Environmental hydroacoustic monitoring
Passive Acoustic Monitoring (PAM)

Shallow-water environmental variability research
Shallow-water sonar signal performance
Multipath robust signal design
Sonar array (sparse) algorithm development
HYDROACOUSTIC MONITORING OF PILING OPERATIONS IN THE NORTH SEA

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Overview

• Summer 2004, BP North Sea “Hot Tap” installation

• Future connection of Forties Pipeline to Encana Buzzard development

• Hot-Tap connection protective structure secured to sea bed by piles, depth: ~100m

• Piles: 22m long, 0.75m diameter tubular steel

• BP underwent voluntary EIA

• HWU/Genesis contracted for hydroacoustic work

• Source level estimates through measurement/modelling
Piling operations

• four piles located at each corner of protective structure
• pile driver aligned with top of pile
• 10 tonne hammer + hydraulic charge
• several “single mode” blows to test penetration
• automatic mode: rapid blows
Methodology

- silent recording vessel
- July 04: ambient noise
- August 04: piling noise
- shallow hydrophone B=120kHz
- deep hydrophone B=45kHz
- CTD measurements
- GPS logging
Methodology

- silent recording vessel
- July 04: ambient noise
- August 04: piling noise
- shallow hydrophone $B=120\text{kHz}$
- deep hydrophone $B=45\text{kHz}$
- CTD measurements
- GPS logging
Environment: ambient recordings

- weather: good
- sea state: 2-3
- shipping: seismic vessel @ 45km, fishing boat @ 3.5km
- sound speed profile
- white beaked dolphins present
Environment: ambient recordings

- **weather**: good
- **sea state**: 2-3
- **shipping**:
  - seismic vessel @ 45km
  - fishing boat @ 3.5km
- **sound speed profile**
- **white beaked dolphins present**
Environment: ambient recordings

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Results: ambient recordings

- seismic survey @ 45km – two vessels?
- seismic booms seen to feature sympathetic “downward chirps”
- geometrical dispersion of sounds undergoing multiple reflections
- wind-driven noise decreases with depth

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Results: ambient recordings

- Sound Pressure Density (SPD) spectra
- Averaged over 1 minute
- $\Delta f \approx 3$ Hz
- $\Theta$ve gradient SSP: energy concentrated in lower layers
- Sub 100 Hz: deep Rx 20-40 dB > shallow
- Above 1 kHz: levels > due to agitation
- High levels compared to deep water Wenz curves
Environment: piling recordings

• weather: good

• sea state: 2-3

• shipping:
  100m support ship
  - diesel electric
  - dynamic positioning
  ROV

• no MMs observed
Methodology: piling recordings

- Recording vessel downwind of ops
- Drifts from <500m to >2000m over 4 hours
- 1600 pile hammer emissions recorded
- Hydrophone depths logged
Results: piling recordings

- time-pressure series for a pile hammering operation
- smaller amplitude sound associated with hammer charging
- following this, impact of hammer against anvil/pile assembly
Results: piling recordings, spectral

- charging pulse & hammering pulse are broadband with low frequency bias
- hammering pulse energy extends to >100kHz
Results: piling recordings, spectral

- maximum difference between ambient and hammering: 55dB in 100Hz to 1kHz band
- at 120kHz: approximate increase of 10dB
- at 20Hz, a modest increase of 5dB (100ms record, Δf ≅ 9Hz)
Results: piling recordings, spectral

- 82ms spectrogram “slices” for 224 hammer signatures concatenated
- taken from start of hammer signature
- no evidence of spectral line gradient increase with pile progress
- indicates that pile resonance is not the major component of signatures
Results: piling recordings, peak SPL versus range

• maximum peak SPLs of 168 & 166 dB/µPa for shallow and deep RX @ 500m
• as R ↑, relative increase in SPL between shallow & deep RX respectively – why?
Results: piling recordings, rms SPL versus range

- rms pressure over peak-10% envelope
- maximum rms ≅ 153 dB//µPa
- deep/shallow comparable with range except for >2000m
- > 2000m, reverberation field in upper layer has less intensity
Modelling

- Modelling allows estimation of source levels through extrapolation.
- PROSIM broadband normal mode underwater acoustic model.
- Piling is modelled as a broadband (100-9000Hz) point source located 10m from floor.
- Inputs: smoothed CTD profile relative receiver positions.
- Peak source level estimation: $210\text{dB}/\mu\text{Pa}@1\text{m}$
Conclusions and recommendations

• Seismic noise may be considered part of the ‘normal’ noise climate

• Acoustic data clearly indicates that the percussive piling dominates the sound field

• Received signals are wideband with significant energy extending to over 100 kHz

• At 500 m range: peak and rms sound pressure levels of 168.6 and 153 dB/µPa

• Propagation loss curve was generated using broadband normal mode acoustic model

• Modelling exercise indicates a peak source level of 210 dB/µPa @ 1 m

• Point source modelled, hence physical processes are not modelled in their entirety

• Impulse spectra stable with pile progress: pile resonance is not a major contributor
Conclusions and recommendations

- valuable addition to knowledge of anthropogenic sound pollution in the sea

- while acoustic processes present a complex modelling challenge, point-source modelling enables a valuable source level estimation

- Closer range measurements would further substantiate predictions (future work)

- Mitigation: further work required on impacts to marine life

- PRP, duty cycle may be key factors
PART II
THE PASSIVE ACOUSTIC MONITORING GUARDIANSHIP PROJECT

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School of Engineering and Physical Sciences
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Methods of detecting marine mammals

Visual surveys

• operators employ teams of dedicated Marine Mammal Observers (MMOs)
• highly skilled at spotting animals which surface

Task of MMOs:

• minimise the probability of false detections (costly to the operator)
• maximise the probability of true detections (increased protection for MM)

Problems:

• Non-surfacing MMs
• Poor visibility
• Rough seas

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Methods of detecting marine mammals

**Passive Acoustic Monitoring (PAM)**

- many marine mammals produce loud and distinctive vocalisations
- these can often be detected more reliably than visual cues

**PAM:**

- offers an effective means of detection
- can detect creatures at ranges in excess of visual observation
- particularly useful for odontocetes, especially deep divers (sperm whales) and species that are difficult to spot (porpoises)
Existing PAM systems

Most commonly used freely available PAM software:

• IFAW suite
  • two element array
  • provides ambiguous hyperbolic bearing information rotational on array axis

ISHMAEL

• spectrogram viewer
• three acoustic localisation methods (including >2 element)
• three methods for automatic generic call detection (energy summation/matched filter/spectrogram correlation)
The vision for the PAMGUARD initiative:

To address the fundamental limitations of existing cetacean passive acoustic monitoring (PAM) software capabilities by creating an integrated PAM software infrastructure that is open source* and available to all PAM users for the benefit of the marine environment.

www.pamguard.org

Open source* – publicly owned freely available

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PAMGUARD – software design

Platform independence

wide computing hardware/operating systems configuration options

Reusability

important for contributions from the PAMGUARD community

Generic behaviour of software components

captured in classes, which are extended into new capabilities/algorithms

“Infrastructure on which PAM can evolve”
**Data Preparation objects**

- receive acoustic data from Data Reader
- prepares data, e.g.: noise reduction,
- band pass filtering,
- down sampling,
- enveloping...

* Data Input from either Live or File based sources.
**Detector objects**

- receive & process prepared acoustic data
- search for instances of acoustic signatures
- initially generic, e.g.:
  - MF clicks (e.g. sperm whales)
  - HF clicks (e.g. porpoises)
  - whistles/tonals (e.g. dolphins)

* Data Input from either Live or File based sources.
Matrix Generator objects

- receive detection event objects
- build TDOA matrices
- cross examine multiple acoustic sources to find high confidence candidate matches for the same acoustic event

PAMGUARD data flow

Audio Data *

Data Reader

Data Preparation 1

Detector 1

Matrix Generator 1

GPS Data *

Localisation Parameter Data *

Cartographic Data *

User Annotation Input

* Data Input from either Live or File based sources.

Data Preparation 2

Detector 2

Matrix Generator 2

Localisation Manager

Tracking Manager

 Classifier

Environmental Data *

Data Fusion Manager

Data-Store

Processed Data Access Manager

Signal Viewer

World Viewer

Audio Output
Localisation objects

- uses TDOA matrices to place detection events in space
- draws upon:
  - GPS position
  - hydrophone array configuration
  - sound speed profiles

* Data Input from either Live or File based sources.
PAMGUARD data flow

**Tracking object**

- monitors detections, localisation classification information for evidence of individual animals

* Data Input from either Live or File based sources.
PAMGUARD data flow

Data Fusion Manager object

• collects event objects
• combines them with:
  - localisation information
  - user annotations
  - cartographic data
  - environmental conditions
• combined information is:
  - presented in GUI
  - stored in database

* Data Input from either Live or File based sources.
How can you participate in the PAMGUARD venture?

If you wish to know more, please visit:

PAMGUARD web site: www.pamguard.org

SourceForge web site: https://sourceforge.net/projects/pamguard/

....and join us as a contributor to the PAMGUARD initiative.

First full prototype release due December 2005.