PASSIVE ACOUSTIC ASSESMENT OF VAQUITA

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INTRODUCTION

Since 1997 we have been using an acoustic detector equipment to survey for vaquitas. In 2001 we started to use systematically a sampling designed based on fixed stations and a new version of the acoustic detector was introduced. Since 2004 a stereo version of the detector is being used. The results of these surveys have been presented on past reports (Jaramillo-Legorreta *et al.*, 2001; 2002; 2003; 2005).

During April 1997 the acoustic detector was successfully used to detect vaquitas for the first time. On that occasion we surveyed on a fixed location, aboard an outboard motor skiff boat (panga), only during daylight hours. The sampling effort on fixed stations was similar to the one applied later on (starting in 2001). The panga was anchored in a spot (with the motor turned off and the acoustic detector deployed and operating at all time) near San Felipe Bay (Figure 1) under daylight conditions during five consecutive days, totaling 31 hours of effort. Since June 2001, up to April 2007, we have completed more than 790 hours of effective effort acoustically surveying for vaquitas in 63 fixed points. This effort has been spread along the potential areas of distribution, in the upper and northern Gulf of California. However, vaquitas have been detected only in front of the coast of Baja California, near San Felipe harbor, a fishing and touristic town (Figure 1).

In this report we present the trend of the acoustic detection rate (number of confirmed acoustic encounters of vaquita groups / effective effort) in this area and discuss its meaning for vaquita current status and recovery plans.

DATA

Until now (1997-2007) more than 520 hours of effective effort have been applied in the area where vaquitas have been detected (Figure 1), and 76 acoustic encounters with vaquitas have been confirmed. Forty six stations have been completed, having obtained acoustic encounters with vaquitas on 21 of them (Table I).

The sampling can be divided into five periods. The first one corresponds to April 1997, when the first acoustic survey for vaquitas was done. During five consecutive days we made effort in fixed points inside the hot spot aboard a skiff boat. A total of 31 hours of effort were applied in the five stations. A total of 8 acoustic encounters with vaquitas were confirmed. Every day, during this period, at least one acoustic encounter was recorded (Table I).

The second period belongs to the survey carried out on June 2001. In this survey, an experiment was done to compare the sampling efficiency between fixed stations (with the boat anchored, propulsion engine turned off and electrical plant running at intervals) and transect lines (with the boat traveling across predefined lines). At that occasion the time on every sampling point was restricted to about 5 hours, in order to cover most of the area during the restricted cruise time. A total of 12 stations were completed including 55 hours of effort. A total of eight acoustic encounters with vaquitas were obtained (Table I). This cruise was carried out aboard a motor boat 30 feet long called *Pasaporte*. During the stations the propulsion engine was off as well as the generator engine.

The third period covered the cruises from September 2001 till May 2002, performed aboard the *Pasaporte*. In this period we tried to sample the fixed stations for as long as a full day (24 hrs) on every station, in order to include variation due to the tidal cycle. This was not possible at some stations due to weather conditions. During the sampling period the propulsion engine was off, and the generator engine was turned on by discrete periods to charge batteries and to make some other duties. A total of 192 hours of effort were applied in 12 stations, and 24 encounters with vaquitas were confirmed (Table I).

The fourth period includes three surveys on board vessels of opportunity. During the first one, performed on March 2003, more hours were invested in some stations in order to obtain vaquita video and photographs of vaquitas. This cruise was done aboard a sport fishing vessel, 50 feet long, anchored in the site of the station with the propulsion engines turned off and the generator turned on at all times. The second one was performed during little time aboard a skiff boat with the engine turned off. The last cruise was performed aboard a trawling boat, anchored also with the generator engine turned on at all times. Eight stations were done, summing a total of 84 hours of effort. Twenty encounters with vaquitas were recorded (Table I).

During the last period four more cruises were done aboard the vessel Koipai Yú-Xá (built with support from IFAW, US-MMC and Mexican Government), a boat constructed specifically for monitoring vaquita, as well as other marine mammals, in the Gulf of California. The sampling time also was tried for a full day at every station. In this period the effort applied was of 162 hours distributed among 9 stations. A total of 16 encounters with vaquitas were obtained (Table I).

TREND

In Figure 2 we show the acoustic detection rate values for the 46 sampling stations done (circles). The regression line represents the relationship between the acoustic rate and sampling date. The functional relationship used was a logistic with offset (effort hours per station):

$$\#\ of\ \ acoustic\ encounters = e^{\left(\ell n[effort]+\alpha+\beta * date\right)}$$

Then the acoustic encounter rate is:

$$\frac{\#\ of\ \ acoustic\ encounters}{effort} = acoustic\ encounter\ rate = e^{\left(\alpha+\beta * date\right)}$$

The parameters of this model (and) were fitted supposing a negative binomial error (White and Bennetts., 1996) model under a Bayesian framework. The prior distributions for the parameters were non-informative, as the volume of data imposed a large load on the likelihood portion of the posterior distribution (Gelman *et al*., 1995).

The posterior distribution was approximated with a simulation method (Markov Chain Monte Carlo, MCMC) as implemented in the computer package AD Model Builder (copyright Otter Research Ltd., otter@otter-rsch.com) using the Metropolis-Hastings algorithm. To reduce the effect of autocorrelation inherent to the Markov Chains, only one out of every five simulations was stored for further calculations.

The convergence of the posterior distribution was assessed trough the observation of mean and standard deviation of the generated chain. It was assumed that when these two measures showed no further drastic changes (stabilize) the number of simulations generated was enough to describe precisely the posterior distribution. In Figure 3 it is shown the convergence plot for the slope of the model (parameter). This plot was constructed by calculating mean and standard deviation every time 1,000 more simulations were added to the chain. It can be observed that standard deviation stabilized approximately at 400,000 simulations, while mean at approximately 500,000. Therefore, the 1,000,000 of simulations generated are more than enough and were used all to describe the posterior distribution.

In Figure 4 it is shown a histogram describing the posterior distribution for parameter . The black line divides the distribution into a left portion containing negative values for the parameter, and positive values to the right. It can be observed that approximately 85% of the distribution predicts a negative value. Saying in another way, there is 85% credibility that the acoustic encounter rate in the period 1997-2007 has been decreasing.

The regression line shown in Figure 2 was constructed with the average values of the 1,000,000 simulations chain for parameters and . With these values it was calculated that the decreasing of the acoustic encounter rate was -0.581 of the acoustic rate in 1997. There is also approximately 85% credibility of a negative trend.

DISCUSSION

The vaquita inhabits the most turbid area in the Upper Gulf of California (Jaramillo-Legorreta, 2008), where the use of echo-location must be vital for prey detection and other activities. Individuals must be emitting signals regularly; therefore their acoustic detection is more likely. Also, the area size that vaquita inhabits is too small, thus increasing the probabilities of detection.

The combination of a small and turbid distribution area; the likely fact that vaquita must rely in its echolocation capabilities to perform important biological activities; the analysis design that only included the area where acoustic encounters with vaquitas were obtained, and the fact that the species is distributed forming very small groups (in average two individuals; Jaramillo-Legorreta *et al*., 1999), are the basis to infer that the acoustic detection rate must be closely linked to the population density. The acoustic detection methodology used detects groups, which may contain several acoustically active individuals. The death of individuals in species forming relatively large groups may not have a proportional impact on the detection rate, because the groups can be still detectable as many acoustically active individuals may remain. In species forming small groups, as vaquita, the death of individuals must have a greater impact on the acoustic detection rate; therefore the decreasing trend of the acoustic detection rate is an indication of a further and recent reduction of vaquita population abundance.

In recent years the fisheries that use gillnets in the region have not only been operating constantly, but applying an increased effort in number of boats and nets (data provided by Biol. Jose Campoy, Director of the Biosphere Reserve Upper Gulf of California and Colorado River Delta, during the Third Meeting of the International Committee for Vaquita Recovery). Vaquitas are by-caught in this type of nets; hence the indicated reduction of vaquita population can be explained by this fact.

A possible alternative explanation, for the reduction of the encounter rate, is a displacement of the preferred distribution area of vaquita. During the surveys we have been sampling throughout the potential distribution area, and no vaquitas have been found both, acoustically nor visually. It is also necessary to consider that from 1997 up to early 2003 the vaquitas were constantly detected in the same area, including a survey to estimate abundance (Jaramillo-Legorreta *et al*., 1999). The detection of eight groups during our last survey in April 2007, confirms the presence of vaquitas in the area but at lower rates, which must be the effect of a recent reduction of population density.

In 1997 it was estimated that around 567 vaquitas inhabited in the Upper Gulf of California (Jaramillo-Legorreta *et al*., 1999). Considering the -0.581 proportion of reduction of the acoustic encounter rate in the period 1997 to 2007, and that the abundance estimate was made just in 1997, the current abundance could be around 238 animals. But, because we are detecting groups that in average are composed of two animals, the current abundance could be the half, it is around 119 animals. It closely agrees with the estimate of 150 animals for 2007 made from information on fishing effort and by-catch rates (Jaramillo-Legorreta *et al*., 2007), which supports the vision of the critical status of the species, as well as the usefulness of the acoustic detection methodology as a tool for monitoring vaquita.

Mention should be made that recently the Government of Mexico recognizes that bycatch is the main risk factor for the survival of vaquita and that it's current population size is about 150 animals. With this in mind the government is promoting productive and technological reconversion of the fishing communities of the region. This through a mechanism to retire fishing permits, and consequently entangling and gill nets, as well as fostering new economic alternatives together with the use of alternative fishing gear and methods that do not bycatch vaquita. The government has also started a permanent enforcement and surveillance program with the participation of different agencies.

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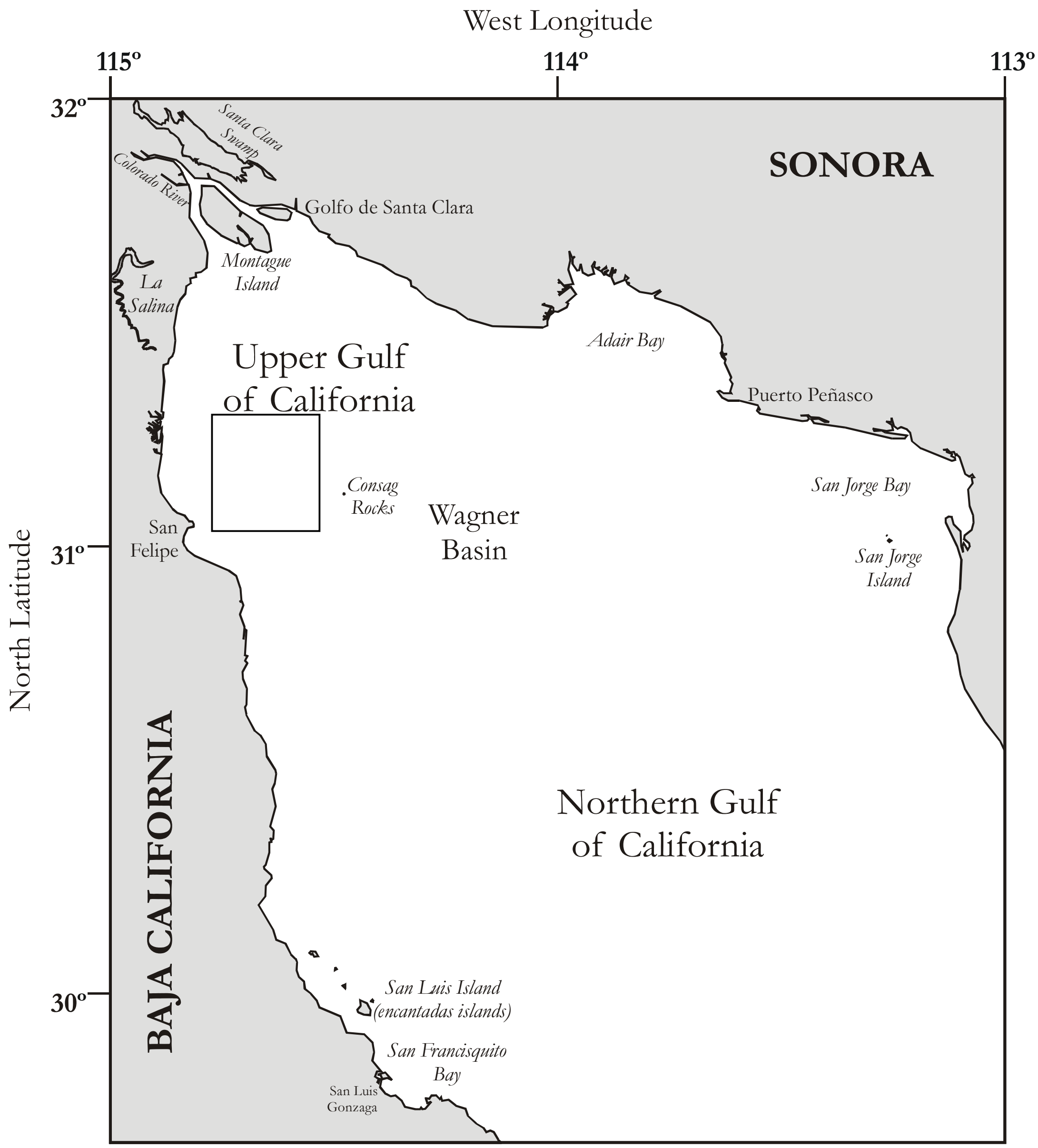

Figure 1. Upper Gulf of California. The square represents the area where vaquitas had been detected acoustically. Only the sampling stations inside this square were included in the analysis of acoustic detection rate trend.

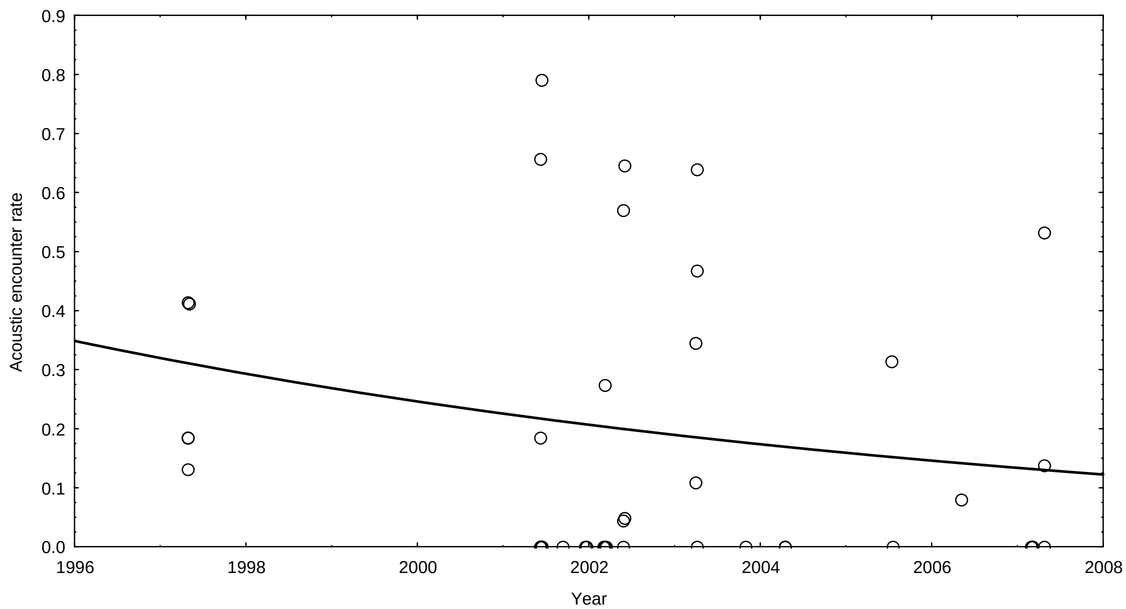

Figure 2. Acoustic encounter rate trend 1997 – 2007 (line). The circles represent the acoustic encounter rate for every one of the stations sampled.

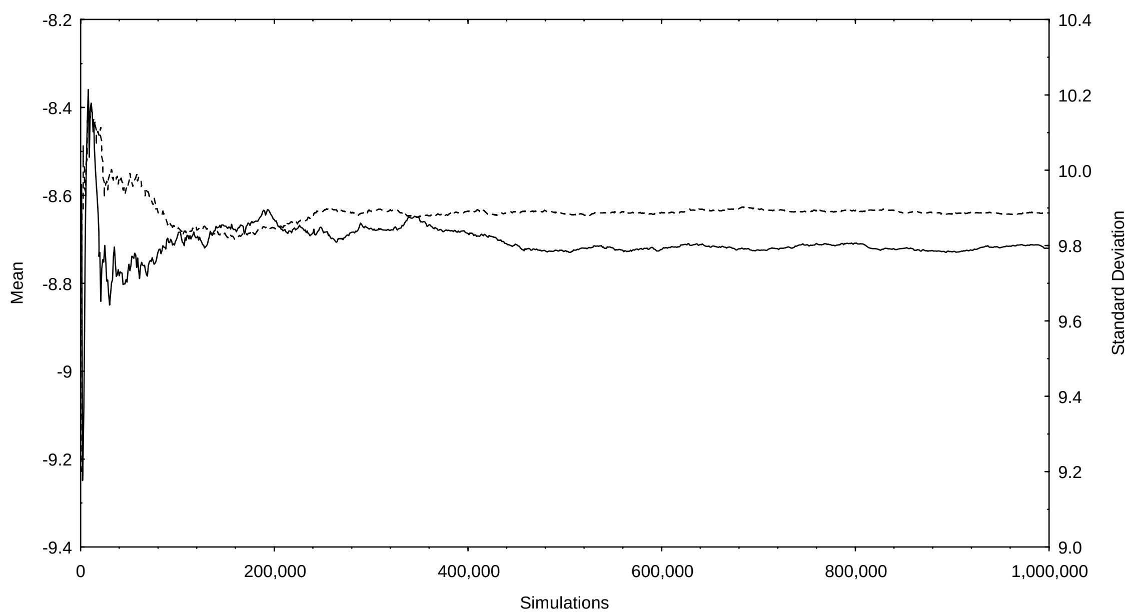

Figure 3. Convergence plot of the parameter . The solid line represents the mean and the broken line the standard deviation. The plot was constructed by calculating the mean and standard deviation of the chain every time 1,000 more simulations were added.

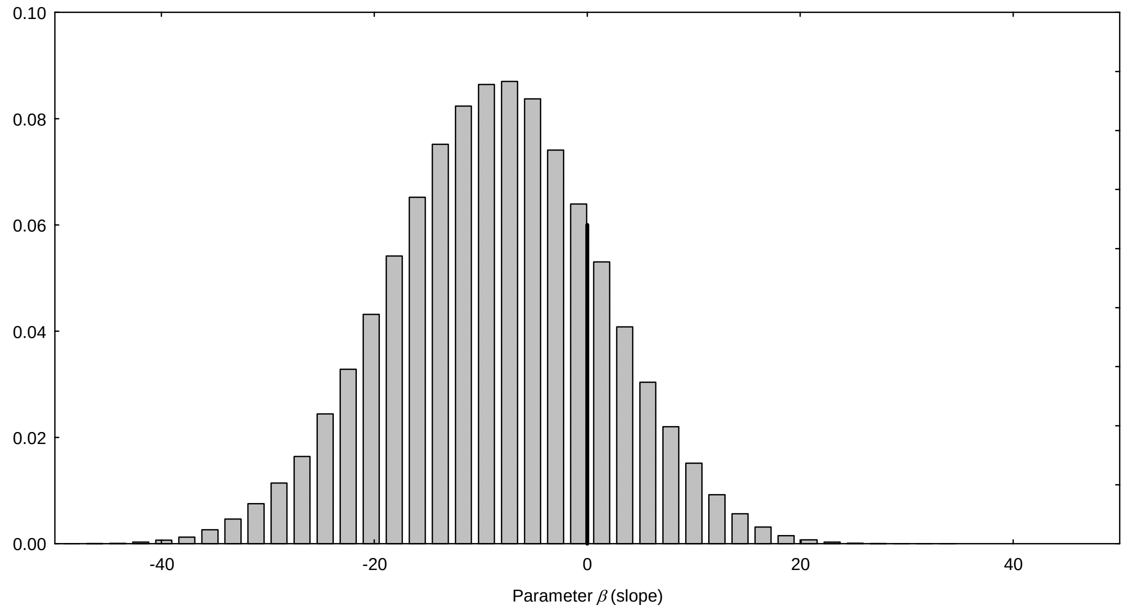

Figure 4. Posterior distribution of the parameter . All the 1,000,000 simulations generated were used to construct the histogram. The black vertical line divides the distribution into an area to the left representing the proportion of the distribution for negative values of the parameter. This area is approximately 85% of the distribution.

Table I. Sampling stations used to estimate the acoustic detection rate trend. The blank cells in the columns "Acoustic Encounters" and "Acoustic Encounter Rate" means a value of zero.

Cruise	Boat	Station	Effort Hours	Acoustic Encounters	Acoustic Encounter Rate
1997-04	Panga	1	7.65	1	0.131
		2	5.39	1	0.186
		3	9.63		0.415
		4	2.43	1	0.412
		5	5.44	1	0.184
2001-06	Pasaporte	1	3.48		
		2	4.98		
		3	4.69		
		5	5.38	1	0.186
		6	6.09	4	0.657
		8	4.54		
		9	4.45		
		11	4.59		
		12	4.54		
		13	4.70		
		14	3.75		
		15	3.79	3	0.791
2001-09	Pasaporte	4	16.06		
2001-12	Pasaporte	4	4.44		
		5	16.11		
2002-03	Pasaporte	1	15.36		
		2	10.96	3	0.274
		4	17.82		
		6	17.01		
2002-05	Pasaporte	1	19.42		
		3	19.25	11	0.571
		5	22.08	1	0.045
		6	20.84	1	0.048
		8	12.40	8	0.645
2003-03	José Andrés	1	34.67	12	0.346
		2	9.17	1	0.109
		3	16.57		
		4	3.12	2	0.641
		5	10.70	5	0.467
2003-10	Panga	1	1.11		
2004-04	Oviedo II	1	3.93		
		2	4.98		
2005-07	Koipai Yú-	1	19.13	6	0.314
		3	6.17		
2006-05	Koipai Yú-	2	25.26	2	0.079
2007-02	Koipai Yú-	1	12.04		
		2	21.65		
		3	22.82		
2007-04	Koipai Yú-	1	9.41	5	0.532
		2	21.54	3	0.139
		4	23.77		