Documenting and assessing dolphin vocalizations and ambient and anthropogenic noise levels via PAM and an SPL meter

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Abstract

The Song Meter SM2M Marine is an autonomous passive acoustic recorder that allows collection of audio data including ambient, anthropogenic, and animal sounds. We deployed SM2M recorders at three sites, documenting dolphin sounds off Bimini, The Bahamas, and ambient (wind, wave action) and anthropogenic (boats engines, generators) noise levels at Dolphin Encounters (DE), The Bahamas, and Sumay Cove (SC), Guam. The SM2M was deployed for continuous recording over each 24-hour period in order to collect data while field-testing the device in collaboration with ongoing research of Atlantic spotted (*Stenella frontalis*) and bottlenose (*Tursiops truncatus*) dolphins around Bimini. When recordings were divided into 2-hour time segments per 24-hour period over the 7-day deployment, no segment was without dolphin vocalizations. At DE, one SM2M was deployed to collect SPL data to investigate ambient and anthropogenic noise levels; average received levels (RL) ranged from 110 - 125 dB re: 1 µPa @ 1 m, and the highest source level calculated in association with a vessel approach to the dock was 147.98 dB re: 1 µPa @ 1 m. Baseline ambient RL were documented using two SM2Ms deployed for 72 hours twice at two SC locations, resulting in an overall average ambient RL below 118 dB re: 1 µPa @ 1 m (range was 110 - 135 dB re: 1 µPa @ 1 m). Each monitored location varied slightly in range and average RL with the area adjacent to the boat ramp presenting the loudest ambient noise levels. Ambient and anthropogenic noise levels recorded by the SM2M were compared with values documented with a custom-built SPL meter (ST1400ENV) at both DE and SC. The methods and results presented here confirm that the SM2M is a useful tool for assessing animal sounds and ambient and anthropogenic noise levels.


Atlantic spotted dolphin mom/calf pair, Bimini, The Bahamas

Introduction

Passive Acoustic Monitoring (PAM)

- Cost-effective tool to document acoustic activity from naturally occurring, biological sound sources over days, weeks, months or years
- Least direct labor, highest degree of safety to human observers, and least disruption to study species (Mellinger et al., 2007)
- Used to document behavior of species in a given study area (Clark et al., 2010) to assess species distribution (Kimura et al., 2010), habitat use (Munger et al., 2008), or migratory behavior (Simon et al., 2010)


Figure 1a. The SM2M deployed near Bimini, The Bahamas.

Ambient and Anthropogenic Noise Levels

- Can be monitored via a SPL meter to assess both received or source levels
- Can be documented via PAM (Mellinger et al., 2007)

Focus

- Compare the application of a PAM unit deployed in three different study sites to document ambient and anthropogenic noise levels and dolphin calls
- Compare data collected via PAM for SPL with values obtained with a custom SPL meter

General Methods

Equipment

Song Meter SM2M Marine Recorder (SM2M)
- Submersible 16-bit digital recorder
- Short- or long-term deployments
- Fresh or salt water
- Depths of up to 150 m
- 165 mm diameter, 794 mm length, weighs 13.5 kg in air with 1.5 kg of buoyancy (with full battery population)
- Multiple power options (up to 32 LSD NiMH, alkaline or lithium manganese D-cell batteries); we used between 8 and 32 alkaline batteries, depending on deployment length
- Record to SDHC flash cards
- Flexible sample rates
- Integrated hydrophone (sensitivity of -165 dB +/-1 dB re: 1 V/µPa, with recording bandwidth of 2 Hz – 48 kHz and flat frequency response)

ST1400ENV SPL meter
- Partnered with a CR1 omni-directional hydrophone (Sensor Technology Ltd, Serial # CR1-9041-15; Sensitivity –197.98 dB; Capacitance 9.8 nF; Dissipation 0.017%)
- Calibrated mobile data recorder and sound level monitor with NIST-certified calibration
- Portable, self-contained and designed specifically to record underwater sounds while simultaneously monitoring and logging SPLs (Figure 1b.)


Figure 1b. T1400ENV model SPL meter

Data Collection

- SM2M: to collect dolphin vocalizations off Bimini, assess ambient and anthropogenic received noise levels at DE, and assess baseline ambient noise levels in SC
- ST1400ENV SPL meter: to document ambient and anthropogenic noise RL at DE

Field Site Locations

Bimini, The Bahamas

Bimini Deployment Procedures
- Deployment 1: 29 July – 9 August 2011, N25°51.098/W79°15.914, 10.06 m, 3 Hz filter
- Deployment 2: 18 – 30 September 2011, N25°52.563/W79°14.014, 9.86 m, 1 Hz filter
- Each deployment ~2 weeks long with continuous recording, 0 dB gain and 44.1 kHz sample rate
- Anchored with a cement-filled, 5-gallon bucket (Figure 1)

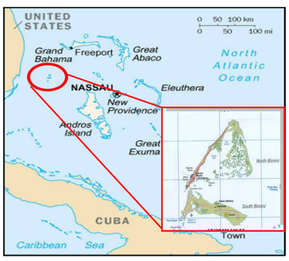

Figure 2. The waters north and west of North Bimini are the site of long-term research into dolphin behavior (Melillo, 2008; Greene et al., 2011; Dudzinski et al., 2012). The seafloor consists of white sand, void of major reef habitat. A small population (~120 individuals) of Atlantic spotted dolphins (*Stenella frontalis*) is resident year-round with bottlenose dolphins (*Tursiops truncatus*) also present (Melillo et al., 2009).

Data Analyses - Bimini
- Audio files parsed into 30-min files
- Examined for presence of dolphin calls (e.g., whistles, clicks, brays) via manual review of spectrograms
- If a call was detected at any point in a file, the file was identified as possessing calls and the next file was reviewed.
- Process repeated for each 30-min file


Atlantic spotted dolphins in Bimini, The Bahamas

Dolphin Encounters, Nassau, The Bahamas

DE Deployment Procedures
- 5 – 7 November 2011
- 12 h long deployments
- Continuous recording, 0 dB gain, 2 Hz filter, 44.1 kHz sample rate
- 3 day, 2 night sessions, 5 different locations in dolphin habitat
- Depths ranging from ~ 3 – 4 m (Figure 3)
- Secured via nylon webbing to a piling (see below)
- Goals: to document ambient noise levels without and with vessels, including DE passenger ferries and other vessels. Vessel arrivals and duration of stay at dock were documented during day deployments. Vessel arrival and departure times at start and end of night sessions only were noted.
- SPL meter deployed in January 2013 at 8 locations

Figure 3. Dolphin Encounters (DE) is a natural seawater facility located within the lagoon of Blue Lagoon Island, The Bahamas. The habitat is over 3 ac in surface area with depths ranging from shore to 7.62 m, depending on the pool. There were 20 dolphins resident in the DE facility at the time of this study. Participants in dolphin programs arrive via one of 3 DE passenger ferries that dock at the western edge dolphin habitat

Data Analyses - DE
- Average ambient levels were examined for diurnal patterns
- Each 30-min audio file was time stamped and compared with surface notes regarding weather and anthropogenic activity (e.g., boat arrival)
- RLs at SM2M were identified as related to boat presence versus absence
- Source levels were estimated (using a modified equation as a compromise between cylindrical and spherical spreading SL = RL + 15LogR, where SL=source level, RL=received level and R is the range in meters between SL and RL) to estimate values at vessels. (Note: distance between SM2M and vessel engine was directly measured.)


SM2M secured to piling in dolphin pool

Sumay Cove, Guam

Sumay Cove Deployment Procedures
- January 2012
- 2 SM2Ms
- 4 deployment locations
- Similar to procedures for Bimini deployments (as in Figure 1)
- Surface float buoys were used during each deployment (active vessel traffic area)
- 72 h long deployments
- Continuous recording, 0 dB gain, 1 Hz filter, 32 kHz sample rate.


Figure 4. Sumay Peninsula is located between Sumay Cove (SC; to the southeast) and Clipper Cove (to the northwest) on the southern edge of Outer Apra Harbor, Guam. Underwater ambient noise levels were recorded with 2 SM2Ms inside SC near the boat ramp and marina, in SC Channel, in the Clipper Cove Channel, and in Outer Apra Harbor for a minimum of 3 full 24-h eyeles (i.e., 72 h per site) to determine baseline ambient sound levels.

Data Analyses - SC
- Log scale waveform view in Song Scope was used to obtain average dB values per 15 min of recording per SM2M dataset.
- Calibrated gain and hydrophone sensitivity values provided with SM2M were used in calculations.
- Resultant ambient received dB sound level has an error of +/-1 dB carried over from hydrophone specification.


Long view of Apra Harbor, Guam

Results

Bimini: Dolphin Calls

- Each day was divided into 2-h blocks
- No 2-h period was without dolphin vocalizations
- Some periods had slightly fewer presence detections
- Data from deployment 2 will compare summer to early autumn

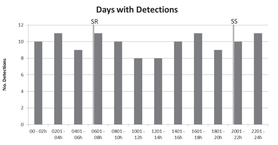

Figure 5. Dolphin call detections by 2-h period and day. Dolphin calls were detected throughout every day. SR = sunrise, SS = sunset.

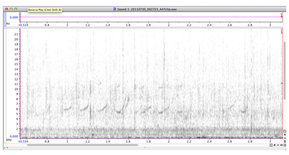
Figure 6. Example whistles from dolphins recorded with SM2M near Bimini in late July 2011.

Dolphin Encounters: Noise Levels

- SM2M: Average noise levels ranged from ~110 - 125 dB (re: 1 µPa @ 1 m when associated with vessel noise)
- SPL Meter: Average noise levels ranged from 105.87 to 107.56 dB (re: 1 µPa @ 1 m when associated with vessel noise, Table 1a)
- Each location is exposed to varying levels of noise from different sources (e.g., vessel engines, wave action)
- Little difference observed between day & night periods (Table 1b)


Common bottlenose dolphins at DE

Table 1a. Noise levels documented via SPL meter at DE in January 2013. See Figure 3 for location specifics.

DEPLOYMENT	Samples (N)	Ave. Freq (Hz)	SPL (in dB re: µPa at 1m)
Location 1, mean	353	2020.28	106.33
range		19.9 - 23931.3	96.8 - 113.1
Location 2, mean	356	1881.48	106.33
range		15.2 21850.5	96.6 - 120.6
Location 3, mean	306	1388.95	106.58
range		996.3 - 3001.1	97.0 - 113.8
Location 4, mean	305	1383.67	105.87
range		997.1 - 3003.2	97.8 - 113.5
Location 5, mean	165	1352.18	106.40
range		23.4 - 3002.1	98.1 - 114.8
Location 6, mean	306	1348.55	107.29
range		25.2 - 3997.4	98.9 - 120.1
Location 7, mean	240	1504.39	106.49
range		997.9 - 3002.1	101.7 - 110.2
Location 8, mean	257	883.74	107.56
range		164.3-16503.4	104.0 - 119.9

Sumay Cove: Ambient Noise

- Overall average ambient noise level was below 118 dB (re: 1 µPa @ 1 m)
- Ranged between 110 and 135 dB (re: 1 µPa @ 1 m)
- Each monitored site varied slightly in range and average level; area adjacent to a boat ramp presented the loudest ambient noise levels (139.57 dB re: 1 µPa @ 1 m)


Sea turtle

Table 1b. Received sound levels for each deployment. See Figure 3 for location specifics. Mean, median and range (minimum to maximum) values provided per location. NA signifies no recordings collected.

DEPLOYMENT	Day (in dB re: 1 µPa at 1 m)	Night (in dB re: 1 µPa at 1 m)
Location 1, mean	117.12	NA
median	116.39	NA
range	108.4 - 130.32	NA
Location 2, mean	NA	114.15
median	NA	113.46
range	NA	107.83 - 124.56
Location 3, mean	124.36	NA
median	123.96	NA
range	119.44 - 131.47	NA
Location 4, mean	NA	115.10
median	NA	115.05
range	NA	111.45 - 120.18
Location 5, mean	115.44	NA
median	115.18	NA
range	112.46 - 121.14	NA

Discussion

Bimini: Dolphin Calls

- Deployment 1: dolphin calls detected each day and during each 2-h period.
- Some periods had slightly fewer call presence detections.
- Sighting data (DCP unpublished data, 2003 – 2012) indicate that dolphins regularly use the area immediately around the deployment site during afternoon hours.
- These PAM recordings marked the first time researchers were able to document dolphin presence in the area at night.
- Dolphins in this area have been observed socializing, playing, traveling and crater feeding (Melillo, 2008; Melillo et al., 2009; DCP, unpublished data, 2003-2012).

Dolphin Encounters: Noise Levels

- Average and maximum noise levels were below upper limit values proposed by the National Marine Fisheries Service (NMFS) regulations (160 dB re: 1 µPa @ 1 m) for confirmed behavioral disturbance related to sound pressure values (Southall et al., 2007).
- Minimum SPL values were consistent between recording periods while highest levels were recorded in association with vessel noise.
- Source levels were estimated from RLs based on a modified equation for spreading loss.
- These levels were estimated when a known anthropogenic noise source was identified as present and within range.
- Note: vessel activity and associated noise levels under water were only documented for the first two locations because of inclement weather.
- Wind and wave action was excessive in early November 2011, and likely added to the ambient noise levels and eliminated vessel noise during deployments 3 - 5.

Sumay Cove: Ambient Noise

- Recordings collected in advance of a repair and renovation construction project.
- Intended to confirm assumptions related to noise levels and potential impact on sea turtles.
- Baseline ambient noise levels over four 72-h periods remained below 118 dB re: 1 µPa @ 1 m.
- Areas adjacent to a boat ramp presented the loudest maximum ambient noise levels, predictably.
- It was likely maximum values coincided with vessel traffic when boats were launching or returning.
- Potential sources of sound in SC: boat traffic in and around the inner harbor, dry dock located close to SC, commercial port across from SC (~ 2 km away), mooring anchorage near the entrance to Apra Harbor, channel markers and floats with metal parts, and barking frogs.

Acknowledgments

Major funding and support was provided by Wildlife Acoustics, Inc., the Dolphin Communication Project (DCP), Dolphin Encounters, and Geo-Marine, Inc. All data from Bimini were collected under permits obtained annually by DCP for our studies of dolphins in The Bahamas, from the Department of Marine Resources, Ministry of Agriculture and Marine Resources, Nassau, The Bahamas. DCP's 2011 summer interns assisted with the SM2M deployment in July 2011. W. Dunn assisted with data analysis of the Bimini audio data. A. Sweeting, Jr., provided use of the photo in Figure 2 and vessel time and assistance for deployment/recovery procedures from Bimini. At Dolphin Encounters, R. Meister and K. Terrell gave permission to deploy SM2M recorders in five different pools. Funding for data collection on Guam was provided by the Navy. J. Anderson, A. Banda, S. Bates, N. Danaher-Garcia, and A. Whitt reviewed drafts of this poster and proceedings paper. C. Gomez printed this poster.

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