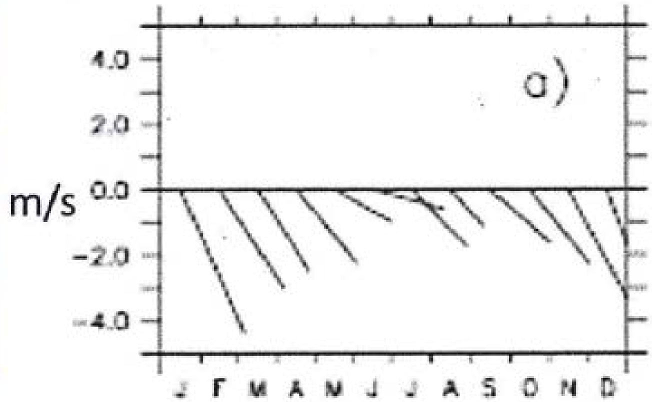
BIPO. All the *R/V Ocean Starr* technical advantages being argued can be adapted to the *BIPO* with expert support. I recommend using preferably the *BIPO*, preparing it to make this type of work now and/or in the future. It is necessary to make an estimate of the technical cost-benefit and of other nature. As another option, the *R/V Ocean Starr* could be used not in the autumn of 2015 but in the spring of 2016.

BIP XI. Its participation and some problems in 2007 are briefly mentioned, but it is not taken into consideration again. I recommend using this vessel or INAPESCA I for what is mentioned below.

Acoustic equipment. It is intended to modify the 2007 methodology using hydrophones (CPODs) in the areas where the *BIP XI* and platform were used. Additionally, for the price of these devices, they are a good alternative. It will be necessary to have one or two support boats to assist installation, changing of batteries and downloading the memories periodically. It is imperative to clearly discuss the minimum number of hydrophones needed, as well as their orientation to maximize the likelihood of detecting the "clicks" of the vaquita.

Dates and Vessels. If, as mentioned in the document, the ideal conditions for sighting vaquitas are under Beaufort 0-2 conditions, the option to realize the cruise on the *R/V Ocean Starr* in the October-December period, is not advisable because these months are usually of strong and constant winds (Parés-Sierra *et al.,* 2003).





Strategic issues.

- To consider this as a matter of the greatest importance for Mexico.
- To generate national capacity so in the shortest possible time we could design and execute these assessments on our own and in a robust way.
- To request that all CIRVA reports are published in refereed and indexed journals.
- To stay within the group of experimental design.
- To find a way to provide training in these techniques to a group of Mexicans: students, faculty and INAPESCA staff.
- As part of this, to achieve the inclusion of Mexican staff in the meetings and cruises.
- To contact Mexican statisticians, specifically from the Centro de Investigaciones en Matemáticas (CIMAT) from CONACYT in Guanajuato, which has researchers knowledgeable in fisheries and natural resources. Hire them for advice and training of Mexican staff.

Summary

This is a matter of the greatest importance for Mexico. It is also clearly geared to use a US vessel at a great cost, as well as discarding the use of the *BIP XI* and drones. However, the technical arguments are not convincing or at least in the appendices are not clearly explained why. The best assessment should include a large, silent boat (like *BIPO*), one of medium draft (like *BIP XI* or *INAPESCA I*) for logistical support in areas of medium depth, and one smaller (*UNICAP XVI*) for the shallow areas; as well as the use of drones and hydrophones placed strategically and with the proper orientation to detect the “clicks” of the vaquita. Due to technical reasons (experience) it is desirable that at the moment the traditional research group should carry out this work. However, emphasis should be made on generating capabilities and expanding the group of experts to include young researchers or people outside the traditional group. In the meantime, Mexico will have to find national experts in statistics to being training national personnel in the method. In addition, Mexico will have to request CIRVA for training for national staff on the visual and acoustic identification of the vaquita. Definitely, Mexico must ask the researchers to publish in scientific journals the results of past evaluations that at the moment are only internal reports.

It is important to assess what can be done by 2015: If it is not feasible to use the *R/V Ocean Starr* at the ideal time (spring), it would be necessary to evaluate the feasibility of conditioning *BIPO*. It is suggested to continue working on the feasibility (properties, relocation and installation) to build a semi-fixed platform to be used in the Consag rocks.

Parés-Sierra A, A. Mascarenhas, S.G. Marinone and R. Castro. Temporal and spatial variation of the surface winds in the Gulf of California. 2003. Geophys. Res. Letters, 30, 6, 1312. doi. 10.1029/2002GL016716. 6294

APPENDIX E6

Observations to the Manuscript
"**Research design to estimate vaquita abundance**"
Rojas-Bracho et al., 2015

The manuscript contains what the authors planned to do and their proposal for data capture in the field. However, what would be done with the obtained data was not mentioned. What models would be applied was not specified; neither how was the efficiency of the sampling design nor how statistical uncertainty would be dealt with in the different sampling processes and in the analysis. This lack of information limits the opinions of what could be done with respect to the methods, and there is no way of contrasting what the authors proposed to measure against what they expected to obtain. Considering the aforementioned, we would like to make the following observations.

Hydroacoustics

No evidence was found regarding the efficiency of the method proposed; thus its real usefulness cannot be determined. The use of hydrophones is really not new, and it is based on the idea of isolating the frequency of the vaquita "clicks". However, the technical information related to the efficiency of the method, especially in shallow areas, was not clear.

In the writing we identified an apparent contradiction. On the one hand, the authors mentioned that it was easy to count individuals because the vaquita clicks were known, and it was relatively easy to isolate these frequencies with the techniques used. On the other hand, they mentioned that the acoustic signals received in shallow waters contained more "noise" than those from deeper waters (snaps from shrimp, crash from materials associated to sea bottoms, noise from bubbles), which interfered with reading vaquita clicks.

It seems that a good characterization was obtained from the vaquita hydroacoustic signal despite that the correct identification of the signal depends on the noise of sea bottoms. However, the experiments to detect these signals were made in waters that were not strictly shallow, within depths from 20 m to 30 m. Curiously enough, the hydroacoustic equipment would be installed in shallow waters. In other words, there is no way of knowing if these samplings with hydroacoustics will provide the expected information; or at least, it was not explained in the manuscript.

This point is critical because the plan is to stop all fishing operations in the area for three months. Leaving the social cost of this action aside (which is unconceivable unless fishermen are paid during this time) in the manuscript, no information was offered to allow assessing if the procedure with hydroacoustics would be successful, giving rise to question the need to stop fishing activities.

The authors are asking to guarantee no fishing in the sampling area; by the same token, reliable observations deriving from the method should also be guaranteed. The information shown does not allow assessing this situation. They mentioned in the protocol they have used the hydroacoustic instruments in the last four summers in a specific zone, but no data were shown to help determine if the method was efficient and reliable enough to justify stopping the fishery activity completely in the area.

Sampling season

In reference to the season when fieldwork will be performed, it is known that summer is the best time to make visual observations. In spite of that, the proposal was to perform them in autumn. It was clear that the ship "Ocean Star" (OS) will be available starting from September, but the authors did not explain why the INAPESCA ship could not be used during the summer. There are two important points here: (1) Nothing was mentioned on what could be the error of observing vaquitas in autumn with respect to summer; and (2) An observation efficiency of 57% was estimated using OS; however, the authors did not mention how that efficiency was estimated making it unclear why the INAPESCA boat cannot be used. Moreover, other types of methods to estimate vaquita population size could have been proposed (see an alternative on visual methods). One question is still in the air. Whatever the method used to estimate the method efficiency by observing on the OS, could it be applied on the INAPESCA ship?

Research vessel

In the manuscript, it was stated that the INAPESCA ship will not be used because it was bigger than the OS, making it an impediment to navigate in shallow waters (as for the requirements for the height of the viewing platform, there was no difference). This argument does not make much sense because the difference in draft between the two ships is less than 1 meter (less in the OS), which does not imply a significant difference between the two ships as to the areas to be covered during the sampling. Moreover, no observation could be made in the area around the ship because when the vessel reaches one kilometer from the animal, it moves away from the ship. The areas that the INAPESCA ship would not cover with respect to the OS would be small, and supposedly they would be the areas where overlapping would occur with the hydroacoustic instruments.

From the technical point of view, no substantial difference between both ships was found and no reason was provided to show preference from one ship to the other (except for the matter of estimating efficiency of the INAPESCA ship, which could be done relatively easy). It is possible that the operation cost of the ships represents a sound reason. The operation cost of the INAPESCA ship is around four or five times less than the cost specified for the OS.

Visual sampling methods

Visual methods will provide relative abundance data, and the hydroacoustic methods could give both absolute and relative abundance data. To have an estimate of the total number of vaquitas in the sea, estimates of both procedures should be considered. However, how it would be done was not mentioned in the manuscript; evidently it is not a simple sum of the individuals counted in each procedure because the efficiency of both is different. It was not mentioned if the observation methods (visual and hydroacoustic) should have certain technical characteristics to join both sets of data in one single estimate of population size. In case that the information of both procedures could be joined, it was not mentioned how the data adjustment would be done, that is, how would the “observation efficiency” be standardized in each case to later obtain a global estimate. Because this point represents the omission of key elements in the sampling design and data treatment; it is a priority to provide information to assess estimates.

An additional aspect not mentioned and which is fundamental in the case of vaquita was to be able to measure uncertainty in the estimates. This uncertainty is closely associated to the models to be applied in the different stages of the study and the data generated; for example, how will uncertainty of the visual observations be combined with those derived by hydroacoustics? It is therefore essential because it gives an idea of the reliability of the estimates.

Synthesis

A. No information referring to the quantitative aspects of the estimates was found; population models to be used, methods to assess efficiency of the viewings, and efficiency of the hydroacoustic equipment were also not mentioned. It was not specified how the data from hydroacoustics would be combined with those of visual observations. Neither was anything mentioned on how to manage the uncertainty generated by the different procedures to make population estimates, which is relevant because the estimate of the number of vaquitas in the sea and the reliability of the estimate depend on it.

B. No technical arguments providing evidence of the need to use the Ocean Star ship specifically as a viewing platform were found. It was mentioned that observation efficiency was estimated, but the efficiency for the INAPESCA ship could have also been estimated.

C. The difference in draft of both ships is minimum, less than a meter, which might not represent a loss in observation capacity; however, the INAPESCA ship allows performing observation in the summer when visibility is greater (compared to September when the OS would start operation) and more days for viewing would have been achieved. Additionally, the operation cost of INAPESCA is substantially less that that of the OS.

D. In the hydroacoustic method proposed no information was provided on equipment efficiency to detect vaquitas in shallow waters. The information provided was contradictory. The authors mentioned they had used this equipment during the last four years in relatively less favorable conditions as to depth than those they have proposed now; nonetheless, no evidence on efficiency was provided. These procedures should have been analyzed to see if they were really fruitful with respect to the alternative methods for visual observation. It was essential because the proposal required stopping fishing activities during the time the project would be developed, which will surely generate an important social problem.

E. In the proposal the authors mentioned that other observation methods, as the use of drones, have not been fruitful, but no information was shown in this respect. On the contrary, it seems its use was discarded without much experimental information. Because of the cost vessels imply and considering monitoring in the future, it would be convenient to conduct research to make these viewing platforms useful (e.g. infrared cameras).

Recommendations

1. Adjust the proposal by incorporating all the necessary aspects, specifically quantitative procedures and uncertainty and reliability of the estimates; then subject it to assessment by pairs regardless of the affiliation and field of the proponents.

2. Consider a technical-scientific audit at the end of the project. The audit, besides being a peer review of the results, is a way of guaranteeing them to be of the best quality possible and totally independent form personal or group positions. It guarantees to have the best technical-scientific work available (the profiles of the auditors should be those of persons experienced in sampling design, model application to estimate existence, and mathematicians for the appropriate management and assessment of the models and uncertainty).

3. The INAPESCA ship should have the field information that would allow making its own estimates so that at any moment they could be confronted with the equipment of the proposed project.

4. The INAPESCA ship has modern hydroacoustic equipment and it seems convenient to analyze the possibility of using it to asses vaquita (see below)

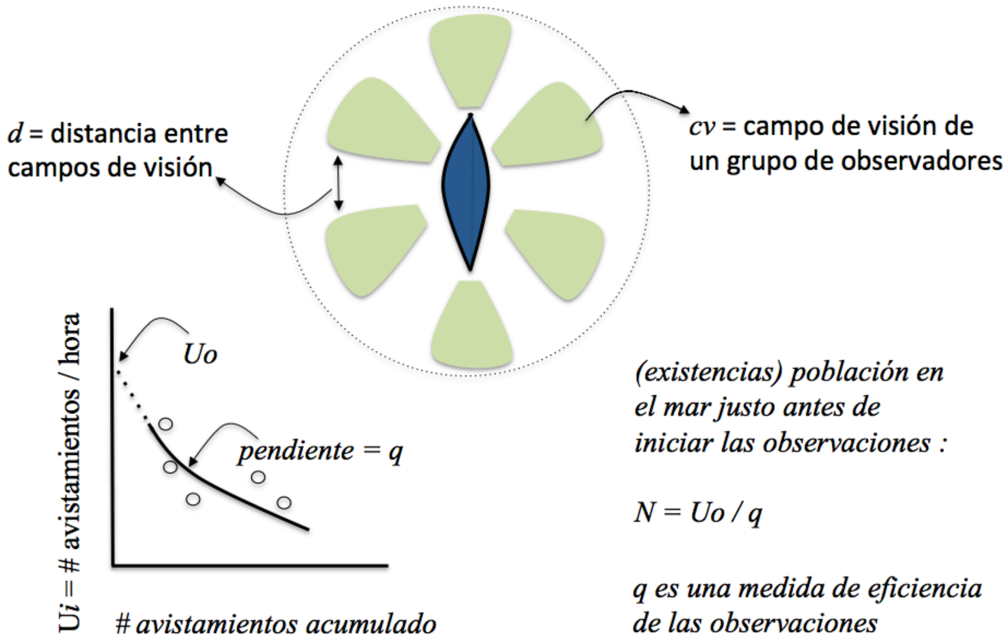
Alternative on visual methods

Adaptation of the Leslie model to vaquita population estimate based on observations. The figure below represents the procedure.

Considering six groups of observers on the ship (blue color) each group would have a *cv* (green color, for its abbreviation in Spanish) field vision, which should not overlap with the others: besides, a minimum distance *d* should be observed between *cv* in such a way the likelihood of viewing a vaquita in the two succesive fields would be minimum.

The total observation time should coincide with the low likelihood associated to *d*.
The procedure could be repeated *n* times and the strategy to repeat it in several ocassions, in different sites, or re-visits should be planned jointly with the cruise leader and the captain of the ship.

The experiment and analysis of the data can be performed according to the method of stock reduction (or Leslie matrix). The estimate associated to the uncertainty method is a well-known procedure.



d = distance between vision fields; *cv* = vision field of a group of observers; U*i* = # viewings / h; # of viewings accumulated; (existence) population in the sea just before starting observations; *q* is an efficiency method of observations

Alternative on hydroacoustics

As mentioned, the INAPESCA ship has modern hydroacoustic equipment and it seems convenient to analyze the possibility to use it to assess vaquita. Experts should be consulted (e.g. SIMRAD-Spain) for operating capacity close to the surface. The target assays could be performed in combination with observers. Besides, the scope of the hydroacoustic equipment and its emission field (in vertical and horizontal direction) has a higher scope than the other equipment proposed.

UNIVERSITY of OTAGO

SAPERE AUDE

Te Whare Wānanga o Otāgo

15 May 2015

Re: review of "Research design to estimate vaquita abundance"

Dear Dr Rojas-Bracho and Dr Taylor,

I have completed my review of your proposal. As Mexico embarks on a new set of conservation measures to save vaquita, I believe that it will be crucially important to establish abundance as reliably as possible, so that progress can be measured.

I have made several comments on the proposal itself in "track changes". Most of these are intended to improve the English of the proposal, and are editorial in nature.

I have no fundamental criticisms of the research design. I agree wholeheartedly that a combination of a high-quality visual line-transect survey, conducted from a ship large enough to accommodate two independent teams of observers with 25 power binoculars, coupled with with extensive static acoustic monitoring in the shallow areas, is by far the best approach in this situtation. The resampling approach taken to estimate ship time required for a 2015 survey is clever and appropriate. Of course it would be desirable to have more ship time, but this may not be needed (or possible).

I am not convinced of the value of the coarse zig-zags proposed in the addendum. These cover the area so sparsely that in the unlikely event that any sightings are made, the uncertainty in the density estimate from this stratum will be very great. I'd prefer to see this effort go into a higher density area.

I note that the quality of the scientists and observers involved is truly World class. I have worked directly with many of them. I also note also that many of the observers have had direct experience with vaquita, and those that do not have worked extensively with harbour porpoise, which has very similar behaviour. There is no research group anywhere that could do a better job.

Stephen Dawson PhD

Professor of Marine Science
Email: steve.dawson@otago.ac.nz

Department of Marine Science – Te Tari Pūtaiao Taimoana

Campus Facilities: 310 Castle Street
PO Box 56, Dunedin, New Zealand
Tel 64 3 479 8306 Fax 64 3 479 8336

Portobello Marine Laboratory
PO Box 8, Portobello, New Zealand
Tel 64 3 479 5810 Fax 64 3 479 5825

New Zealand Marine Studies Centre
PO Box 8, Portobello, New Zealand
Tel 64 3 479 5826 Fax 64 3 479 5844

marine-science@otago.ac.nz http://www.otago.ac.nz/marinescience

DUNEDIN • CHRISTCHURCH • WELLINGTON • AUCKLAND

APPENDIX E8

Comments on Research Design to Estimate Vaquita Abundance

Mr. Luis Fleischer, CONAPESCA's representative in the Mexican Embassy in Washington, D.C.

14th May 2015

This document contains comments on the document "Research design to estimate vaquita abundance, with Addendum to optimize design given new results on 2013-2014 rate of decline" by Rojas-Brancho *et al*.

General comments

The three key requirements for all the Density-based Survey Methods described in the document could be used for the defined estimation objective.

1) The survey must be random with respect to the distribution of the animal within the study area

2) The probability of detection must be estimated (as a function of distance from the survey platform for line- and point-transect surveys); and

3) Animals must be detected before they move in reaction to the survey platform.

<u>Visual Line-transect Survey Methods from Boats & Ships</u>

High power binoculars mounted on a pedestal are recommended, and ideally needed in order to detect the vaquita before they deviate from the line of the transect in reaction to the vessel. Alternatively, hand-held binoculars 7 x 50 or 20 X reticle binoculars with built-in compass could also be used by the increase in the number of observers working together. This is, having three observers working at the same time on the observation deck. I agree that the vessel should also be large enough to carry two teams of observers to allow the estimation of the detecting probability over a zero distance. The use of this method and three work boats working simultaneously produced an estimate of 1000±200 vaquitas (Pending reference).

<u>Land-based survey</u>

It is mentioned that the cost-benefit ratio is very poor for a land-based survey because it can only survey from a single point in an area of very low density of vaquitas. Besides, during the 1997 cruise (and subsequent ones) it was clear that the closest vaquitas to the Rocas Consag were more than 2 nmi away. They determined that the platform has limited value for a proper survey; however, having several land observation spots working at the same times may provide a way to solve the problem in the shallow areas. This will complement without a doubt the effort made by vessel surveys.

<u>Acoustic Line-transect Survey Methods from Boats & Ships</u>

A difficulty faced in this method is the determination of the true detection area or the sensitivity of the acoustical equipment in terms of detecting distance from the acoustic source. The probability of detecting a vaquita as a function of its distance from an acoustic array (CPOD) cannot be estimated from a sparse array of single instruments.

Conclusion

It is considered necessary to explore other possibilities in regards of the binoculars being used; hand-held binoculars 7x50 or 20X reticuled binoculars with built-in compass could also be used by increasing the number of observers working together.

The authors mentioned the estimate of the fraction of vaquitas missed on the trackline for the Ocean Starr. It would be important to have the references or methodology that allowed them to calculate those estimates.

I recommend that small boat surveys or fixed land observation counts could complement the other survey methods. These methodologies have been used for other cetacean surveys.

APPENDIX E9

Comments to the proposed research to estimate visual and acoustic abundance of the vaquita

Dr. Héctor Pérez-Cortés Moreno, Sub-delegate for SEMARNAT in Baja California Sur

14th May 2015

This document contains comments on the document "Research design to estimate vaquita abundance, with Addendum to optimize design given new results on 2013-2014 rate of decline" by Rojas-Brancho *et al*.

General Comments

In the article signed by two researchers who propose the surveys (Taylor, B.L. and T. Gerrodette. (1993). *The use of statistical power in conservation biology: the vaquita and northern spotted owl*. Conservation Biology. 7 (3): 489-500), is concluded that the statistical power to detect a decrease in abundance in a reduced population, decreases as the population gets smaller, and in the case of the vaquita is unacceptably low.

In other words, when there is sufficient information showing a tendency of reduction of the population, it may be too late to take appropriate conservation measures. Based on the foregoing, it can be said that it is much more important to allocate resources to implement management actions (such as surveillance in the refuge and search for economic alternatives) that put more emphasis on an expensive census.

In the proposal, the authors acknowledge that there is no method that allows the estimation of abundance of vaquita without a degree of statistical uncertainty; and that the best method will be one that minimizes this uncertainty considering the available budget.

To perform a comparative analysis of the available methods there are three basic requirements for those based on the estimate of the density, which are the following: 1) the sampling must be random with respect to the distribution of the animals within the study area; 2) the probability of detection needs to be estimated; and 3) the animals must be detected before they react to the sampling platform. All of these assumptions can be met using the "silent" vessel. And depending on the characteristics of the vessel, it is likely that the estimate could be more accurate. In comparison, an acoustic census would be less precise and controversial. The estimations should not be based exclusively on an indirect method as an acoustic survey.

Interestingly, when comparing different methods in the proposal, the authors do not refer to the importance of the surveys being developed under the best conditions of observation, i.e. with a Beaufort 1-3, which is definitely more likely to happen during the summer instead of the autumn when cyclones in the Pacific occur most frequently towards the North of the country.

Clearly, the conclusions of their proposal can be achieved in situations and conditions different from the ones that they propose: it is definitely suitable the use of another vessel such as a "silent" one that does not cause the animals on the transect line to react to great distances. It is better to perform a survey when it is more likely to find the optimal observation conditions. Apparently, the conditions of the "silent" vessel comply with the requirements of a high platform, and enough space to accommodate sufficient observers to make rotations during the hours of effort. If the draught of the "silent" vessel is smaller than the one from the NOAA's vessel, it will be possible, in addition, to extend the transect surface.

The fulfillment of the assumptions and the conditions needed for a survey are not necessarily obtained by the methods and season that they propose in the text.

University of St Andrews

Dr Len Thomas
Director
Centre for Research into Ecological and Environmental Modelling
Reader in Statistics
School of Mathematics and Statistics

Vaquita Survey Design Steering Committee

17th June 2015

Sirs,

I am sorry I cannot be present at the webinar today. I give below my comments, structured to fit in with the agenda Dr. Donovan sent out yesterday. I emphasize that I am broadly very happy with the plans and fully supportive of the survey design as detailed in the original document, with amendments proposed in the response to reviews. My comments below are minor and largely relate to analysis matters that can be finalized at a later date.

Best wishes,

2. PRACTICAL SURVEY ISSUES
2.1 Survey areas and timing

I am pleased to see that the response contains survey area boundaries.

A very minor suggestion:
Reviewing the Gerrodette et al. (2001) publication, I see that the acoustic survey was for that survey stratified into (among others) North and West strata, and that the North had some animals while the West had none. This made me wonder whether the current survey should be similarly stratified a priori, in case density is similarly structured. This would have the effect of increasing precision on the final abundance estimate, with no need to move any of the planned C-POD locations – it simply means drawing a stratum boundary at some suitably chosen latitude (perhaps about 31.3'N), ensuring there are adequate (approx. >=20) sensors in each stratum. I emphasize that if this is done, it needs to be done before any data from the planned survey is reviewed, in order to avoid under-estimating variance.

2.2 Trackline design for visual survey

Again, I am pleased to see a random systematic design is now planned within a defined survey area.

A minor suggestion:
Few, long lines is a less than optimal design from a variance estimation perspective, especially when some are very long and some very short, as is planned for the low density stratum. I wonder if the team might consider orienting the lines in an E-W direction rather than N-S, and so having many more lines. In addition, a zig-zag design might be more efficient, with much less off-effort time. In this case, I would

The Observatory, Buchanan Gardens, St Andrews, Fife KY16 9LZ, Scotland
Tel: 01334 461801 Fax: 01334 461800 email: len@mcs.st-and.ac.uk

run the lines across the whole area (both high and low density strata), except for the N-E section of the low density stratum, which I would place separate lines in. This is because zig-zag designs (specifically, and equal spacing zig-zag, which is the recommended variety for even coverage) are laid out within a convex hull around the survey area, and one wishes the convex hull to match the survey area as best as possible. I am happy to go into more detail here after the meeting, if this is of interest.
Perhaps there are other practical reasons why a N-S design is better; in this case I'm content with the design as laid out here.

2.3 Placement and number of acoustic buoys

I am happy with this.

2.4 Visual methods – personnel, equipment incl. vessel choice, independent observer and tracking

I am broadly happy with this.

I invite Dr. Borchers to comment on the plans for tracking sightings, in relation to the planned analysis methods using Borchers and Langrock (2015). (This may be better discussed when we come to analytical approaches, in section 3.2 below.)

2.5 Acoustic methods – personnel, equipment

I am broadly happy with this.

One minor suggestion is that consideration be given to refining the playback design. I apologize for not suggesting this in my original review, and am happy with the design as described. However, a few additional considerations are:

- Might it be better to play back recordings of real vaquita clicks rather than synthetic ones, in order to test the classifier as well as the detector. They could perhaps vary in amplitude to simulate the head sweep of a vaquita?
- As a possible alternative, might a directional transducer be used, and rotated in a realistic way?
- Might playbacks be performed at a systematic set of depths in the deeper areas, to investigate the relationship between vaquita depth and detection probability?

I do not strongly recommend the first two of the above options, because it is hard to know what is "realistic" and so this may raise more issues than it solves. However, these might be worth considering.

2.6 Consideration of supplementary methods e.g. drones, land-based observers, small boats

I am very happy with the design and survey modality as laid out in the documents we have. I do not believe, given our current state of knowledge, that other methods will perform better, and I do not think this is the time to experiment with unproven methods.

2.7 Other

No comments.

3. ANALYTICAL APPROACHES

A note: I am very pleased to see that these are being discussed in detail at this stage; however, I note that the vital thing at this stage is to get the survey design and planned field methods right. It is not essential that all analysis questions are resolved at this meeting, or even before the data are collected. For example, we do not have to completely agree on what model-based methods are to be used, or what variance estimation method is to be employed. Our primary aim should be to satisfy ourselves that the right data are being collected to obtain, as far as possible, an unbiased and precise estimate of abundance.

3.1 Design-based and model-based

I am happy with the current plan. I would be happy to discuss design-based variance estimation techniques at some point in the future, especially with respect to systematic design variance estimation and approaches to dealing with the fact that each N-S lines is not surveyed in a single day. I do not think it's essential to resolve this at today's webinar.

3.2 Biases – availability, detection, responsive movement

This is not my area of expertise, but it is an important topic and I hope there is a robust discussion here.

3.3 Acoustic – detection area and calibration

I was confused by the response to St Andrews question 5. Dr. Barlow is in an excellent position to understand the issues, having recently participated as reviewer in the SAMBAH analysis review. My suggestion is that a binary generalized additive model is used to construct a detection function for the playbacks as a function of transducer depth (if depth is varied), receiver depth, horizontal distance, and other covariates judged to be important; model selection is performed; horizontal distance and transducer depth are integrated out (making some assumption about animal depth) to give an effective detection area (EDA) for each location. The mean EDA can be calculated for the calibration stratum and the acoustics-only stratum. The ratio of these EDAs can then be used as an additional multiplier in the standard distance sampling abundance formula, much like g0 is used as a multipler. A parametric (or nonparametric) bootstrap can be used for variance estimation. Other approaches are possible, and I would be happy to discuss this at length with the analysis team if this seems useful. I do not think it is a make-or-break issue for the current survey plans.

3.4 Calibration of acoustic and visual data

Apart from the above, I am satisfied with the proposed approach.

3.5 Accounting for uncertainty

I would be happy to discuss this at a future date, if discussions at the meeting are deemed inadequate.

3.6 Other

No comments.

4. OTHER SCIENTIFIC MATTERS, IF ANY

No comments.

5. CONCLUSIONS AND RECOMMENDATIONS

No additional comments to those given above.

APPENDIX E11

Comments on Research Design to Estimate Vaquita Abundance

Biol. Pedro Ulloa. Associate General Director of Research in Fisheries in the Atlantic.

14th May 2015

This document contains comments on the document "Research design to estimate vaquita abundance, with Addendum to optimize design given new results on 2013-2014 rate of decline" by Rojas-Brancho *et al*.

General comments

The hydroacustic results for Vaquita clicks (ID based on a 1991 paper) for 2011-2013 have not been published. Based on these indirect measurements a remaining 97 vaquitas have been estimated by the CIRVA in 2014. It is of the utmost importance that these acoustic research results be published (peer-reviewed, indexed journals) as soon as possible. It is also important that CIRVA considers publishing its results (i.e. in 2014 it estimated an 18% rate of decline) and recommendations.

The proposal calls for installation of numerous hydrophones (CPODS) in the northern shallow waters for auxiliary estimation, but the no fishing of any kind requested in this huge area is highly impractical. It must be considered that CPODS will be lost or stolen in this large area, rendering its usefulness limited. In addition, the assumption that in this large shallow area vaquitas are left is unfortunately weak. Only a few sightings were recorded in this area in 1997 and in 2008. It would be then best to survey this area on an opportunistic fashion, rather than in a permanent one, and concentrating efforts and CPODS on the southern portion of the known range, where only a handful CPODS are planned in the latest addendum.

The acoustic results from 2011-2013 clearly show no clicks, even in the northern portion of the vaquita refuge. However, there are encouraging hotspots in the southern portion of the refuge. It would then be best to place CPODS in the area of the refuge, especially the area not covered yet (a few corners) and in the area immediately adjacent to its southern border. This, coupled with the calibration work proposed in this area would also help to rule out the possibility that click density is tracking the density-dependent range contraction of vaquitas to their southern range, in part out of the refuge. It is important to at least attempt to rule out this hypothesis and this survey offers a good opportunity for it.

It is generally agreed that the best time to observe vaquitas is summer (Beaufort 0-2), but the *R/V Ocean Starr* will not be available until September and the survey will extend until December. This is dangerously close to the very bad weather season (November-December-January) where sighting effort would be significantly impaired. There is clearly a tradeoff between vessel availability and the need to obtain enough sightings for a precise estimation. There should be a careful consideration of this tradeoff, as there are other vessels (newer and cheaper) available at better weather times. One possibility is to consider again a spring survey in 2016 using the *R/V Ocean Starr* as was considered in an earlier proposal. Another is to consider another vessel such as *BIPO* and weigh the possibility of estimating g(0) for this vessel as well, given that two sets of observers are proposed, which is highly advisable anyway, even if the *R/V Ocean Starr* is used again.

An additional advantage of *BIPO* is that it features a specifically designed silent infrastructure. It was designed that way (main engines are electric, and other silent features) for hydroacustic surveys of the highest quality. Such a vessel could be very useful to approach the vaquitas, whose elusive behavior towards engine noise is well documented. As this has clear bearing on g(0) and the fractions of vaquitas avoiding the vessel, this silent characteristic should be carefully considered.

Perhaps the consideration of a combination of platforms and survey times will give us the best possibility of obtaining the precise estimation we are seeking.

The usefulness of other methods should be carefully examined again, especially in the mid-term. There are now drones and other aerial and underwater platforms that could be used from support vessels. The tower at Rocas Consag and other alternatives that have been considered in the past should be examined again, especially on the light of the small population remaining. It is important to consider the relative importance of every available platform available.