Marine Ecosystems

Acoustics Program

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Mission:
Use underwater sound to assess the health of marine ecosystems

**Ambient Ocean Sound:**
Evaluate the impacts of sound from human activities, and natural processes, on the marine environment

**Bioacoustics:**
Assess changes in abundance and distribution of marine mammals due to man-made noise and climate

**Geophysics:**
Quantify volcanic processes and develop methods to estimate CO₂ gas release from submarine volcanoes

**New Technologies:**
Develop innovative ocean sound sensing technologies
Relevance

NOAA’s Missions:

- Assessing health and productivity of marine ecosystems (Healthy Ocean Goal)
- Advance understanding of the oceans, manage marine ecosystems

OAR/PMEL Science Goals and Objectives:

- Develop Next Generation tools and technology
- Monitor, understand and predict key aspects of the ocean environment
- Identify ocean issues of major consequence

National Acts:

Marine Mammal Protection and Endangered Species Acts:

- Provide acoustic information on presence, distribution of at risk cetaceans
- Our data used by NOAA/Navy to assess impacts on marine animals

Marine Sanctuary and Federal Power Acts:

- NOAA’s responsibility to assess man-made noise impacts on marine sanctuaries
- Mitigate noise impacts from oil exploration and renewable energy development
Quality

Leading NOAA program for acoustics technology development, data archiving, and analysis

Unique Acoustic Program Assets

• 23-year archive of N. Pacific ocean sound (using U.S. Navy SOSUS hydrophone arrays)
• Global sound dataset (31 TB) from stationary and mobile hydrophone deployments
• *Ishmael & Seas*: In-house bio- and geo-acoustic analysis software (online free-ware)

Technology Transfer to Operations

• Passive acoustic recording module (WISPR Board), commercialized by EOS LLC
• Acoustic profiling float (QUEphone) available through Teledyne Webb, Inc.

Involvement in NOAA-wide Policy Initiatives

• Ocean Noise Strategy – assess affects of man-made noise on marine animals
• Team to evaluate NOAA echo-sounder impacts on marine mammals
Background

Why is passive acoustics ideal for ocean monitoring?

Physics of ocean sound propagation:

- Sound travels faster in water (1500 m/s) than in air (340 m/s)
- Existence of sound channel, low velocity zone (~ 1 km deep)
- Sound waves travel long distances with little energy loss
- Higher marine organisms are acoustically oriented
Background: Ambient Ocean Sound

- Noise 3-4 times (12 dB) higher now in some regions than in 1960s
- Many marine animals use sound to communicate, navigate, find food

Global Shipping

Global Oil and Gas Reserves

Coastal Populations

Offshore Oil Rigs
PMEL-Navy partnership to collect real-time hydrophone data in N. Pacific

SOSUS: a cold-war era cabled hydrophone network for anti-submarine warfare

PMEL first accessed SOSUS in 1991, one of longest civilian archive of ocean sound

PMEL used the SOSUS sound archive to:
• Detect numerous submarine volcanic eruptions
• Track endangered blue and fin whales
• Evaluate long-term trends in ocean noise
Performance: PMEL Hydrophone Mooring

Following the success of SOSUS: PMEL developed portable deep-ocean hydrophones

Current capacity:
- 5 kHz sample rate
- Up to 2-3 year recording capability
Autonomous Hydrophones: Global Reach

17 Geographic Locations ~200 Individual Deployments and Recoveries
Mobile platforms and near-real-time communication

Slocum Glider

Seaglider

QUEphone
Quasi-Eulerian Float

Roboat
Austrian Society for Innovative Computer Sciences

EMILY – Unmanned Surface Vehicle
NOAA – Weather Service

Winch Mooring:
under-ice recording
Performance

Acoustic Assessment of Marine Mammals

Why?
Basic research
  - migration patterns
  - feeding habitats
  - trophic interactions
Find endangered species
  - e.g., only ~500 right whales left in North Atlantic
  - even fewer in N. Pacific
  - finding seasonal distributions is critical

How?
Develop quality detection algorithms to find whale calls in acoustic data
  - efficient
  - robust to noise
For....
  - Detecting baleen whale calls and toothed whale/dolphin clicks

Partners: ONR, NOAA-NMFS, Cornell U., U St. Andrews
Acoustic Identification of Marine Animal Species

- **Baleen Whales (9)**: Blue, Fin, Bryde’s, Sei, Humpback, Right, Bowhead, Gray, Minke
- **Toothed Whales (14)**: Sperm, Beaked (5 species), Dolphins (5 species), Killer whales, Pilot whales, Harbor porpoise
- **Pinnipeds (5)**: Leopard seal, Weddell seal, Crabeater seal, Harbor seal, Walrus
- **Fish**

**mobysound.org**
Free online library of marine animal sounds to test detection & localization algorithms

**Partner: Office of Naval Research**
New Cetacean Tracking Techniques

Monitoring whales with ocean gliders

• Many cetacean species are thought to be sensitive to Navy sonar
• Deployed gliders in Navy test area off Hawai‘i
• Detected Beaked whales, Dolphins, and Sperm whale calls
• All detections were reported to shore stations

Partners: ONR, U. Washington-APL

2014 PMEL Lab Review
Establish a network of ten noise reference stations across the U.S. EEZ (3 Sanctuaries, 2 National Parks)

Cooperative program between PMEL, Sanctuaries, all six NOAA Fisheries Science Centers, and Park Service

Goal: Create first comprehensive network to study long-term noise in US waters

Future: Expand coverage globally
Overall Sound Levels:
- Highest at Equator.
- Arctic higher than Antarctic
- Poles lowest in Winter due to sea-ice cover

Man-Made Noise:
- Airguns year-round at Equator
- Summer only in Arctic
- Very little in Antarctic

Marine Mammals:
- Blue-fin whales dominant sound in 15-30 Hz band (all locations)
- Leopard seals add 15 dB (~5 times ambient) over 300-350 Hz

Sea-ice breakup contributes significantly to ambient noise

**Antarctica**

- Recorded sounds of iceberg breakup off Antarctica
- One fracturing event equal to the noise of several hundred super-tankers
- Ice sounds detected as far north as equator

**Arctic**

- Deploy winch mooring for under sea-ice recording
- Quantify variation in sound levels due to seasonal changes in sea-ice cover

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**A53a**

Fractures forming in A53a prior to calving

South Georgia Is.
Supporting Renewable Energy:

PMEL/DOE/OSU partnership to study ambient sound at the wave-energy buoy test site

- Investigate noise produced by wave energy devices
- Understand impacts to marine mammals and fish
- Ambient noise dominated by surf, blue whales, ships
Geophysics: Eruption Processes and Gas Flux from Submarine Volcanoes

**NW Rota-1 in the Mariana Isles**

- First multi-year sound record of explosive deep-ocean eruption (512 m)
- Used sound to estimate flux of magmatic CO$_2$ gas into ocean
- Based on infrasound methods

**Results**

- CO$_2$ flux ≈ 0.4 ± 0.1 Tg per year
- This estimate is ~ 1% of global CO$_2$ flux from subaerial arc volcanoes

**Partners:**
*NSF-Ocean Science Program, US Coast Guard, PMEL-EOI*
Using a Glider to Detect an Erupting Volcano

- First use of a glider to detect erupting volcano
- Mata volcano is dominant source of sound in the region (add 15 dB)
- Gliders effective means to map regional sound field

Glider purchased with a grant from OAR AA Fund

West Mata
1200 m deep

Partners: NSF – Ocean Sciences
PMEL- ED&D

Cross section of ocean sound field
Education and Outreach

**Mission:**
Provide accurate information about the science we conduct to educate the public and inform society

 NOAA youtube: 600K views in 1 month
 NOAA Ocean Today Kiosk video At 40 sites worldwide
 SeaGrant Saturday Academy: Build a hydrophone
 Scientist-in-Residence Exploratorium - SFO

Sounds, videos and animations available at our poster and [www.pmel.noaa.gov/acoustics](http://www.pmel.noaa.gov/acoustics)
Future Directions

- Complete deployment of Noise Reference Station network, continue development of a NOAA-wide Ocean Noise Policy
- Expand hydrophone deployments for global coverage of ambient sound levels (e.g. Challenger Deep, Arctic and Antarctic)
- Continue analysis of SOSUS archive to evaluate 20+ year trends in ocean noise and cetacean populations
- Deploy winch mooring for baseline sound levels in the Arctic as ice-cap recedes (expand to deeper parts of Arctic Ocean)
- Continue development of near real-time, mobile hydrophone platforms
Thank You!