LAGUNA SAN IGNACIO ECOSYSTEM SCIENCE PROGRAM
ACOUSTICS FIELD REPORT 2019

2019 TEAM
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INTRODUCTION

Since 2005, scientists from Scripps Institution of Oceanography have collected acoustic data during the gray whale breeding season in Laguna San Ignacio, Mexico. The overall objectives of this long-term passive acoustic monitoring study are:

- To demonstrate the potential of autonomous acoustic recorders and novel techniques such as tracking vocalizing gray whales and monitoring population trends using sound measurements alone.
- Monitor trends in the lagoon's dynamic acoustic environment.
- Study the vocal repertoire and behavior of gray whales in their breeding grounds.

During the 2018 season, an observation tower was placed at Punta Piedra (PP), overlooking the acoustically monitored area. This allowed recording visual observations of the whale's surface behavior.

This year, visual observations were made by recording video with a drone. The acoustic deployment consisted of two pairs (arrays) of independent recorders deployed on the bottom, so that detected sounds can be localized in 2D (latitude/longitude), if their internal clocks can be time-synchronized and their relative positions can be estimated. A waterproof drone that was capable of landing on water was also used with a hanging hydrophone to take acoustic observations of whales that were simultaneously being visually monitored using the other drone. The goals of this year's study are:

- Time-synchronize and determine relative positions of acoustic recorders in order to localize detected whale calls in 2D space (latitude/longitude).
- Show that this acoustic tracking deployment can be combined with drone visual observations to study acoustic behavior of gray whales.
- Determine whether there is a relationship between certain call types and surface behavior/group composition (single whales, mating groups, mother/calf pairs).
- Show that acoustic data can be recorded from a drone in order to make observations from targeted whale groups.

This report summarizes acoustic fieldwork carried out during the 2019 season by presenting the methodology, the data collected and giving an overview of the upcoming data analysis.

METHODS & EXPERIMENT

2019 TIMELINE

02/21/2019 – Ludovic arrives at Kuyimita.
02/26/2019 – Aaron & Héloïse arrive at Kuyimita.
02/27/2019 – Ludovic, Aaron & Héloïse move to PP.
02/28/2019 – Acoustic gear is deployed off PP.
03/05/2019 – Aaron leaves PP and goes back to SD.
03/09/2019 – Regina arrives at PP.
03/19/2019 – Héloïse & Regina leave PP and go back to SD and La Paz.
03/22/2019 – Ludovic moves back to Kuyimita.
03/23/2019 – Acoustic gear retrieved.
03/25/2019 – Ludovic leaves Kuyimita and goes back to SD.

Acoustic Deployment

A total of four acoustic recorders, divided into two separate arrays, were deployed on the bottom of the lagoon near Punta Piedra, in the same area where acoustic gear has historically been deployed.

Each array was composed of two SoundTrap 300STD (Ocean Instruments, NZ) acoustic recorders, one transponder, attached to a 100ft polypro rope, with an anchor at each end (see Figure 1). The "transponders" are actually acoustic release units (model AR-60-E). In this case, they were just used to communicate remotely, via acoustic pings, with a transponder box (model ARI-60) to estimate range. The acoustic pings will also be used to confirm time-synchronization and relative position of the instruments.

Each SoundTrap was assigned a color (Red, Orange, Green and Blue), with the closest anchor assigned with the same color. Each array can then be referred to as the Red/Orange and Green/Blue arrays. The position of the anchors from each array are given in Table 1 and plotted on a map in Figure 2.

The SoundTraps were connected to a custom-built external battery pack that extended their battery life to about 30 days in total. Note that SoundTraps can also measure acceleration and temperature, which were recorded at 10 second intervals.

The acoustic gear was deployed in the afternoon of February 28th, 2019, as shown in Table 1, with the Red/Orange sitting at approximately 20ft, and the Green/Blue array at approximately 40ft. Note that these depth measurements were taken at approximately mid-tide. The actual depth of the instruments will therefore slightly vary depending on the tide cycle. All the gear was recovered in the morning of March, 23rd, 2019.

Table 2 shows the SoundTrap deployment sheet, which lists activation and stop date/times for each unit, as well as their sampling frequency (144kHz). The listed times were manually recorded when activating/stopping the instruments. Note that the Green SoundTrap does not have a stop time because it had stopped recording by the time it was recovered (this is further discussed in the "Data Inventory & Upcoming Analysis" section).

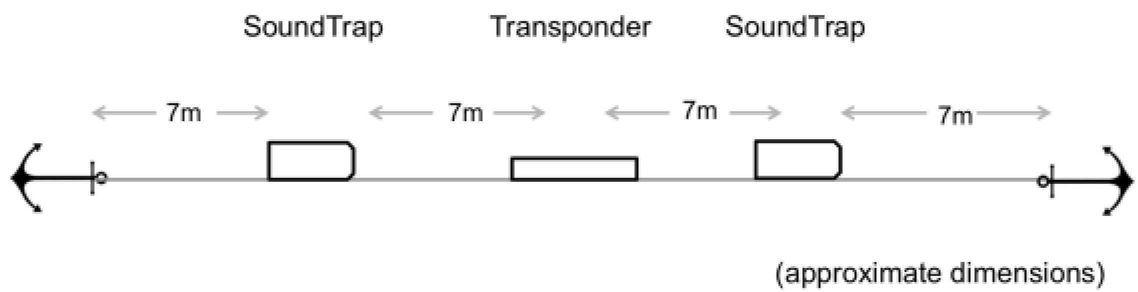

Figure 1 *– Schematic diagram of one of the deployments. Each array consisted of two SoundTrap 300STD acoustic recorders and one transponder, attached on a polypro rope, with an anchor on each end.*

Anchor	Latitude	Longitude	Depth (ft)	Date deployed	Time deployed	Date recovered
Red	26.79028	-113.2456	17.7	02/28/2019	16:00:14	03/23/2019
Orange	26.78985	-113.24537	20.2	02/28/2019	15:59:32	03/23/2019
Green	26.79278	-113.24681	40.2	02/28/2019	15:48:32	03/23/2019
Blue	26.79321	-113.24654	40.5	02/28/2019	15:49:49	03/23/2019

Table 1 *– GPS coordinates, depth and deployment date/time of each anchor. The given depths were measured at the time of the deployment. Actual depth will vary according to tide.*

SoundTrap	Fs (kHz)	Activation Date	Activation Time	Stop Date	Stop Time
Red	144	02/28/19	15:53:20	03/23/19	17:05:30
Orange	144	02/28/19	15:52:54	03/23/19	17:08:05
Green	144	02/28/19	15:43:40	03/12/19	N/A
Blue	144	02/28/19	15:44:55	03/23/19	17:01:59

Table 2 *– SoundTrap deployment sheet. Times listed here were manually recorded when activating/stopping the instruments. Note that the Green SoundTrap does not have a stop time since it had stopped recording by the time it was recovered.*

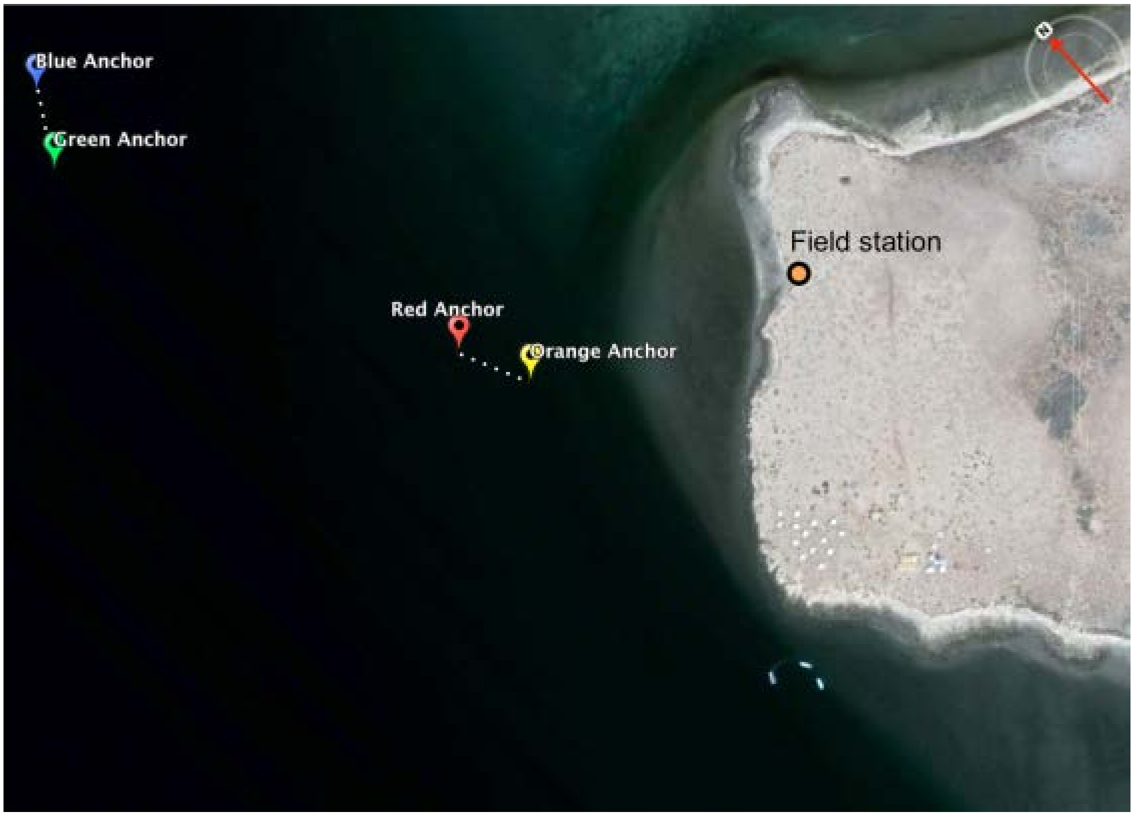

Figure 2 *– GPS position of each anchor plotted over satellite image, showing the position of each array relative to Punta Piedra. The position of the field station (from which visual observations were made and the drone was launched) is also displayed.*

"Visual" Drone

A DJI Phantom 4 Advanced Plus was used to make the surface observations of whales over the period from February 27th to March 17th, 2019. As seen in Figure 2, the field station overlooked the acoustically monitored area. Whenever wind conditions were favorable (approximately 5 m/s or less) and a whale or group was observed from the field station, the visual drone would be launched towards them, with priority given to whales closer to the acoustic arrays.

4K resolution videos with 3840×2160 pixel resolution were recorded to visually document surface behavior of whales. Videos were shot with the camera pointing straight down so that GPS coordinates of the center of the frame at any given time can be extracted from the flight log. If only one whale was being observed, it was usually kept in the center of the frame so that it's exact 2D position could be determined from the drone videos (see Figure 3). If multiple whales were being observed, their approximate positions should still be determinable by combining GPS coordinates and drone orientation data, which is also included in the flight logs. To avoid affecting the behavior of the whales, the drone was usually not flown any lower than 30m altitude. When nearby whales were being recorded at the same time, the drone would often have to fly at higher altitudes (up to 100m or more) in order to get all the animals in the same frame.

In order to have the video time-stamped to GPS precision, the drone would rotate around its vertical axis at the end of each video. This can then be picked up in the flight log with the associated GPS time.

Figure 3 *– Screenshot from DJI Phamton 4 drone video with a mother/calf gray whale in the center of the frame.*

"Acoustic" Drone

A second drone was used to proof test the idea of recording underwater sound, by hanging an acoustic recorder from a drone. Here, a SoundTrap (same model used for the acoustic deployment) was attached to a 2-meter line, hanging from the bottom of a waterproof drone (see Figure 4). The drone used was a Swellpro SplashDrone 3+, which is waterproof and can land of the water. If a group of whales were observed, the drone could then be launched towards the area of interest, land, turn off its engines, and record sound at 2 meters below the surface. Note that the SoundTrap would have to be activated manually before the flight, and deactivated after the flight. Audio from the entire flight would therefore be recorded.

Foam noodles were fitted to the drone's landing frame in order to improve its buoyancy. Wire loops from a whisk were also fitted to the SoundTrap in order to protect the hydrophone when landing back on land.

The goal here was to not only show that drones could be used to record sound underwater at close range from a whale/group, but to simultaneously observe the surface behavior of the animals with the other drone.

Figure 4 *– Swellpro SplashDrone 3+ with hanging SoundTrap 300STD.*

Visual censuses & weather

Approximately every hour during daylight hours, a visual census of the number of whales in the area was performed from the field station. Before each census, weather parameters were also measured (wind speed, air temperature and atmospheric pressure) with a Kestrel 2500 Pocket Weather Meter.

Rather than an absolute count, the census provided an index of how many whales were present in the region facing the field station. The area was divided into 10 degrees slices, from 270 to 340 degrees, based on magnetic north. Using binoculars, an observer would then spend one minute on each slice, and count the number of single whales and mother/calf pairs, which would be recorded by a second observer.

DATA INVENTORY

Table 3 is a brief summary of the data collected this season. All four deployed SoundTraps successfully recorded data continuously for approximately 12 days (02/28/2019 to 03/12/2019), until the green unit unexpectedly stopped recording. The other three units continued recording for a total of 23 days. Even though this still needs to be confirmed, the failure of the green unit is likely to be due to leakage in the external battery pack. This would explain why it failed after 12 days, which is the amount of time it would have recorded without the added battery pack.

A total of 185 drone videos observing surface behavior of gray whales were taken with the DJI Phantom 4. 114 of these contained only single whales, 58 of them contained only mother/calf pairs, and 13 of them contained both demographic groups. These videos were taken over 16 different days (between 02/25/2019 and 03/17/2019), 10 of which overlap with all four SoundTraps recording.

A total of 123 censuses and weather measurements were performed every day between 03/04/2019 and 03/19/2019. These are plotted in Figures 5 and 6 respectively. Note that there is an inherent bias towards single whales versus mother/calf pairs, since calves are harder to spot at long ranges.

A total of 7 flights using the acoustic drone were performed over 5 different days, between 02/27/2019 and 03/17/2019. All of these flights overlap with drone videos from the Phantom 4. Due to some technical issues, the acoustic drone could not be used on a regular basis. These issues included notably, no video transmission between the drone’s camera and the remote control [no visual control], and the loss of the transmission signal on some occasions after landing on water [antenna position issue]. It was decided to use the acoustic drone only when whales were observed near to the field station (less than 350 m) and a boat was available for a potential drone rescue.

Red SoundTrap	Recorded audio (144kHz), acceleration & temperature (10sec interval) from 02/28/2019 to 03/23/2019. **~23 continuous days total**
Orange SoundTrap	Recorded audio (144kHz), acceleration & temperature (10sec interval) from 02/28/2019 to 03/23/2019. **~23 continuous days total**
Green SoundTrap	Recorded audio (144kHz), acceleration & temperature (10sec interval) from 02/28/2019 to 03/12/2019. **~12 continuous days total**
Blue SoundTrap	Recorded audio (144kHz), acceleration & temperature (10sec interval) from 02/28/2019 to 03/23/2019. **~23 continuous days total**
Phantom drone video	185 videos observing gray whale surface behavior (114 containing single whales, 58 containing mother/calf pairs and 13 containing both demographic groups) recorded during 16 distinct days over the period from 02/25/2019 to 03/17/2019. **10 of these days overlap with the period over which all four SoundTraps are recording.**
Census & weather	123 censuses and weather measurements were performed between every day 03/04/2019 and 03/19/2019 (see Figures 5&6).
Splash drone SoundTrap	Recorded audio (96 kHz) on 7 occasions (5 distinct days) between 02/27/2019 and 03/17/2019. **All these acoustic recording sessions overlap with simultaneous drone video**.

***Table 3** – Summary of the collected data.*

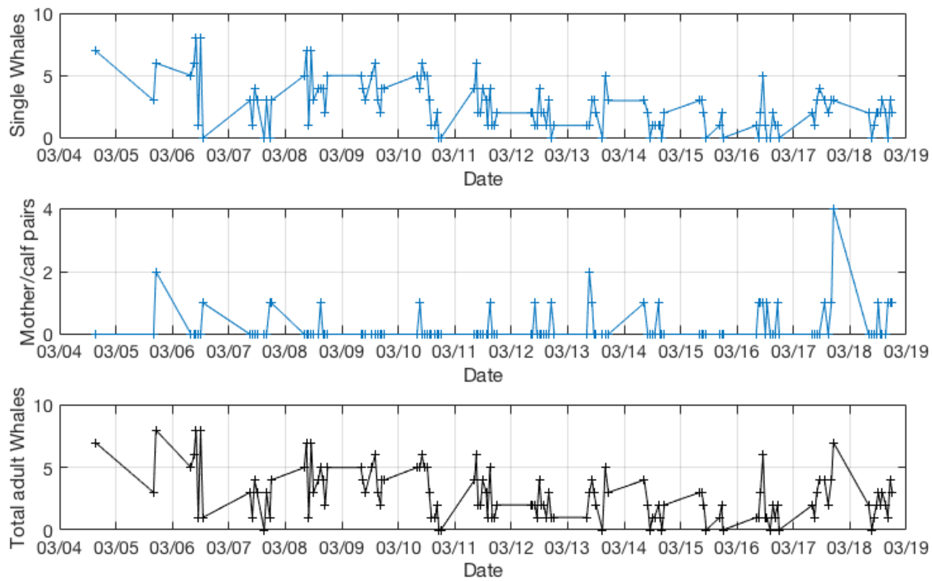

Figure 5 *– Results from the visual census performed from the field station between 03/04/2019 and 03/19/2019. The top, middle and bottom panels show the number of single whales, mother/calf pairs and total adult whales respectively.*

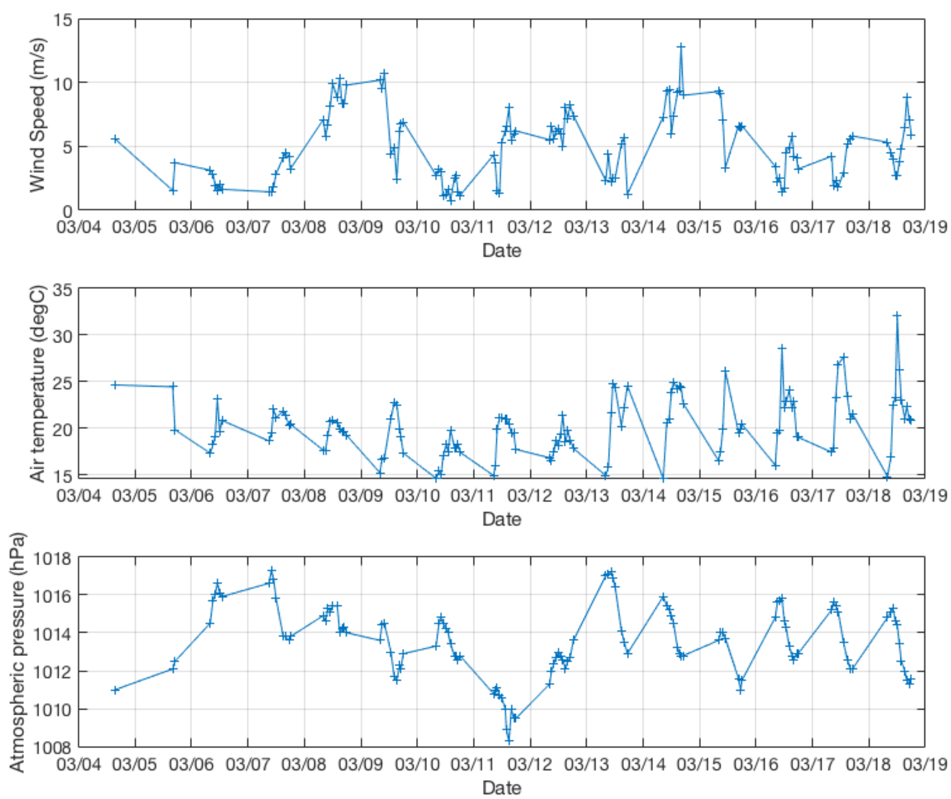

Figure 6 *– Wind speed (top), air temperature (middle) and atmospheric pressure (bottom) measured at the field station between 03/04/2019 and 03/19/2019.*

UPCOMING ANALYSIS (OVERVIEW)

A key part of the analysis is to time-synchronize the data from the acoustic deployment and estimate the position (spacing and orientation) of the SoundTraps in each array. Given the configuration of the experiment, it should be possible to determine the horizontal direction of any sound picked up at each array, using time-difference-of-arrival between instruments. With one bearing from each array, the 2D location of the sound source can be determined from the intersection of these bearings. Bathymetry and land contours should in most cases allow resolving potential ambiguities.

Time-synchronization and position estimation will be done using three independent methods:

- The acoustic signals sent back and forth between the array transponders and the transponder box.
- Engine noise from the boat at the time of the deployment/recovery.
- Ambient noise alone (Sabra et al. 2005). Successfully applying this technique should result in a peer-reviewed publication.

The next step will be to go through the drone aerial footage of whales. At this point, it should be possible to localize any sounds picked up and confirm that sounds are coming from the same general area as the video (using drone GPS data). Videos that track a traveling (and vocalizing) whale for a long time should allow validating our acoustic localizations.

Even though the sample size will most likely be too small to carry out a complete study, the simultaneous drone footage and acoustic recordings should allow getting some insight into the whale's acoustic behavior. If proven effective, the method itself should be publishable.

In addition to being another novel tool to study acoustic behavior, the combined acoustic/visual dual-drone approach should allow estimating the source level of certain calls, which are still unknown for gray whales. Based on the received level and the range of the animal to the acoustic drone, which will be visible from the aerial video drone, the source level can be deduced.

A quick review of the acoustic drone data has already shown a large diversity in the types of calls detected, in comparison to data collected in previous years from the traditional bottom deployments. We speculate that a lot of these sounds are fairly quiet and were only picked up by the acoustic drone because of its proximity to the whale, making this approach of particular interest.

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