WORLD OCEAN FORUM 2026

Listening at Scale

AI and the future of passive acoustic monitoring in the ocean

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Ocean Science Analytics

OCEAN SCIENCE RESEARCH & TECHNICAL TRAINING

Artificial intelligence has given the ocean new ears. Human expertise is still what turns listening into understanding.

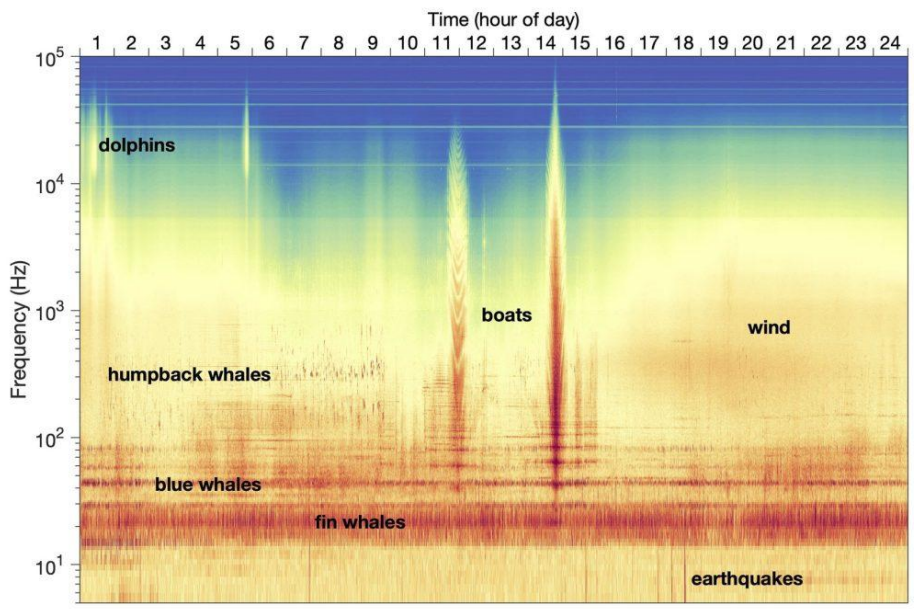
AI IN PASSIVE ACOUSTIC MONITORING

SECTION 01

The Ocean Is Not Silent

Sound is one of the clearest windows we have into how marine life lives and how its environment is changing.

A Complex Underwater Soundscape



Long-term spectral average of ocean sound. Credit: MBARI

Every recording mixes three kinds of sound:

BIOLOGICAL

Whales, dolphins, fish and invertebrates

GEOPHYSICAL

Wind, rain, ice and earthquakes

HUMAN-MADE

Ships, surveys and construction

Sentinels in a Shared Soundscape

Marine mammal calls never occur alone:

- They share frequency bands with ships, wind and other species
- They overlap in time, from hours to seasons
- That makes them powerful sentinels, and hard to isolate

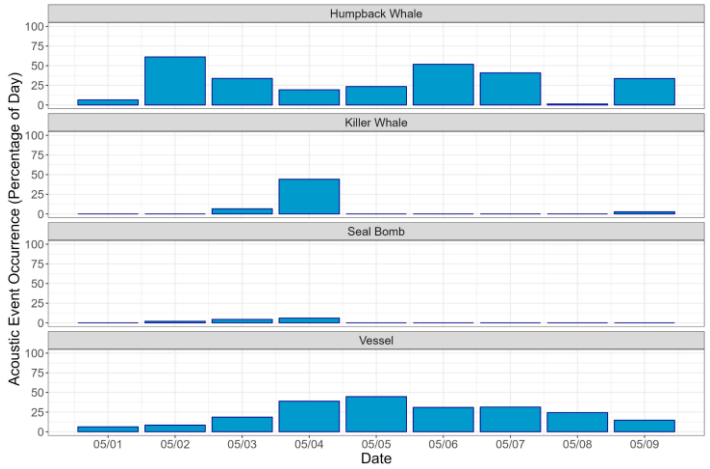


Figure 1. Occurrence of marine mammal calls and other sound sources. Source: Ocean Science Analytics

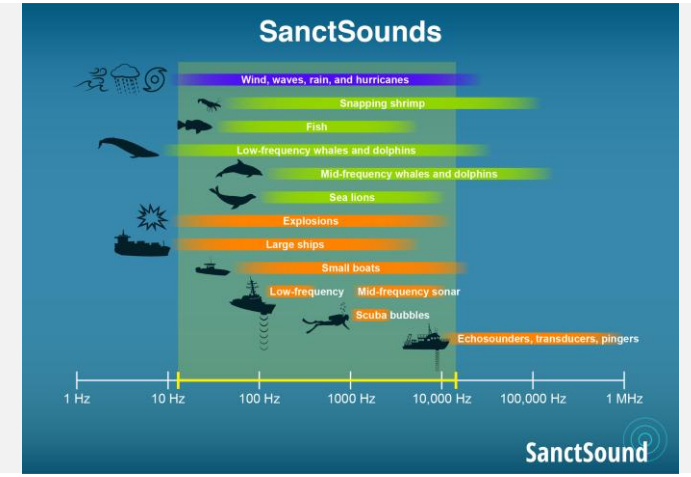
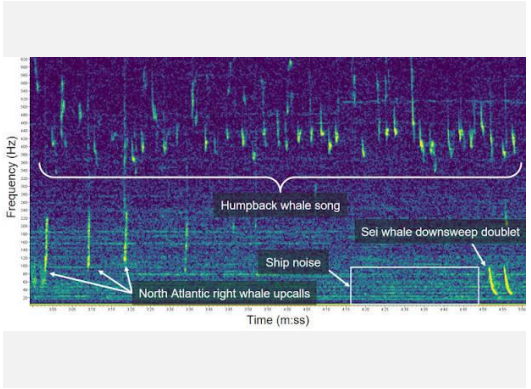


Figure 2. Credit: NOAA and U.S. Navy SanctSound project, sanctuaries.noaa.gov/sanctsound

What Passive Acoustics Tells Us



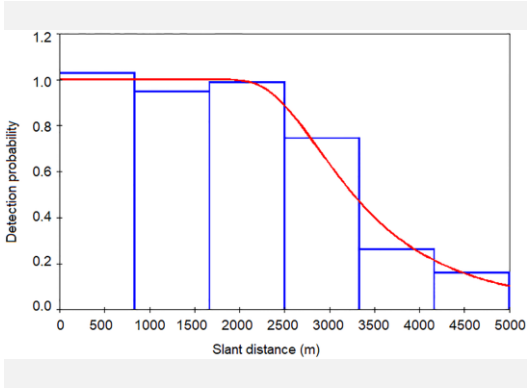
Occurrence

Humpback, right and sei whale calls with ship noise. Credit: NOAA Fisheries



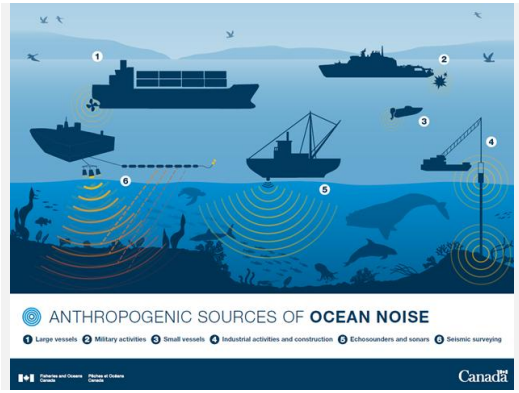
Behavior

Fin whale downsweep and backbeat calls. Credit: NOAA Fisheries



Density

Sperm whale acoustic abundance. Credit: Boisseau et al. (2024), Frontiers in Marine Science



Human Impacts

Ocean noise and marine life. Credit: Fisheries and Oceans Canada

How Acoustic Processing Has Evolved



SWSS survey, 2003. Photo credit: Tom Norris

EARLY 2000s

Limited capacity

Data on CDs, short recordings, spectrograms read by eye

2000s AND 2010s

Machine learning matures

Better detection, but tuned per species, site and instrument

LAST 2 TO 3 YEARS

Deep learning generalizes

Detection that carries across ocean basins and instruments

Noise is the real culprit. Ships, weather, flow and instrument self-noise change everywhere we listen.

Why We Streamline: The Scale of the Data

~1 TB

Per 30 days of recording

From one instrument at a modest sample rate

28 TB

Wake Island HARPs alone

A single OSA project dataset

100s

Of terabytes processed

Our best estimate across OSA projects

Every step we streamline lets us scan whole deployments, keep results consistent, and free experts for interpretation.

SECTION 02

Deep Learning Changes the Pace

Neural networks read sound the way trained analysts do, at the scale our data now demands.

Neural Networks with Experts in the Loop

DATA
Record
Hydrophones capture continuous audio

→

DATA
Visualize
Audio becomes spectrogram images

→

EXPERT
Annotate
Specialists label calls to build training data

→

NETWORK
Train
Networks learn from expert labels

→

NETWORK
Detect
Box and classify calls in archives or live

→

EXPERT
Interpret
Validate results and read them in context

Validated results flow back into training. Treating sound as an image borrows years of progress from computer vision, but the analyst's role is not disappearing; it is shifting to work alongside AI at every stage.

A Growing Deep Learning Toolkit

DeepAcoustics
Ocean Science Analytics
Train and deploy object detection networks without code

PAMGuard
SMRU, Univ. of St Andrews
Open-source PAM software with a deep learning module

Ketos
MERIDIAN, Dalhousie Univ.
Python toolkit for acoustic deep learning

Perch and SurfPerch
Google DeepMind
Bioacoustic models, including coral reef sounds

Koogu
Cornell Yang Center
Python toolkit for bioacoustic classifiers

OpenSoundscape
Univ. of Pittsburgh
Python library for bioacoustic detection

Whale Model
Google Research and NOAA
One model for eight whale species

BirdNET
Cornell Lab and TU Chemnitz
Identifies thousands of bird species by sound

Open access by design. DeepAcoustics models now run inside PAMGuard's deep learning module, alongside models from other tools, in real time or post-processing.

Case Study: DeepAcoustics

An open-access tool to train, test and deploy custom deep learning detectors.

- Tiny YOLO, ResNet and Darknet object detection networks
- Multiclass detection, with noise learned as its own category
- User guide and step-by-step tutorial
- MATLAB-based today, with a Python version planned
- Models run in PAMGuard's deep learning module

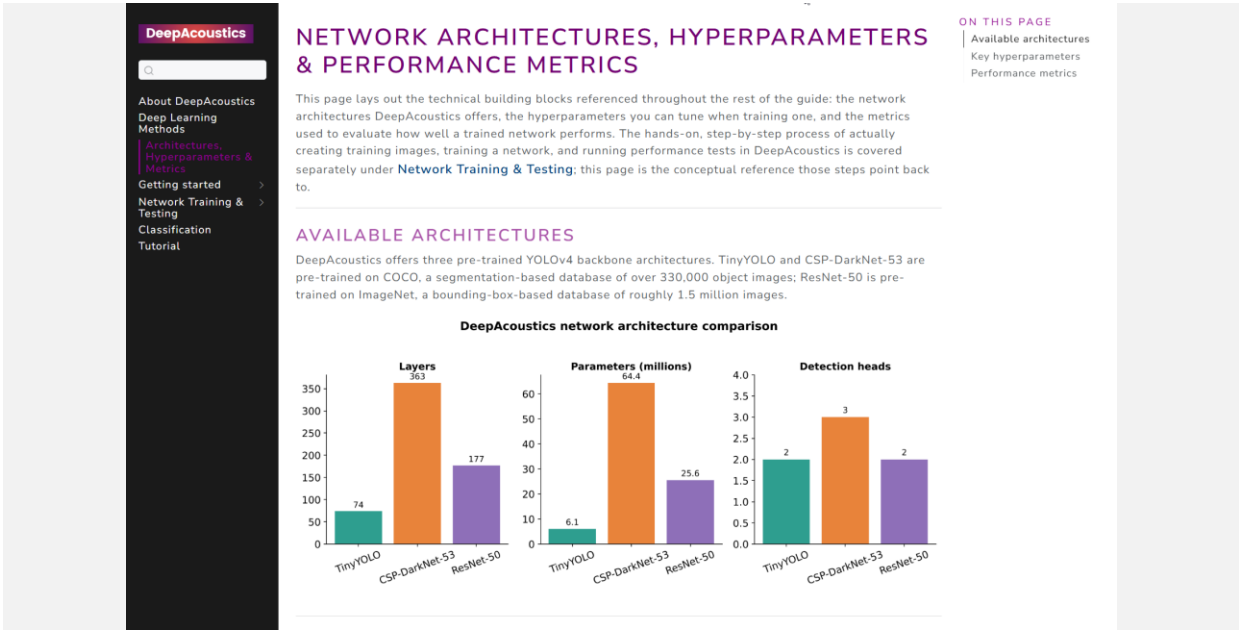


Figure 2. DeepAcoustics. Source: Ocean Science Analytics. [GitHub or guide link]

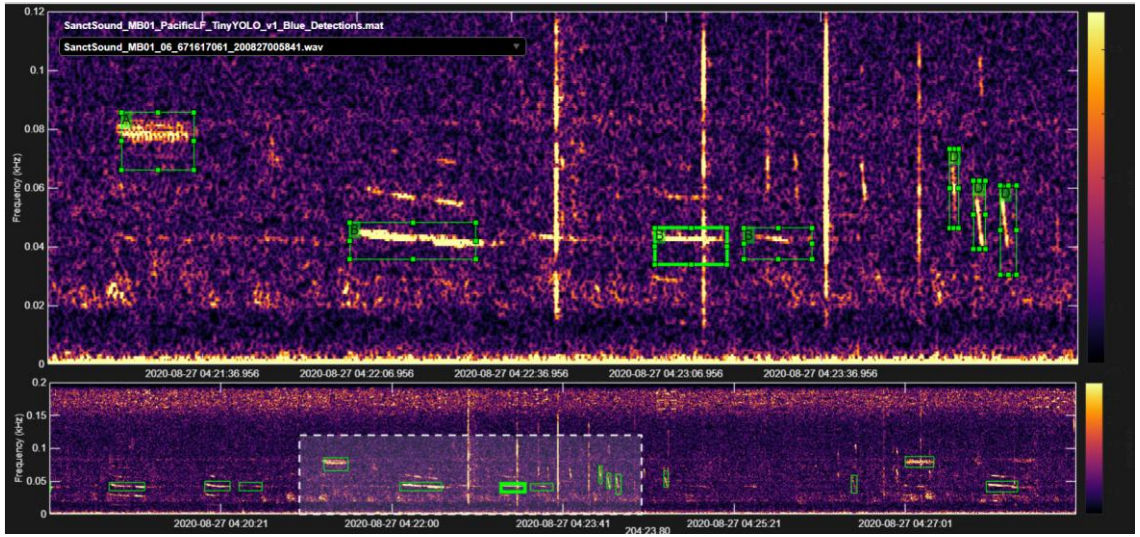
Case Study: Pacific Baleen Whales

One multiclass network:

- Fin whale 18, 20 and 40 Hz pulses
- Blue whale A, B and D calls, and sei whale downsweeps
- Trained on multiple datasets, instruments and sites

Built on expert annotation:

- Five analysts, each dataset reviewed by a second
- **Four to five rounds of review and re-annotation**
- New datasets added as they became available
- Faint calls included so it holds up in noise



Multiclass detections in DeepAcoustics. Source: Ocean Science Analytics

Alongi, G. C., Ferguson, E. L., Toll, M., Hom-Weaver, C. A., Pelio, J., and Sugarman, P. C. Leveraging object detection networks to scale identification of variable baleen whale call types in acoustic data. Frontiers in Marine Science (under review).

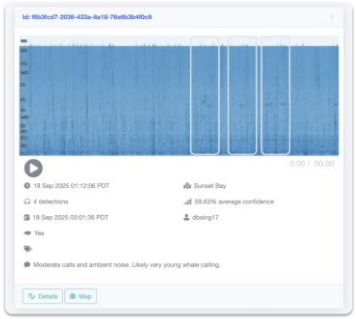
AI in Action: Decoding and Listening Live



Project CETI

- Nearly 9,000 sperm whale codas analyzed
- A combinatorial “phonetic alphabet” found
- Goal: understand why whales communicate

Image and information: projectceti.org



OrcaHello

- Listens around the clock on 7 hydrophones
- AI trims review to under 10 minutes a day
- Experts confirm before ferries and ports act

Image and information: ai4orcas.net/orcahello

SECTION 03

From Archive to Real Time

New hardware moves detection into the water and turns infrastructure we already have into listening networks.

Edge Processing: Detection in the Water

01 INSTRUMENT

Collect

A hydrophone on a buoy, glider or float records continuously

02 INSTRUMENT

Detect

A compact neural network runs on the instrument itself

03 INSTRUMENT

Transmit

Detections, not raw audio, go out by satellite or cell

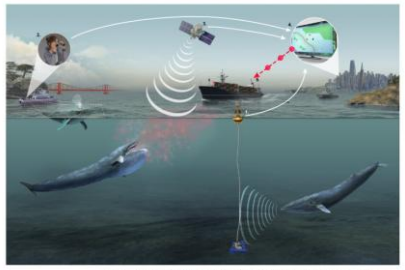
04 EXPERT

Validate and act

An analyst confirms detections and decides when to alert mariners and managers

Raw audio is too large to send from the open ocean. Sending detections instead turns months of delay into minutes, and the final call stays with a person.

Real-Time Detection in Action

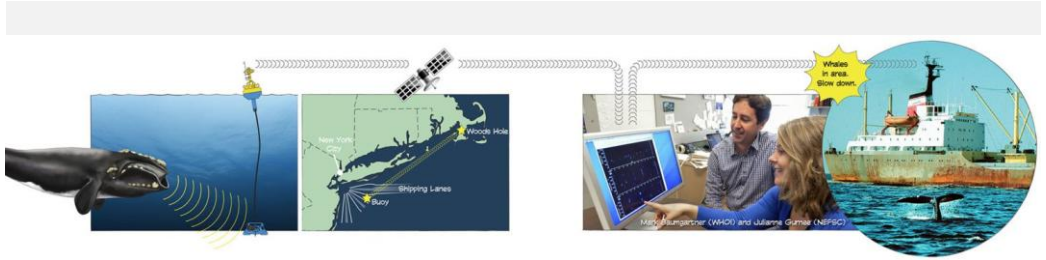


Infographic of Whale Safe technology deployed along the California coast

Whale Safe, Santa Barbara Channel

- Buoy detections sent by satellite every 15 minutes
- Analysts verify blue, humpback and fin whale calls
- Combined with a habitat model and sightings

Image and information: whalesafe.com



Right whale buoys, Boston shipping lanes

- Ten buoys along a 55-nautical-mile corridor
- Onboard computers flag possible right whale calls
- Experts validate before ships slow or reroute

Image and information: whoi.edu

Edge AI for Industry and Mitigation

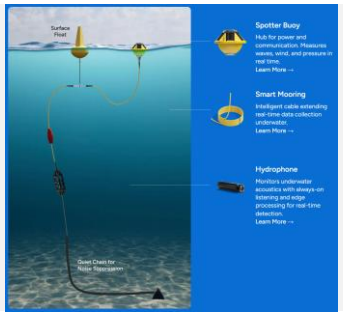


CAB Guardian

SMRU CONSULTING

- Detects, classifies, localizes
- Built on PAMGuard
- Alerts for mitigation

smruconsulting.com/cabgrd

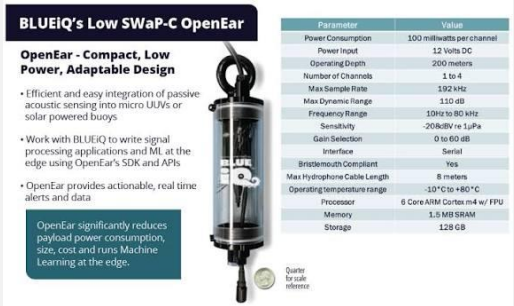


Spotter Sound

SOFAR OCEAN

- AI hydrophone for Spotter
- Detects mammals and vessels
- Sends detections, not audio

sofarocean.com



OpenEar

BLUEiQ

- Low-power acoustic AI sensor
- Real-time edge processing
- Biodiversity and ship noise

blueiq.us

Distributed Acoustic Sensing

DAS turns existing seafloor fiber-optic cables into dense listening arrays.

- A laser sends pulses of light down the fiber
- Passing sound strains the cable and alters the light scattered back
- Every few meters of cable acts as a sensor, across tens of kilometers

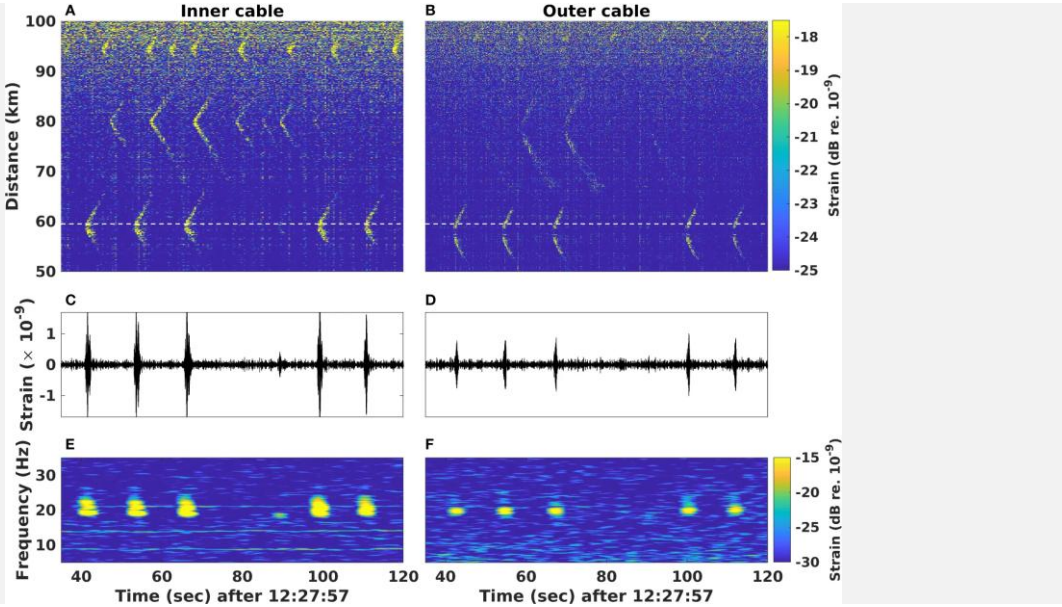
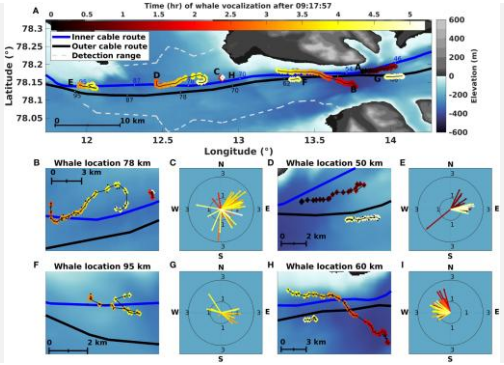


Figure 3. Fin whale calls recorded on two fiber-optic cables. Rørstadbotnen et al. (2023), Frontiers in Marine Science, CC BY 4.0

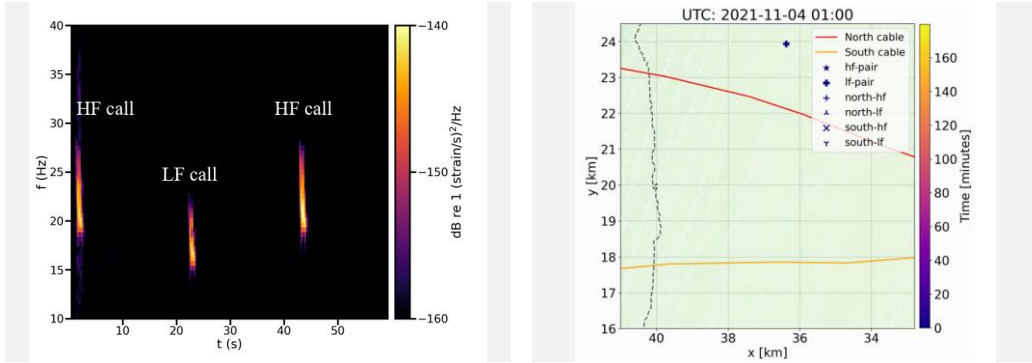
DAS in Practice



Arctic fin whales, Svalbard

- Two existing 260 km telecom cables
- Eight fin whales tracked at once
- About 100 m localization error

Rørstadbotnen et al. (2023), Frontiers in Marine Science, CC BY 4.0. frontiersin.org



Pacific Northwest cables

- OOI cables off Oregon: fin whales localized
- San Juan Islands: humpbacks and killer whales
- 177 TB of public DAS data from one survey

S. Abadi, University of Washington, with Bluecline. DOSITS webinar (2026), dosits.org

SECTION 04

From Detection to Ecosystem Insight

Pairing acoustics with environmental data reveals why animals are where they are, and how ecosystems are changing.

Two Views of the Same Ocean

Passive acoustics sees:

- Which species are present, minute by minute
- What they are doing: feeding, singing, socializing
- Only within each sensor's listening range

Satellites see:

- Sea surface temperature and height
- Chlorophyll and colored dissolved organic matter
- Whole ocean basins, again and again

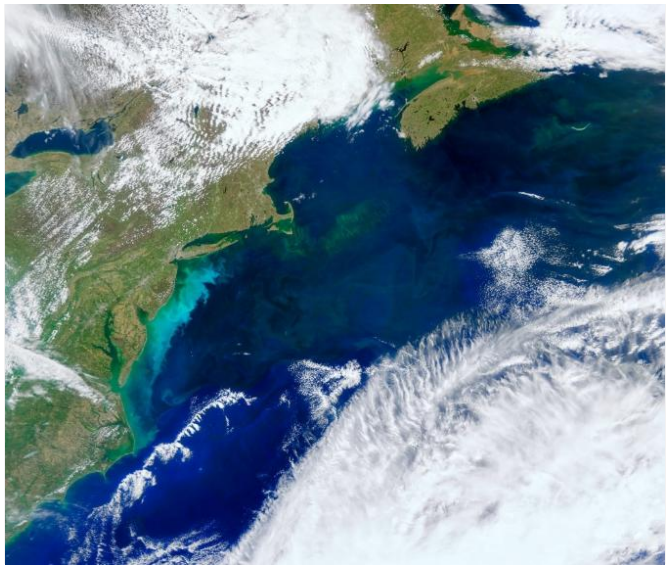
Together, they link where animals are to the conditions that draw them there.

A New Generation of Ocean Satellites

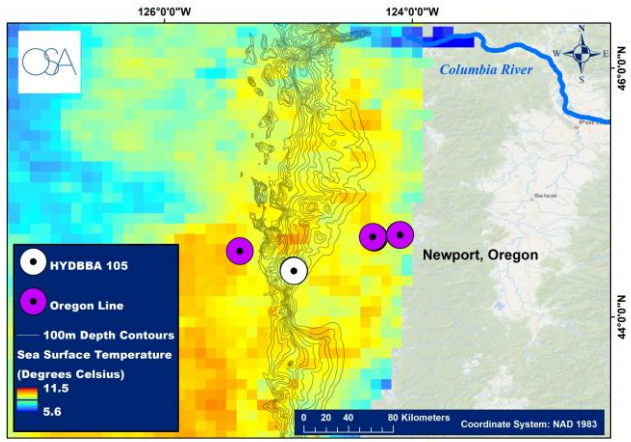
Hyperspectral and higher-resolution imagery are changing what we can see from space.

Example: NASA's PACE mission

- Ocean color in many narrow bands of light
- Chlorophyll, net primary productivity and biogeochemistry
- MOANA: three phytoplankton groups at the base of the food web



MOANA phytoplankton groups. Credit: NASA PACE, pace.oceansciences.org



Sea surface temperature near the OOI Cabled Array. Credit: [source]

An Integrated View of Habitat

PHYSICAL OCEAN

Temperature, sea surface height, fronts and upwelling

FOOD WEB

Chlorophyll, phytoplankton groups and prey fields

ACOUSTIC RECORD

Occurrence, call types and feeding calls

INTEGRATED

Habitat models

Link animals to the conditions around them

- **Where and when animals occur**
- **Why they are there**
- **What they are doing, such as feeding**
- **How it is changing over time**

The Future: Listening at Scale

We are recording far more ocean sound than we have ever analyzed.

01

Unlock the archives

Apply generalizable networks to the terabytes already sitting on hard drives

02

Streamline what comes next

Build detection into every step, from edge processing to cloud workflows

03

Optimize the human in the loop

Focus expert time on annotation, validation and interpretation

Open tools, shared data and common standards are how we get there, together.

The ocean has always been speaking. We have recorded more of it than we have ever heard. Now we can finally listen, with machines that scale and people who understand.

THE OPPORTUNITY AHEAD

LET'S CONTINUE THE CONVERSATION

Thank You

Liz Ferguson, CEO and Founder

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