STATUS OF THE ACOUSTIC MONITORING SCHEME FOR POPULATION TREND OF VAQUITA (Phocoena sinus) AFTER TWO SAMPLING PERIODS

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ABSTRACT

This report presents partial results of an investigation aimed at estimating the population trend of the vaquita, through monitoring of individuals of the species with passive acoustic techniques, as designed by a group of experts after a survey to test available acoustic detectors designs and a design workshop (Rojas Bracho et al., 2010).

This monitoring scheme is based on the installation of autonomous acoustic detectors, named C-POD, at 48 sites within the Refuge for Protection of Vaquita and buoys used to delimitate it. Given illegal fishing activities that happen inside the refuge, the 48 sampling sites were restricted to the three months before the shrimping season (June to September) when fishing intensity is the lowest of the year. Efforts have been made to continue sampling all year-round with detectors deployed in the buoys. However, we have experienced loss rates that are not sustainable and new deployment methods are being essayed to try solving this problem.

In its current development, the monitoring scheme envisages the attainment of six years of sampling, in order to detect small increases or decreases of the population during this period. This information is essential to adjust the actions taken by the Mexican government to recover the species. If population is not monitored directly, given its critical current level, it could reach very low numbers before the recovery program is adjusted in a timely manner.

This report presents data obtained during the second year of sampling (first sampling year reported in SC/64/SM19) and numerical analysis with the first two years of sampling. This analysis, of course, is not conclusive. Rather it is an exercise that shows the path of analysis that is intended to follow. It is mentioned the research gaps that need to be filled in the near future, in order to ensure that the estimation model of the acoustic encounter rate trend is guided by changes in the density or population abundance, minimizing the influence of other potential sources of variation and as such, reducing probable biases.

INTRODUCTION

In this document we inform about the continuation of the "Acoustic Monitoring Scheme for the Vaquita", represented by the second sampling season, according to the designed operation plan (Jaramillo-Legorreta, 2011). Tasks done included the installation of the acoustic detectors in both, the buoys delimiting the Refuge for the Protection of the Vaquita, as in submerged moorings within this polygon. The Field Operations and Data Analysis teams were established and given with indications of standardized procedures.

According to the results and guidelines depicted in the document "Assessing Trends in Abundance for Vaquita using Acoustic Monitoring: Steering Committee Report on Pilot testing phase and recommendations for full deployment" (Rojas-Bracho et al., 2011), detectors were deployed during middle June, 2012, and retrieved during September, a period in which fishing operations are minimal, reducing the probability of losing deployed equipment. Deployment dates were selected based on reports of aerial surveys about the presence of boats inside sampling area [1] (Protection Refuge for Vaquita; Figure 1). When the presence was reported as minimal it was decided to deploy the equipment.

The activities to retrieve submerged moorings were carried out during September 17 to 30. Acoustic detectors moored to buoys are intended to be working all year round, in accordance with the Report of the Steering Committee. However, here we report loss of many acoustic detectors due, presumably, to illegal fishing activities. A modified system to mooring detectors to buoys was essayed in a deploying of 11 detectors during September 2012. Again, most of the detectors were lost, evidently, by fishing operations. A similar deploying will be essayed using only stainless steel pieces to avoid thief.

In this work, we present the results of the second sampling period of a total of six that comprise the monitoring program, aimed to detect small changes in vaquita population in a period of five years.

[1] Juan Manuel García Caudillo. Project "Assessment of the effects of the productive and technological reconversion program PACE: Vaquita, on the number and space-temporal distribution inside the refuge for the protection of vaquita and Biosphere Reserve Upper Gulf of California and Colorado River Delta". Pesca Responsable y Comercio Justo S. de R.L. de C.V. Blvd. Zertuche 937-3, Valle Dorado, Ensenada, B.C., México 22890.

FIELD OPERATIONS LOG

Work inside Protection Refuge

Deployed acoustic detectors inside Protection Refuge

On early May 2012, we obtained information about the presence of dozens of fishing boats within the Refuge, sighted during a survey flight. Accordingly, it was decided to delay the deployment of detectors waiting for a reduction of fishing intensity. By June, we were reported that only a few boats had been found, so it was decided to install the detectors by the middle of this month.

All 48 moorings and acoustic detectors of the monitoring scheme (Figure 1) were deployed on June 17-20th. At every deployment it was recorded date and local UTC time (excluding daylight saving adjustments), sampling site number, acoustic detector number and precise geographic coordinates of the sites where each anchor of the mooring was deployed (Table I).

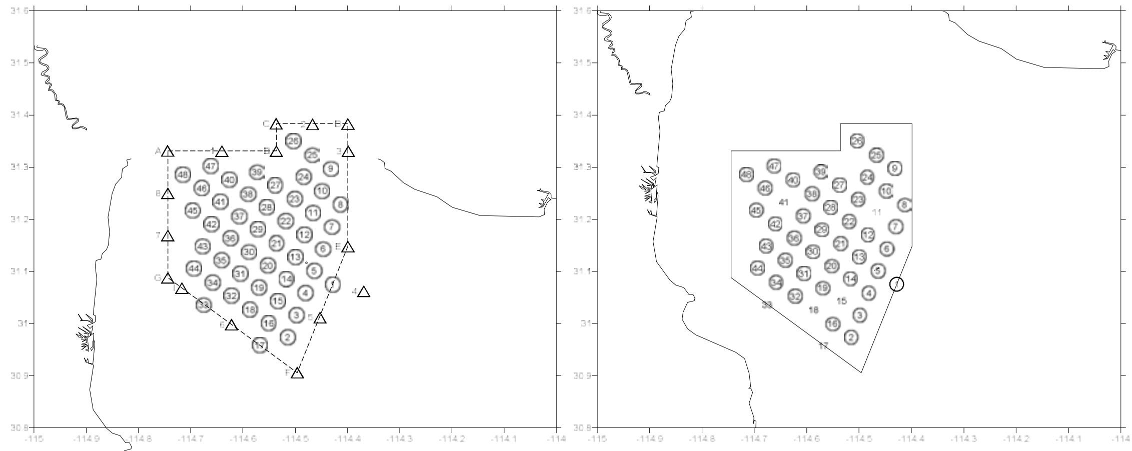

Figure 1. Sampling sites of the acoustic monitoring scheme (left), including sites inside Vaquita Refuge (broken line polygon) where submerged moorings are deployed (circles). Delimiting buoys are indicated with triangles. Right map shows the sites where detectors were recovered (circles) after sampling season 2012.

Retrieved and lost moorings and acoustic detectors inside Protection Refuge

Field work to recover the moorings was carried out between September 17 and 22nd. A total of forty two moorings and detectors were recovered (Figure 1), which represents a loss of 12.5%. In 2011 it was lost 20.8% of the moorings (10; one detector delivered by fisherman after Jaramillo-Legorreta et al., 2012), so that the 2012 sample was more successful in this regard.

Once the boat arrived at each sampling site marked in GPS the average time to find the moorings was 15 minutes, and a maximum of 20 minutes to pick it up and place it on the boat. In sites where moorings were not located search time was extended over two hours, in one or two separate occasions.

The moorings recovered were brought ashore to be cleaned, disassembled and stored. The acoustic detectors were cleaned of algal and faunal growth by pressurized water and scraping with a spatula. Once cleaned were carefully dried to extract safely memory cards.

Once the moorings were stored (in preparation for 2013 sampling period) and acoustic detectors delivered to the analysis team, it was concluded the work of the field operations team.

Work in delimiting buoys of the Protection Refuge

Jaramillo-Legorreta et al. (2012) reported a large loss rate of detectors deployed at buoys, after essaying two methods of deployment. To try gathering data in buoys it was assayed an alternative third method. It consists of attaching a rope to the weight holding the buoy. An anchor was attached to the other end of the rope. In this way, it can be maintained the distal end of the rope away from the buoy and inside refuge boundaries. Then, an acoustic detector is attached to the side of the rope where the anchor is, in order to locate it at a site remote from the buoy (Figure 2) and reduce probabilities of interaction with human activities, mainly fishing with nets.

To retrieve the detectors it will be required to tow a hook behind a boat to grasp the rope and pull it to reach the detector. This method is thus similar to that used in the moorings that are deployed within the refuge. However, it will be not required to waste time searching for the rope with GPS positions, because the buoy marks the position clearly.

Table I. List of the submerged moorings and detectors (C-POD) deployed during the second sampling period of the Vaquita Acoustic Monitoring Scheme, including date and time of deployment as well as the GPS position (North latitude and West longitude) of both mooring anchors. Last three columns show whole days of data gathered per detector, number of identified acoustic encounters of vaquitas and average acoustic encounter rate (encounters / day) at every site.

				Danforth anchor		River Anchor				
Date	Time	Site	C-POD	Latitude	Longitude	Latitude	Longitude	Effort (days)	Acoustic encounters	Encounter rate
19/06/2012	07:13	1	1331	31.07524	114.42812	31.07631	114.42751	90	0	0.000
19/06/2012	06:23	2	1346	30.97557	114.51475	30.97596	114.51403	105	135	1.286
19/06/2012	06:43	3	1319	31.01680	114.49796	31.01744	114.49758	94	31	0.330
19/06/2012	06:59	4	1344	31.05940	114.48103	31.06044	114.48017	92	67	0.728
19/06/2012	07:29	5	1345	31.10127	114.46246	31.10256	114.46152	94	0	0.000
19/06/2012	07:43	6	1341	31.14389	114.44701	31.14506	114.44660	74	0	0.000
19/06/2012	07:58	7	996	31.18640	114.43011	31.18757	114.42926	94	21	0.223
19/06/2012	08:11	8	1312	31.22890	114.41307	31.23048	114.41253	63	30	0.476
19/06/2012	08:20	9	1311	31.29762	114.43207	31.29886	114.43050	91	77	0.846
19/06/2012	08:05	10	1513	31.25524	114.44902	31.25660	114.44785	91	98	1.077
19/06/2012	07:43	11	1509	31.21283	114.46600	31.21395	114.46453			
19/06/2012	07:27	12	1342	31.17047	114.48289	31.17149	114.48132	91	1	0.011
19/06/2012	07:08	13	1337	31.12816	114.49999	31.12907	114.49864	70	22	0.314
19/06/2012	06:50	14	1332	31.08579	114.51687	31.08652	114.51538	60	416	6.933
19/06/2012	06:34	15	992	31.04342	114.53385	31.04398	114.53228			0.000
19/06/2012	06:18	16	1308	31.00106	114.55082	31.00171	114.54928	88	236	2.682
20/06/2012	08:44	17	991	30.95885	114.56770	30.95922	114.56601			
20/06/2012	09:18	18	1004	31.02729	114.58698	31.02861	114.58607			
20/06/2012	09:34	19	1003	31.06982	114.56996	31.07103	114.56909	90	72	0.800
20/06/2012	09:51	20	1511	31.11211	114.55304	31.11289	114.55252	79	48	0.608
20/06/2012	10:09	21	1301	31.15464	114.53611	31.15569	114.53517	81	5	0.062
20/06/2012	10:23	22	1498	31.19699	114.51905	31.19763	114.51794	90	3	0.033
20/06/2012	10:39	23	1338	31.23938	114.50215	31.23999	114.50217	90	2	0.022
20/06/2012	10:52	24	1006	31.28175	114.48504	31.28244	114.48394	84	9	0.107
17/06/2012	12:13	25	1009	31.32400	114.46804	31.32418	114.46645	87	10	0.115
17/06/2012	11:56	26	1506	31.35071	114.50387	31.35120	114.50313	60	0	0.000
17/06/2012	11:06	27	1501	31.26576	114.53798	31.26637	114.53676	54	0	0.000
17/06/2012	10:40	28	1315	31.22331	114.55488	31.22428	114.55372	75	2	0.027
17/06/2012	10:30	29	1339	31.18101	114.57183	31.18210	114.57083	66	19	0.288
17/06/2012	10:19	30	1349	31.13881	114.58870	31.14006	114.58786	56	4	0.071
17/06/2012	10:02	31	990	31.09626	114.60576	31.09710	114.60522	87	59	0.678
17/06/2012	09:11	32	1307	31.05420	114.62259	31.05549	114.62151	86	357	4.151
17/06/2012	09:28	33	995	31.03802	114.67569	31.03873	114.67535			
17/06/2012	09:41	34	1507	31.08019	114.65857	31.08139	114.65773	93	206	2.215
17/06/2012	09:57	35	1350	31.12288	114.64192	31.12393	114.64106	94	41	0.436
17/06/2012	10:11	36	1316	31.16490	114.62463	31.16567	114.62342	87	9	0.103
17/06/2012	10:23	37	1504	31.20729	114.60776	31.20843	114.60701	93	9	0.097
17/06/2012	10:36	38	994	31.24974	114.59075	31.25050	114.59021	93	2	0.022
17/06/2012	10:59	39	1505	31.29212	114.57382	31.29283	114.57347	55	0	0.000
17/06/2012	11:16	40	997	31.27610	114.62660	31.27725	114.62572	96	1	0.010
18/06/2012	07:01	41	1320	31.23363	114.64354	31.23525	114.64252			
18/06/2012	06:47	42	1333	31.19128	114.66051	31.19244	114.65960	71	4	0.056
18/06/2012	06:17	43	1335	31.14815	114.67555	31.14955	114.67479	78	164	2.103
18/06/2012	05:58	44	1302	31.10656	114.69454	31.10770	114.69329	94	74	0.787
18/06/2012	07:20	45	1314	31.21767	114.69652	31.21919	114.69520	65	0	0.000
18/06/2012	07:32	46	1309	31.26006	114.67951	31.26203	114.67852	70	0	0.000
18/06/2012	07:46	47	1347	31.30231	114.66250	31.30376	114.66164	91	1	0.011
18/06/2012	08:03	48	1343	31.28636	114.71543	31.28788	114.71466	91	0	0.000

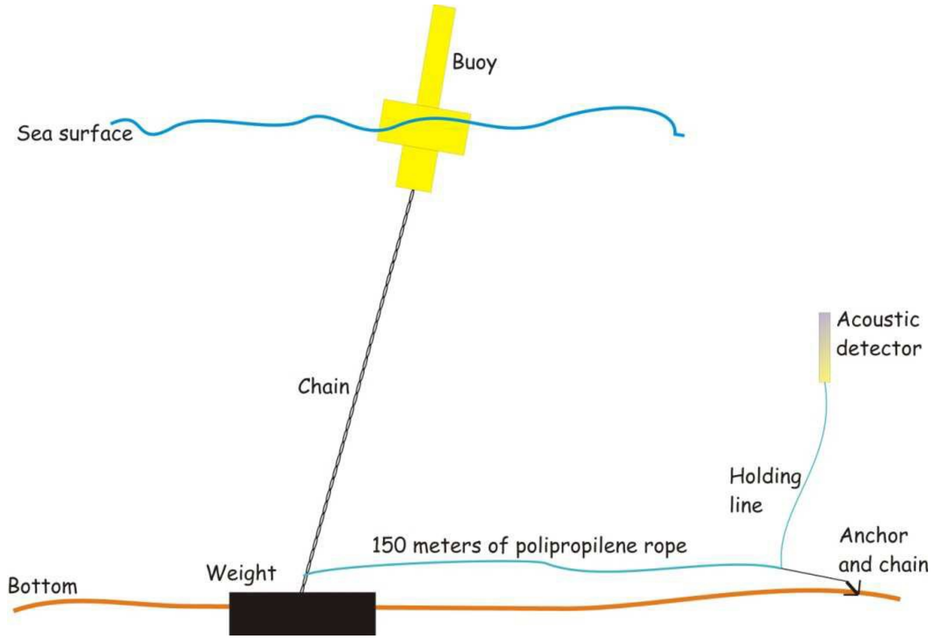

Figure 1. Diagram showing the way acoustic detectors are deployed on buoys under the alternative methodology to reduce the high rate of losses experienced with other techniques. A rope of approximately 150 meters is attached to the weight holding buoy in place. This work was done by professional divers. At the opposite end is installed an river type anchor and another rope to hold the acoustic detector, which has positive buoyancy.

The installation of the rope in the weights holding the buoys is not a job for amateurs, since it is a deep diving under extreme turbidity. As such, it was required the hiring of professional divers. The installation work was conducted from September 7 to 9, when 11 moorings were placed on buoys 1, 2, 3, 5, 6, 7, 8, A, I, F and G (Figure 1). The field operations team worked together with the divers. Once the diver went down and attached the rope to the buoy, a small boat was used to extended rope, into the Refuge, and threw the anchor along with the acoustic detector. The boat team stayed at the site for several minutes to ensure that all the rope got submerged, without any sign on the surface. Deployments were made just days before the opening of the shrimp season 2012-2013. To be successful it is necessary that the devices work for a reasonable period where fishing operations are also taking place.

Some days after the deployment it was informed to us that authorities responsible of maintenance of the buoys retrieved, by error, moorings installed at buoys A and I. Hence, only 6 and 14 days of data, respectively, were gathered. Efforts to recover the acoustic detectors were done first on November 22nd and five of the moorings were properly grasped and detectors retrieved (buoys 2, 5, 6, 8 and F). On December 14th one additional detector was retrieved at Buoy G and few days later a fisherman delivered the detector deployed at Buoy 7. Moorings at buoys 1 and 3 were not located after about two hours of searching effort.

Hence, six out of the eleven detectors deployed were properly located and retrieved even in areas subjected to intense fishing operations. Two of the detectors were not allowed to work due to a lack of coordination with environment authorities, which has been already discussed with them. On the days when the six detectors were recovered other six detectors were deployed with fresh batteries.

Retrieval of the six moorings was tried on March 5th, 2013, and only three of the moorings were located at buoys 6, F and G. After about a total of nine hours of effort it was decided to cease the searching and declare moorings lost. After six months of the original deployment on September 2012, only three detectors remain in place out of the nine deployed (not taking into account the two retrieved accidentally during buoys maintenance duties). Therefore, we again underwent a large loss rate of 67%, which preclude us to keep sampling in buoys.

Essaying of an alternative method of deploying

As sampling in the 48 sites inside the Protection Refuge is only feasible during the three months previous to the shrimp fishery season and the reminder finfish fisheries that use gillnets (chano, sierra, mackerel, sharks and rays), that extend until about May every year, it was identified that deploying detectors in delimiting buoys is the only reasonable way to maintain a year round sampling. However, until now it has not been possible to maintain a sampling program due to very high loss rates of equipment occurring during illegal fishing operations.

Considering that it is practically impossible to solve this under an scheme of surveillance, it will be tried an alternative method of deploying same as the last one explained in the previous section, but using as mooring materials only stainless steel materials. It includes the use of multithread steel wire instead of rope and shackles without any disassembly parts to join the pieces of the moorings. In this way we expect that although a mooring and detector could be trapped in a net, it would be virtually not possible to gather them without large metal scissors. We are going to essay with five moorings during the next shrimp season, using dummy detectors instead of operational ones, as a pilot test.

DATA ANALYSIS

Analysis of raw data

The method of analysis used was the same as in 2011. The project coordinator and data analysis team were responsible for opening acoustic detectors to retrieve data cards. These were read on a portable computer equipped with software for data analysis (CPOD.exe V2.035). The program created CP1 type files, which were backed up in external drives. Once in the lab, CP1 files were processed by the specialized identification routine of the analysis program to isolate potential vaquita like signals and other kind of noises (dolphins, biological signals and mechanical noises). This routine created a CP3 file (which contains only the information of identified signals) for every CP1 file. CP3 files were backed together CP1 files on external drives.

Copies of the pairs of CP1 and CP3 files were given to the analysts to determine the time and type of series in the archives. After the inspection of each file the analysts created a report in text format (created by the CPOD program itself), which was delivered to the project manager for further analysis.

From the 42 recovered acoustic detectors (Figure 1) were obtained a total of 84 files with a total size of 62.9 GB. The start dates of sampling and effort at each site are shown in Table I. The analysis includes only full days of sampling, considering a solar day between 00:00 and 23:59 (1440 total minutes). Thus, the days when the detectors were deployed and retrieved are excluded from the analysis.

A total of 3,453 station-days of sampling were obtained and 2,235 acoustic encounters of vaquitas were confirmed. The average acoustic encounter per day per site is shown in Table I.

It was not required to change analysis protocol applied during 2011. Analysts confirmed the identification of the different types of signals which, if appropriate, were corrected according to the parameters already established. Reports for each file were constructed according to the standard established before.

Data files can be classified by the number of acoustic encounters of vaquitas identified: a) without encounters, b) with only a few encounters (less than 10), c) with several encounters (10 to 50) and d) with too many encounters (over 50). The analysis time for a file type “a” was less than a minute. The type “b” took on average 34 minutes while type “c” approximately 100 minutes. Finally, the type “d” took longer than two hours.

The Table I shows the list of analyzed data with geographical reference, indicating for each site the number of sampling days and total confirmed vaquita acoustic encounters, as well as the encounter rate.

Preliminary analysis of acoustic encounter rate trend (2011 and 2012 samples)

As data coming from detectors deployed in buoys had been very heterogeneous due to high rates of loses explained before, only analysis of data coming from sampling sites inside Protection Refuge will be presented in this report. Analysis of data gathered in buoys is being processed and will be informed in future reports.

Data set description

The data consist of the number of acoustic encounters of vaquitas identified each full day of effort on each of the data available sampling sites inside Refuge, during the periods 2011 and 2012. Sites whiteout data means that mooring and detector got lost. On few occasions detectors had been delivered back to us by fishermen, and the data had been generally available as the detector is returned closed with data card intact.

In 2011 we obtained a total sample of 2,929 days and 1,872 confirmed acoustic encounters of vaquita (encounters corrected after report SC/64/SM19). As previously described, in 2012 a total of 3,453 days were gathered and 2,235 encounters identified. The average acoustic encounter rate (encounters / site / day) in 2012 is 0.647 (variance 2.547), larger than that calculated in 2011 of 0.639 (variance 2.506). The coefficients of variation of the standard error are very similar between 2011 and 2012 (0.046 and 0.042 respectively), showing homogeneity.

The Figure 3 shows the dispersion of all data. It is seen at a glance that the range of the data is very similar and form two samples separated for several months. In this sense, it is supposed that these are independent samples.

It is not easy to distinguish the distribution of the data in Figure 3. At first sight it is noted an accumulation of zero values. In fact, 2,335 days in 2011 had zero encounters and 2,583 for 2012. This represents respectively 79.7 and 77.2% of days without any vaquita encounters.

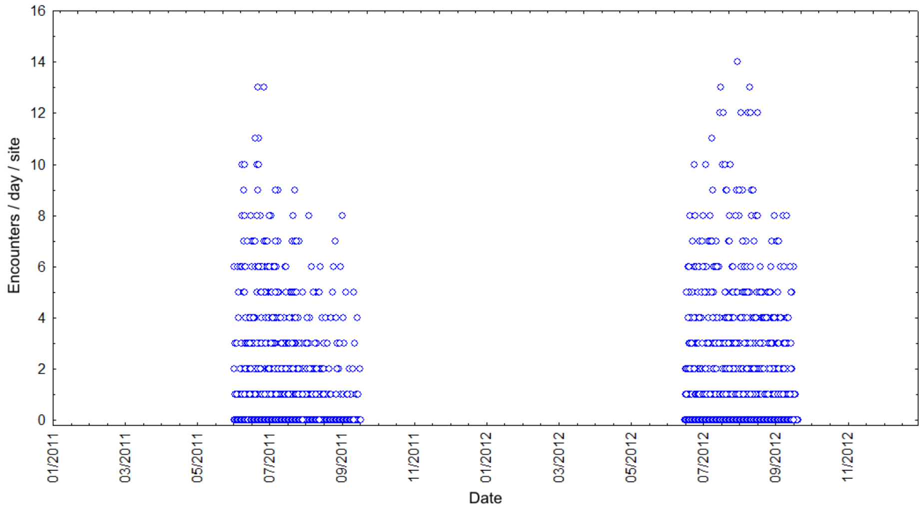

Figure 3. Dispersion of 2011 acoustic encounter rate (group of data to the left) and 2012 (group of data to the right). Each point represents the number of identified acoustic encounters of vaquita each sampling day, regardless of the sampling site in which they were obtained.

Figure 4 shows graphically the distribution of the data, for each year, in a histogram. Clearly there is an accumulation of zeros. Since data are counts it is appropriate to use a distribution for discrete data, such as Poisson, which is frequently used to describe the distribution of events occurring at random (Zar, 1984). In this distribution mean and variance have the same value. In 2011 and 2012 variance is 3.92 and 3.94 times greater than average, respectively, which clearly departs from a Poisson distribution. That is, there is a larger variance that this model fails to explain. The negative binomial distribution can be modified to adjust one of the two parameters so that take into account this additional variation with respect to a Poisson type distribution (Lindén and Mäntyniemi, 2011). Figure 5 presents the distribution of pooled data for 2011 and 2012. This is justified given the similarity of their variances and variance to average ratios. This figure also shows a fit of the data to Poisson and negative binomial distributions. Clearly, the latter distribution better fits to data, hence this will be taken into account in the analysis process.

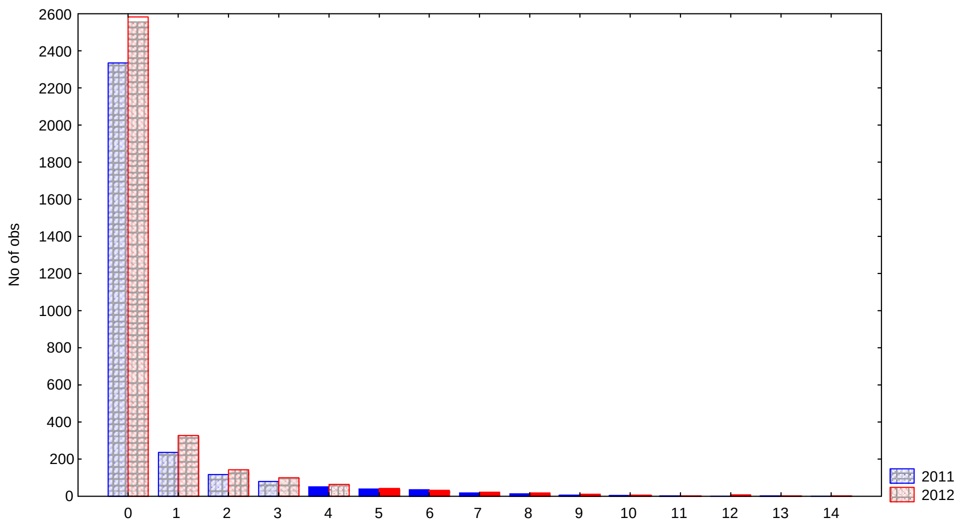

Figure 4. Distribution of acoustic encounter rate data of 2011 and 2012 sampling periods. Is clear the accumulation of zero values, which departs from a Poisson distribution and is more alike to a Negative Binomial one.

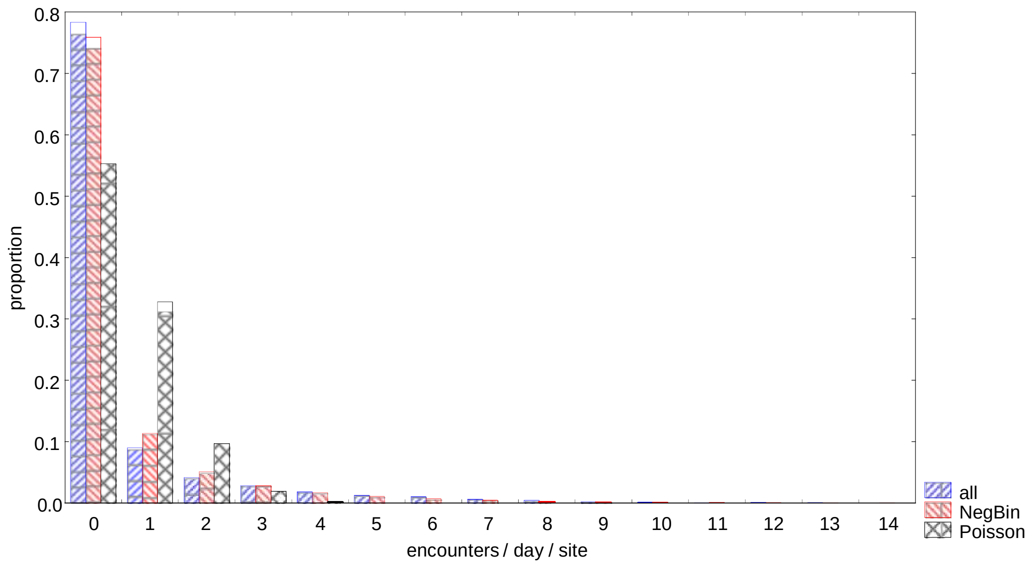

Figure 5. Probability distribution for 2011 and 2012 pooled data (blue bars). Red bars represent a negative binomial distribution fit with mean 0.592 and parameter r = 0.2. The black bars are the fit to a Poisson distribution with the same mean. Clearly the negative binomial distribution better represents the underlying distribution of the data.

Data set pre-analysis preparation

Both sampling seasons during 2011 and 2012 lasted 108 days between the deploying of the first acoustic detector and the retrieval of the last one. Start dates were out of phase by 14 days. Although sampling period extended by more than three months, data was not gathered all along this interval at all sites where detectors were recovered. It is so because, first, not all detectors are deployed in the same day and, second, detectors turned off for some reasons at different days. In 2011 the interval between the first and last deployment was 7 days, and 4 days in 2012. The interval between the day when the first and last detectors turned off was 51 days in 2011 and 53 days in 2012. The reason of these differences obey mainly to memory depletion in noisy sites, problems with firmware writing the last data file and problems associated with moisture inside detectors. In 2012 problems associated with moisture were practically eliminated by a very careful desiccation of silicagel packages. A post-process of data cards appears to recover data stored in the last data file. In noisy sites a reduction of the maximum number of clicks stored per minute can solve the problem for future sampling periods. The average days of sampling per site were 82.2 in 2012 versus 77.1 days in 2011, which shows an improvement. However, we are looking to augment the number of days that a single detector lasts gathering data.

The sample unit is the number of detected vaquitas per day per station. However, the stations are spreading uniformly along the Protection Refuge and hence, they represent the acoustic encounter pattern as a whole per day. We know that encounter rate is not uniform along the study area and, in fact, there is a zone near San Felipe Bay characterized by the highest encounter rates. Therefore, the estimate of acoustic encounter rate most includes only days with a sample enough to represent the encounter rate pattern. On the contrary, the result could be biased if the sample tends to include more stations with higher or lower encounter rates than the average pattern.

To avoid biases the analysis will include only days when all detectors recovered were gathering data. In 2011 the 38 detectors were all on duty during 50 days. The 42 detectors recovered in 2012 lasted 51 days working all together. Hence, the data available for analysis is composed out of 1,900 stations-days in 2011 (1,316 encounters) and 2,142 in 2012 (1,382 encounters). Under this sample, the acoustic encounter rate in 2011 was 0.693 encounters per day per station and 0.645 in 2012. It is the opposite of the picture with the whole sample and shows how an uncorrected sample could bias the results.

Estimation models

As a way to test the power of the sample to detect an annual change of the acoustic encounter rate, a simple approach was used to compare the averages. The approach was to compare the averages of the two sampling periods with the model:

$$y_{2012} = q_{11-12} \cdot y_{2011}$$

where the average encounter rate at 2012 sampling period depends on the average at 2011 and a q coefficient which determines the magnitude and direction of change (values higher than one mean an increase of the average and vice versa). Then, the problem is to estimate the coefficient q given data available in acoustic encounters for 2011 and 2012.

Given the nature of the acoustic data, composed of counts of encounters per day, and the subjacent distribution that fits a binomial negative, it could be appropriate to use a logarithmic model to describe the trend of acoustic encounter rate:

$$y_t = e^{a+bt}$$

where acoustic encounter rate y at time t (y_t) depends on time and parameters a and b. So the problem is to adjust these parameters given the data for 2011 and 2012.

To adjust the parameters of the models we used a Bayesian framework (Gelman et al., 1995), sampling from the posterior distribution using Monte Carlo Markov Chain (MCMC) with the Hastings-Metropolis algorithm (Chib and Greenberg, 1995) as implemented in AD Model Builder (Fournier et al., 2012).

For the simple model the average encounter rate at 2011 was considered a parameter aside q, with semi-informative prior distributions (bounded uniforms). Hence, 2011 data is used in the likelihood term of the posterior distribution instead to be used to construct the prior one.

Also, prior distributions of parameters a and b of the logarithmic model were bounded uniforms. On both models the dispersion parameter (r) of the negative binomial distribution, used in the likelihood term, was also treated as a parameter to be estimated, again with a prior based on a bounded uniform distribution.

Results

The posterior distributions for the simple model are presented in Figure 6. These were constructed with a set of 100,000 MCMC simulations. It is appreciable that the mode of the average acoustic encounter rate in 2011 is slightly larger than the mode at 2012, indicating an annual decrease. The posterior distribution for parameter q shows a credibility of 57.9% of a value equal or lower than one. Hence, this analysis indicates that it is 1.4 times more probable the encounter rate decreased than increased.

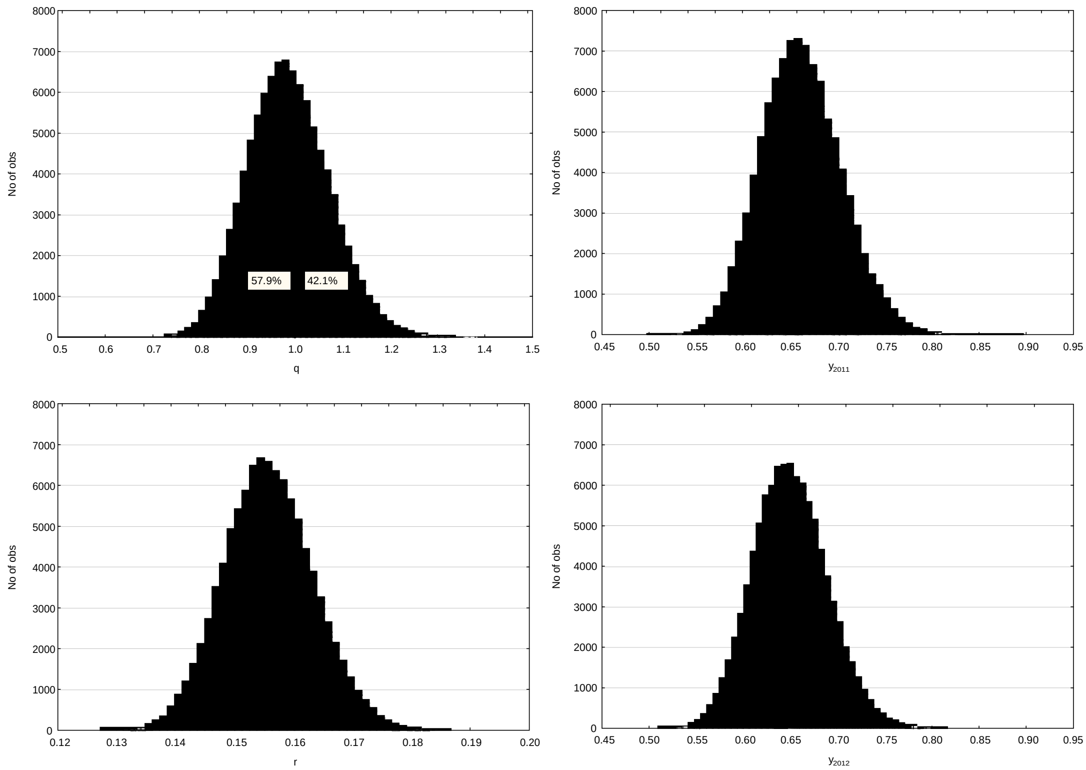

Figure 6. Posterior distributions constructed from 100,000 MCMC simulations for the simple linear model. Panel in the upper left shows the distribution of parameter q and the area under the curve expressed as percent for values equal or lower than 1.0 and the complement. In both distributions at right it is possible to compare the average encounter rate for both analyzed years. Lower left shows the distribution for r, the negative binomial dispersion parameter.

The average of the posterior distribution of encounter rate at 2011 is 0.662, while the original sample has an average of 0.693. At 2012 the original sample average is 0.645 and the one for the posterior distribution is 0.650. The larger difference between the original sample and posterior distribution averages could indicate that the simple linear relationship used do not explains all the variability, which could be explained with other non-linear model.

The posterior distributions for the logarithmic model are presented in Figure 7. Particular relevance has the parameter b, which is the slope of the curve describing the change of acoustic encounter rate with time. The credibility of a slope less than or equal to zero is 60.5%. In other words, the probability of a negative slope is 1.5 times larger than for a positive value. The annualized percent change of encounter rate has a similar posterior distribution than the slope. The mode indicates that the change was around -2.9%.

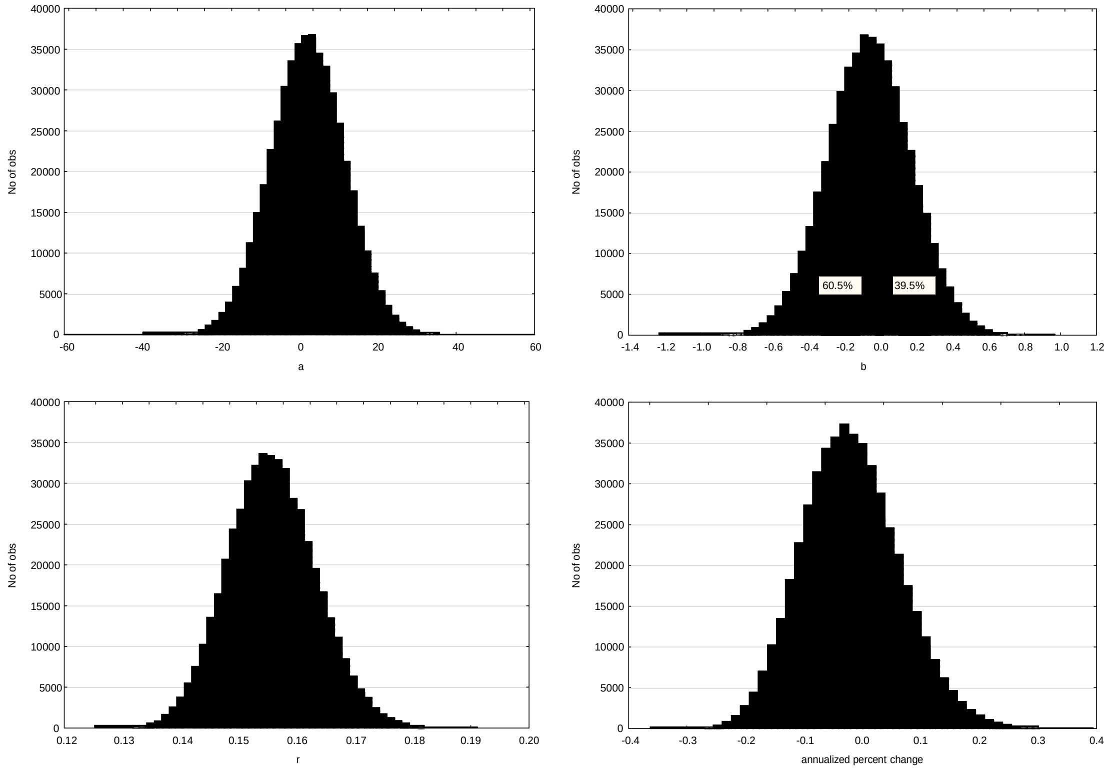

Figure 6. Posterior distributions constructed from 500,000 MCMC simulations for the simple linear model. Upper panels show the distribution of parameters a and b. The distribution for the slope b shows the area under the curve expressed as percent for values equal or lower than 0.0 and the complement. Lower right panel shows the distribution of annualized percent change of the encounter rate, which has same values of area under the curve as the slope b. Lower left shows the distribution for r, the negative binomial dispersion parameter, which is very similar to the one obtained for the fitting of the simple linear model.

The parameter r, the over dispersion factor of the assumed negative binomial subjacent distribution of the encounter rate, has a posterior distribution mode around 0.155 on both models essayed, which is an indication of the consistency of this distribution to explain the variation of this parameter.

Remarks

The acoustic monitoring scheme is designed to detect the trend of the acoustic encounter rate in a period of five years, according to the sample variance measured during the 2008 survey (to test different acoustic detectors) and the small changes the population can experience due to its very small size.

The scheme is expected to detect annual decreases of 5% (due to continuing by-catch) or increases of less than 4% (in the absence of by-catch and according to the maximum increase rate estimated for vaquita; Rojas-Bracho et al., 2010). The scheme will include a total of six annual sampling periods, finalizing in 2016. Hence, the results presented here are not conclusive and are only depicting of the kind of analysis it is intended to follow as more data accumulates.

FUTURE WORK

To succeed in the monitoring of vaquita population trend, through acoustic encounter rate, it is needed that changes in encounter rate be guided significantly by changes in population density or abundance. Due to restrictions imposed on sampling area, as fishing activities with nets are allowed outside vaquita refuge where around 50% of population is at any given time, acoustic encounter rate changes could be the result of distribution shifts in or out of the refuge. On the other hand, some events have been identified that potentially can affect encounter rate, as the presence of dolphins or zones characterized by high levels of background noise. Research on these issues is in process and will be reported as advances are made.

Next sampling season in submerged moorings, inside Vaquita Refuge, will start on middle June 2013. Detectors will be retrieved previous to the start of the shrimp season, expected to initiate after mid-September.

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The Equipe Cousteau, in agreement with the Endowment Fund for Biodiversity – Save your Logo, supported design and trials phase, as well as the first and second sampling season reported in this work. Additional funds are being used to complement the third sampling season. World Wildlife Fund – México supported second sampling period and is currently funding the implementation of a calibration facility to keep the standard of the acoustic detectors. Mexican Government, through the Minister of Environment and Natural Resources and the National Institute of Ecology has being providing financial support since the start of the monitoring design. Chelonia Limited, through its CEO Nick Tregenza, have been supplying acoustic detectors at reduced prices and providing unconditional technical support all along the duration of this work.

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