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.

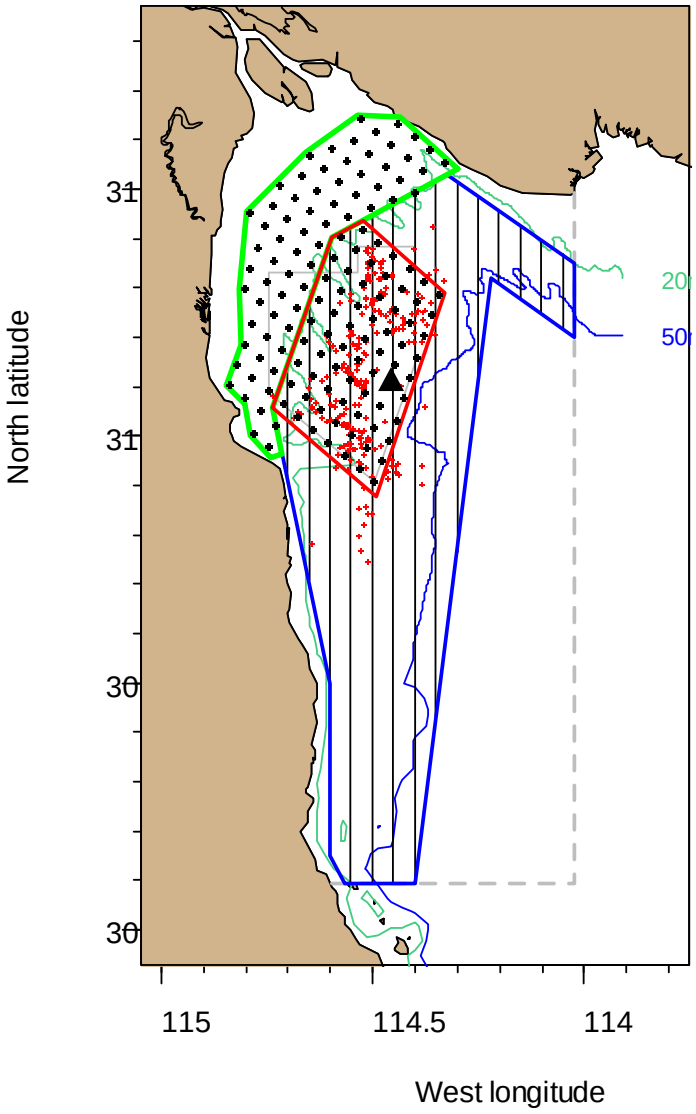

Fig. 1. Research design for the 2015 vaquita abundance study. The area to be sampled visually is outlined in blue, and visual transects are shown as black north-south lines. The area to be sampled acoustically is outlined in green, and acoustic sensor (C-POD) locations are shown as black points. The 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.