



Spectrum
Atlantic

Passive Acoustic Monitoring Plan

1. Passive Acoustic Monitoring (PAM) System Specifications

The PAM system is designed to provide a flexible approach to the monitoring of marine mammals using a towed hydrophone system. The system uses several software modules such that it can be optimally configured for any application, vessel, and deployment method.

The main components of the system are:

- A conventional hydrophone array cable;
- A deck cable;
- An electronics processing unit;
- An audio output unit;
- A rack mounted computer with monitoring software installed and two monitors;
- Primary software will be Pamguard, and a suite of IFAW software will be available as backup.

Each source vessel will have two acoustic monitoring systems installed: a primary system and a secondary system.

The conventional array contains four hydrophone elements and a depth gauge molded into a five meter section of cable. Three of the hydrophone elements are broadband (2 kilohertz to 200 kilohertz) and the fourth element is for sampling lower frequencies (75 hertz to 30 kilohertz). There are preamplifiers embedded in the array cable just ahead of the hydrophone elements. The four-element linear hydrophone array allows for a large range for sampling marine mammal vocalizations, from the low frequency moans of baleen whales (70 to 245 Hertz) to the ultra-high frequency clicks of *Kogia* (dwarf and pygmy sperm whale) species (60 to 200 kilohertz).

The hydrophone cable is connected to the data processing unit at the monitoring station via a deck cable. The data processing unit (DPU) processes raw data from the hydrophones through two external sound cards – a *National Instruments DAQ* card and an *ASIO Fireface* card (contained within a RME *Fireface 800* unit). *National Instruments DAQ* sound cards sample raw audio at 500 kilohertz and are used to detect beaked whale, *Kogia* species, porpoise, and delphinid (echolocation) clicks up to 250 kilohertz. *ASIO Fireface* sound cards sample audio at 48 kilohertz and are used to detect mysticetes, delphinid, and non-delphinid odontocetes (including sperm whale) vocalizations up to 24 kilohertz. The data processing unit also contains a *Measurements and Computing* data logger for the depth gauge and digital signal amplifiers.

A vessel GPS feed is connected to the computer via an ethernet to serial adapter from the ship's GPS antenna and the position of the vessel can be viewed on a map module within *Pamguard*. When vocalizations are detected on more than one hydrophone by the whistle and moan detector or click detectors the difference in time of arrival of the signals to the hydrophones is used to plot bearing lines on the map. If several vocalizations are detected from a somewhat stationary position (relative to the vessel) over a period of a couple of minutes, the bearing lines intersect on the map over the position of the vocalizing animal, and the distance to the animal can be determined with some accuracy.

2. PAM Operator Requirements

Two PAM Operators will be on board the vessel during each offshore rotation. All PAM Operators must have completed a protected species observer training program in addition to a PAM Training course. One PAM Operator will be on watch whenever the seismic source is active (including mitigation source) and for mandatory pre-ramp up monitoring during all times of reduced visibility, including darkness.

During these observations, the following guidelines shall be followed:

- Other than brief alerts to bridge personnel of maritime hazards no additional duties may be assigned to the observer during his/her acoustic monitoring watch
- No operator will be allowed more than four consecutive hours on watch as a PAM Operator
- A “break” time of no less than two hours must be allowed before an operator begins another acoustic monitoring watch rotation (break time means no assigned observational duties, visual or acoustic)
- No person on watch as a protected species observer and/or PAM Operator will be assigned a combined watch schedule of more than 12 hours in a 24 hour period

3. Passive Acoustic Monitoring

3.1 Monitoring Schedule

Two dedicated PAM operator will be present on board each source vessel to conduct acoustic monitoring during all seismic operations undertaken during reduced visibility, including night time. An acoustic monitoring schedule for the operators will be established with alternating shifts of two to three hours. No monitoring shifts will exceed four hours without a two hour break.

The PAM operator will monitor for whales and other marine mammals using the PAM system (headphones for aural monitoring and spectrogram and click detectors for visualization). The PAM operators will be in a suitable location that will not interfere with navigation or the operation of the vessel. The location will provide the PAM operator a comfortable, ergonomic position to monitor the PAM system. The PAM system will be located in the instrument room or close by to provide adequate space for the system and to allow a quick exchange of communications to the seismic operator in case of a shut down or delay. Acoustic monitoring must be consistent, diligent, and free of distractions for the duration of the watch.

PAM will be conducted during all periods of reduced visibility: darkness, fog, rain, etc. Darkness includes the times between dusk and dawn when visual observers cannot visually observe the exclusion zone. Periods of reduced visibility during the day when PSOs are unable to monitor the exclusion zone around the source must be monitored acoustically by the PAM Operator if the source is active.

The guidelines outlined below will be applicable to PAM monitoring:

- No additional duties may be assigned to the PAM operator during his/her acoustic monitoring watch
- No PAM operator will be allowed more than four consecutive hours on acoustic monitoring watch
- A “break” time of no less than two hours must be allowed before a PAM operator begins another acoustic monitoring watch rotation (break time means no assigned observational duties)

- No person on acoustic monitoring watch as a PAM operator will be assigned a combined monitoring schedule of more than 12 hours in a 24 hour period

3.2 Acoustic Monitoring Methodology

Acoustic monitoring for marine mammals vocalizations will be completed aurally with *Sennheiser* headphones and visually with the most up-to-date version of *PAMGuard* available. Delphinid whistles, clicks, and burst pulses as well as sperm whale clicks and baleen whale tonal sounds may be viewed on a spectrogram display within *PAMGuard*. Sperm whale, beaked whale, *Kogia* species, and delphinid echolocation clicks may be viewed on low and high frequency click detector displays.

PAMGuard Beta 1.13.02 contains a function for calculating an approximate range based upon the least squares fit test. The mathematical function estimates the range to vocalizing animals by calculating the most likely crossing of a series of bearing lines generated from tracked tonal sounds or clicks. The vocalizations are tracked in the click detector or whistle and moan detector modules and the bearing lines associated with each vocalization are plotted on the map display. After several vocalizations have been tracked, an estimate range with an associated error is displayed on the map. Several vocalizations must be tracked over a period of a few minutes to obtain a reasonable estimate of range. This method of distance estimation is effective in localizing range to animals that are relatively stationary with respect to the vessel and towed hydrophones.

During detection events where the above method is not appropriate for localizations, distance estimates can be made by the Operator based upon a noise or detection score system developed by Gannier *et al* (2002). Gannier *et al* monitored sperm whales (*Physeter macrocephalus*) in the Mediterranean, both visually and acoustically. A subjective scale was developed based upon the strength or intensity of the sperm whale clicks at various distances that were measured visually when the sperm whales surfaced. Although the scale is subjective and sounds produced in marine environments will vary according to local conditions, the scale provides a measure for approximating distances when using a single, linear hydrophone array.

Sound recordings will be made using the sound recording module in the corresponding high frequency or low frequency configurations of *PAMGuard*, whenever potential marine mammal vocalizations are detected or when unknown or unusual sound sources are noted by the PAM operator.

PAM operators will establish a communication protocols with seismic and maritime personnel using the resources available on the vessel (radios, telephone system etc.).