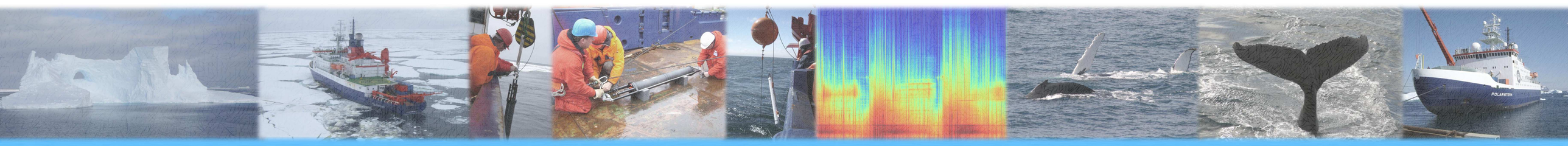

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Passive Acoustic Monitoring (PAM) in the Southern Ocean:
three generations of autonomous recorders in a basin wide array

Introduction

Passive acoustic monitoring (PAM) has emerged as a highly efficient technology for long-term, year-round monitoring of marine mammals at (species dependent) local to basin scales, providing valuable new insights into species' distributions and migration patterns. To study Antarctic mammals and their acoustic environment, we are in the process of establishing a basin scale array of ca. 20 autonomous recorders within the Weddell Gyre (Fig. 1 and 2). Due to this region's remoteness, challenging accessibility, and ensuing logistic constraints, especially during austral winter, recording devices were/are deployed for extended periods (typically 2-3 years), resulting in high demands on their power efficiency and storage capability.

Three types of autonomous acoustic recorders, AURAL, MARU and Sono.Vault were deployed and partially have been recovered. AURAL and MARU were deployed in March 2008 and December 2008, respectively, and recovered in December 2010. A set of 8 Sono.Vault recorders were deployed in December 2010 and are scheduled for recovery in December 2012. Hence, *in-situ* recordings are available for AURAL and MARU to evaluate their performance and guide instrument settings of future deployments. For Sono.Vaults, laboratory tests provide a first technical evaluation of these newly developed systems.

[Picture: Elizabeth Jones, NIOZ]

Fig. 1: Atlantic sector of Southern Ocean; Picture: Google Earth

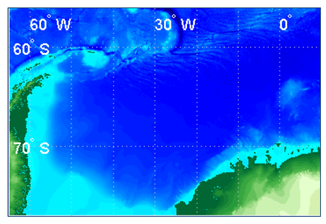


Fig. 2: Weddell Gyre area

Aim:

Establish basin scale PAM array of up to 20 acoustic recorders to:

- Understand marine mammal distribution and acoustic ecology;
- Map the underwater ambient noise environment and changes within the water column.

Constraints:

Logistic:
- Limited accessibility: study area visited once per year only;
- High costs: joint moorings with oceanography; mooring turnaround every 2-3 years.

Environmental:
- Ice cover and adverse weather conditions → recovery delay by 1-2 years possible;
- Risk of mooring loss due to possible entrapment by passing icebergs.

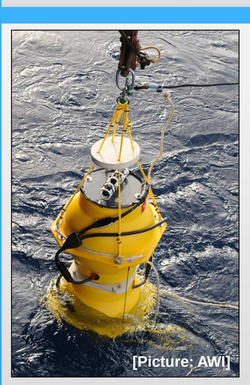
Requirements for PAM recorders:

- Multi-year recording periods:
  → sufficient data storage and power or
  →subsampling / smart sampling options
- Individual calibration and low electronic noise for ambient noise studies
- Reliability – tolerant towards faulty storage media / batteries
- Precise timebase for localization of acoustic sources and event correlation (e.g. passing ship)
- Deployment depth greater than 200 m to minimize chance of entrapment by passing icebergs

Specifications

MARU (Double Bubble)

(Cornell Lab of Ornithology, USA)
1997



[Picture: AWI]

Price (leasing*)	14000-16000 US$ /year
Hydrophone type	HTI-94-SSQ
Hydropone sensitivity	-168 dB re 1V/µPa
ADC	12 bit
Gain	User variable
Sampling frequency	Up to 64 kHz
Max. data storage	one HDD (120GB)
File format	BIN
Housing	Glas Bubble with hardhead
Max. deploy. depth	6700 m
Additional sensors	Temperature, Pressure

* Including service, technical support, data extraction, etc.

AURAL-M2

(Multi-Electronique (MTE) Inc. , Canada)

[Picture: AWI]

Price*	~ 17400 CAD$
Hydrophone type	HTI-96-min
Hydrophone sensitivity	-162 dB re 1V/µPa
ADC	16 bit
Gain	16, 18, 20, 22 dB
Sampling frequency	Up to 32 kHz
Max. data storage	2 HDD (640GB)
File format	Composite WAVE
Housing	Stainless Steel, Delrin, Fiberglass/Epoxy
Max deploy. depth	300 m (tested)
Additional sensors	Temperature, Pressure

* Version designed for 128 Batteries, without batteries

Sono.Vault

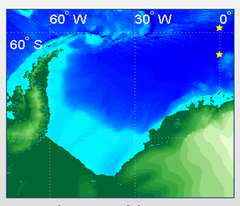
(Develogic Subsea Systems GmbH, Germany)
2009

[Picture: AWI]

Price*	~ 19. 000 €
Hydrophone type	TC4037-3
Hydrophone sensitivity	-193 dB re 1V/µPa
ADC	Dual: 16 bit / 24 bit
Gain	6 - 48 dB
Sampling frequency	Up to 192 kHz (16 bit)
Max. data storage	35 SD Cards (4.4 TB)
File format	WAVE
Housing (Deep Water Version 6000m)	fiber-reinforced synthetics, aluminium, titanium caps
Max deploy. depth	3500 m (Hydrophone)
Additional Sensors	Optional, tbd

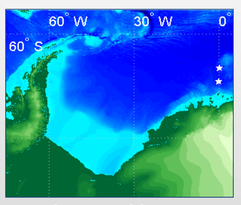
* Version designed for 79 Lithium-Batteries, without batteries

Deployment



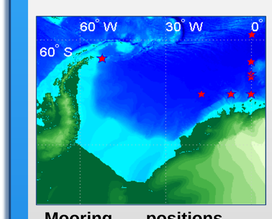
Mooring positions MARU 2008-2010

Number of units depl.	2
Gain setting	23.5 dB
Sampling frequency	2 kHz
Recording interval	6 min every hour
Storage capacity	120 GB
Power supply	Alkali D-Cells
Deployment depth	ca. 4800 m



Mooring positions AURAL 2008-2010

Number of units depl.	2
Gain setting	22 dB
Sampling frequency	32 kHz
Recording interval	5 min every 4 hrs
Storage capacity	160 GB
Power supply	128 Alkali D-cells
Deployment depth	ca. 200 m



Mooring positions Sono.Vault from 2010

Number of units depl.	8
Gain setting	20 dB / 48 dB
Sampling frequency	5.3 kHz
Recording interval	continuous
Storage capacity	1.1 TB
Power supply	78 Lithium D-Cells
Deployment depth	ca. 1000 m

Results

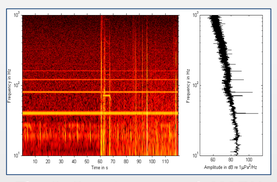


Fig. 3: Spectrogram of MARU file

Deployment period	730 d
Recording period	357 d (batteries empty)
Total recording time	855.6 hrs

The MARU recordings show periodical self-noise from the starting HDD and a now remedied continuous 40 Hz signal with harmonics (Fig. 3). The data contain calls of different cetacean and pinniped species with low background noise. Single Antarctic blue whale (*Balaenoptera musculus*) Z-calls (28 Hz tonal - downsweep - 19 Hz tonal) can be identified in the MARU recordings.

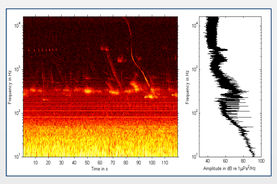


Fig. 4: Spectrogram of AURAL file with leopard seals

Deployment period	1014 d
Recording period	1014 d (recording stopped manually)
Total recording time	> 496 hrs

The acoustic background noise at low frequencies is louder in the AURAL compared to the MARU (Fig. 4). This might result from shallower deployment depths and hence increased ambient noise from the sea surface, particularly during summer. The spectrogram below shows 3 year of recordings from one AURAL. The background noise decreases during austral winter, concurrent with the presence of sea ice.

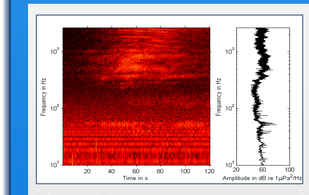
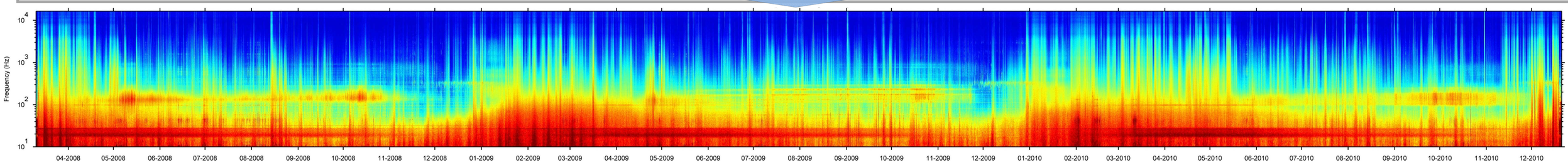


Fig. 5: Spectrogram of Sono.Vault field test in harbour

Deployment period	pending*
Recording period	pending*
Total recording time	pending*

*** lab/harbor test results only**



Summary

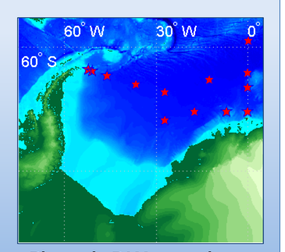
The three acoustic recorder types provide:

Biological data:
- providing baseline data on acoustic ecology and occurrence of marine mammals in the Southern Ocean
- gaining insights into local soundscapes and acoustic habitat quality

Information on recorder scheduling for future deployments:
- to evaluate the use of subsampling regimes to maximize the probability of detection of target species (e.g., high frequency odontocetes)
- providing a base for designing smart sampling patterns, e.g. adapt gain in response to changes in background noise

On-going work

- Recovery of 8 Sono.Vault and 2 AURAL in December 2012
- 17 PAM planned to be deployed in December 2012
- Using RAFOS sound sources as calibrated sound signals to estimate acoustic ranges of 260 Hz signals.



Planned PAM moorings for December 2012

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