Summary Report of Acoustic Measurements in San Ignacio Lagoon
Winter Season, 2008

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In 2008 we conducted our most ambitious San Ignacio Lagoon field season to date, consisting of one long term (four weeks) monitoring exercise using bottom recorders and one intense 10-day tracking effort with added acoustic arrays and bio-acoustic tags on the animals.

The overall, long-term goals of our acoustic study include:

* To measure the behavioral and vocal response of gray whales to the presence of boat traffic, by recording their body movements, vocalizations and ambient noise on a tag affixed on the animal.
* To demonstrate the ability to perform acoustic 3-dimensional tracking of vocalizing gray whales in the lagoon. Tracking is important in order to match an individual's behavior with vocal activity and to convert raw call counts into counts of calling animals, the first step in the concept of an "acoustic census".
* To demonstrate the ability to monitor population trends by sound measurements alone, which may eventually enable monitoring of marine mammal populations along the Baja California coast more accurately than what is currently available using visual surveys alone.
* To explore novel acoustic methods of estimating whale size by analyzing the formant structure of the exhalations/blows recorded on the tag. These formants would be related to the length of the vocal tract and possibly to the absolute size of the whale.
* To study the quantitative contribution of wind to the underwater ambient noise, in order to paint a "sound picture" of the lagoon environment before the completion of an asphalt road leads to a possibly upsurge in tourist activity.

Building the datasets to achieve these goals incorporates the use of three types of instrumentation: long term monitoring (LTM) acoustic recorders, land-based weather stations and B-probe tags that attach to whales via means of suction cups, and record animal orientation, depth, and sounds produced from and heard by the animal. The methods used during the 2008 season are explained in more detail below:

1. Long-term monitoring (LTM):

Current instrumentation allows for the month-long, continuous recording sampling at frequencies of 6kHz and requiring minimum maintenance throughout the season. Two array stations (one one-element, one two-element) were deployed to monitor long-term trends in whale call rates and ambient noise in San Ignacio Lagoon.

Given that the lagoon is conveniently divided into a research area and an area accessible to tourist boats, we would like to quantify the contribution of engine noise to the environment. Therefore in early February, we placed one station in each region, under water columns of about 35ft and on sandy or muddy bottom compositions. The approximate GPS locations are shown on Figure 1 and more exact coordinates are presented in Table 1. The northernmost station was labeled “K Station” for its proximity to Kuyima and the southernmost is named “P station”, since it is located in front of Punta Piedra. “P station” was the two-element array and its location was kept compatible with the location of the four previous years of our research, as well as the location where M. Dahlheim took her measurements in 1982-1984.

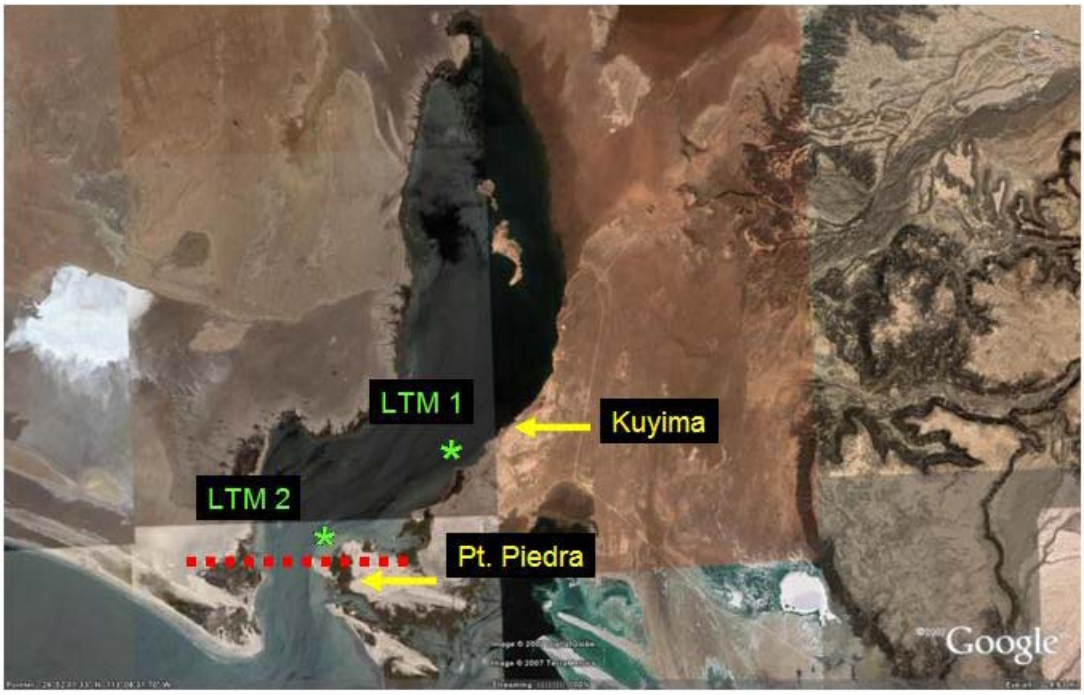

Figure 1.
Map of San Ignacio Lagoon and approximate locations of the two long-term monitoring (LTM) sites

Since weather is one of the major ambient noise contributors that we have identified in this environment (due to the formation of waves and thus, bubbles), we installed a weather station (HOBO S-WCA_M003 wind sensor) that samples wind direction and speed. This instrument was set up on land, in the grounds of the Baja Discovery campsite as seen in Figure 2. This dataset will investigate if there exists a correlation between underwater ambient noise and wind speed and if so, whether wind directionality can be inferred from the noise.

Figure 2.
HOBO wind station sampling direction and speed in Punta Piedra

2. High resolution acoustic-tracking:

Over a two-week period (Feb 28th to March 9th), we deployed additional stations in San Ignacio Lagoon to demonstrate 2- and 3-D tracking ability. The greatest challenge of this effort is finding means of independently verifying the acoustical locations. The first option is to use engine noise to track boats within the tracking array and compare the results to on-board GPS records. The second is to tag an animal and follow it by boat, as will be proposed below.

i. Bottom-mounted recording arrays

Utilizing the same instruments described for the long-term monitoring, acoustic arrays were built by combining them into linear configurations. In the case of the two-element station “M” (for “middle”, located between stations “K” and “P”), it was configured horizontally as seen in Figure 3. One of these two recorders sampled at a higher frequency (50kHz) while the second was programmed at the regular 6kHz.

Simultaneously, a three element vertical arrays was also deployed as an extension to LTM array “K”. The vertical configuration will examine transmission loss by comparing received levels at different depths of the water column. Two of these instruments recorded at high frequency and one at 6kHz.

Results of this dataset would also reveal how far whale calls can travel in the lagoon waters and in turn, what propagation properties govern the environment.

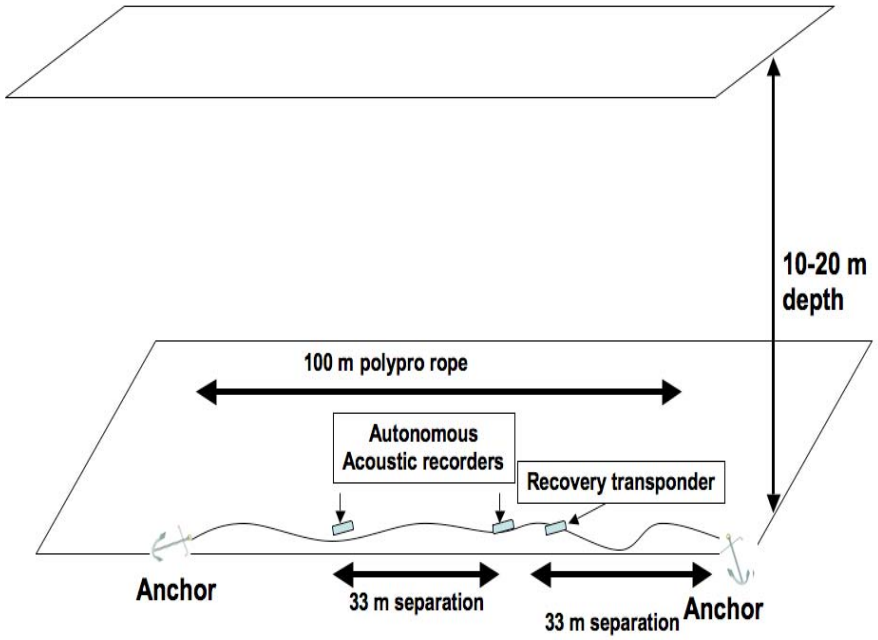

Figure 3.
Bottom-mounted recording stations: acoustic arrays for long term monitoring and passive localization

ii. Acoustic tagging:

During the week of March 1st and March 8th, with the underwater acoustic arrays still deployed, out team tagged gray whales using the Bio-probe tag. This device built by Bill Burgess (www.greeneridge.com) is a recorder that samples acoustic data, depth and orientation of the animal while attached through suction cups to the skin of the whale. Other parts of the ensemble include a floatation unit and a radio frequency transmitter that allows us to track the animal when it surfaces, as well as to locate the tag after it becomes detached. (It is critical that the tag be recovered, since the information can only be collected by downloading it directly from the recorder).

This novel technique had not been tested previously on gray whales, but in the U.S., Cascadia Research Collective has been successful in tagging other major whales, i.e. blues, humpbacks and sperm whales. Given the friendly nature of gray whales in the lagoon grounds and how accustomed they are to interactions with humans, approaching them was easier than other species. If the whale did not show signs of stress from the approach, the tag was placed on its flank using a 5m pole.

By tracking the radio transmitter and establishing bearings (relative to the boat), we would have a rough location of the whale, which would provide an independent verification to the acoustical 3-D location. The tag allows also the collection of statistics on how often these animals call under different behavioral conditions, while providing information about how gray whales react to near-by boating noise, as it records accelerometer data on two axes.

The crew on the panga included one driver, one person in charge of tagging, one GPS navigator and note taker, one holding the antenna and one photographer to capture the tag attachment (for calibrating the accelerometer data). The tagged whale was followed by our vessel thus not more than two whales were tagged at any given time.

Figure 4.
Whale tag with floatation unit (orange) and suction cups (white circles) at the end of the deployment pole

Figure 5.
Tag deployment on the right flank of an adult gray whale

Figure 6.
B-probe tag attached on an adult gray whale

APPENDIX I

Table 1: Summary of Data Collected by SIO in 2008

	Long Term Monitoring		Acoustic Tracking				Weather
	K Station	**P Station**	**M Station**	**Vertical Array**	**C Station***	**Bprobe Tags**	**Wind Station**
Location	26°48.822’ 113°12.652’	26°47.682’ 113°14.603’	26°48.195’ 113°13.353’	26°48.802’ 113°12.667’	26°48.215’ 113°15.146’	N/A	26°47.243’ 113°14.631’
Deployed	02/08/08	02/08/08	02/29/08	02/29/08	03/05/08	start 03/01/08	02/10/08
Moved	03/05/08	N/A	N/A	03/05/08	N/A	N/A	N/A
Recovered	see C station	03/10/08	03/10/08	see C station	03/09/08	03/08/08	03/09/08
Sampling Freq. (Hz)	6000	6000	6000 50000	6000 50000	6000 50000	4665	0.1
Days of data	26	31	10	6	4	7	28

***** C station was the new location where K station + Vertical array were moved to, given that, as the season evolved, the whale traffic was diminishing around the original deployment spot.