Listening to the ecosystem:
the integration of machine learning and a long-term soundscape monitoring network

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Long-term monitoring of ecosystem

- Essential for conservation management
  - Field surveys of wildlife
  - Biodiversity monitoring
- Labor intensive work, require automatic sensing techniques

Remote sensing of ecosystem

Large scale

Satellite sensing

- Entire landscape

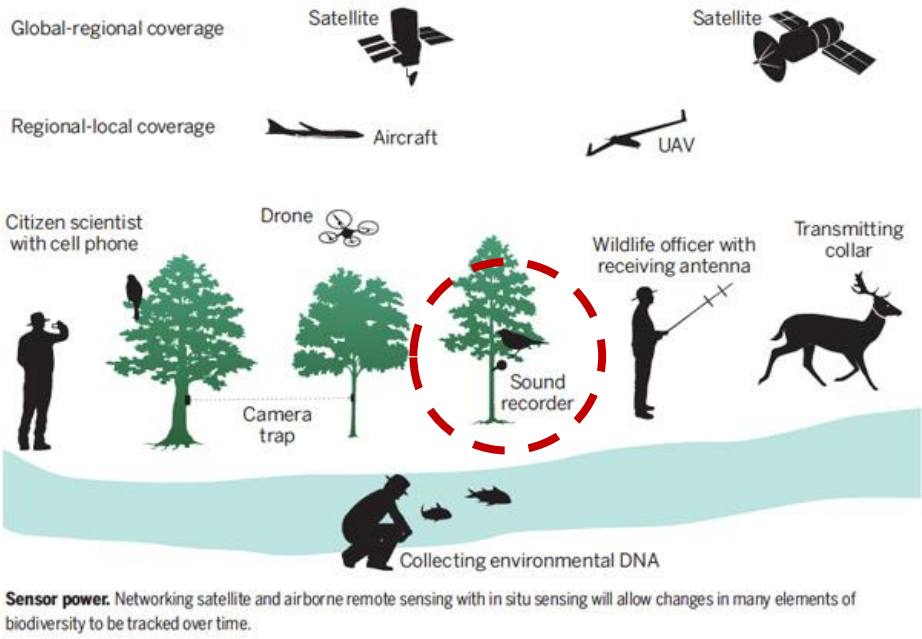
RADAR, LIDAR

- Detail of landscape, wildlife community

Camera trap

- Individual animal

Small scale

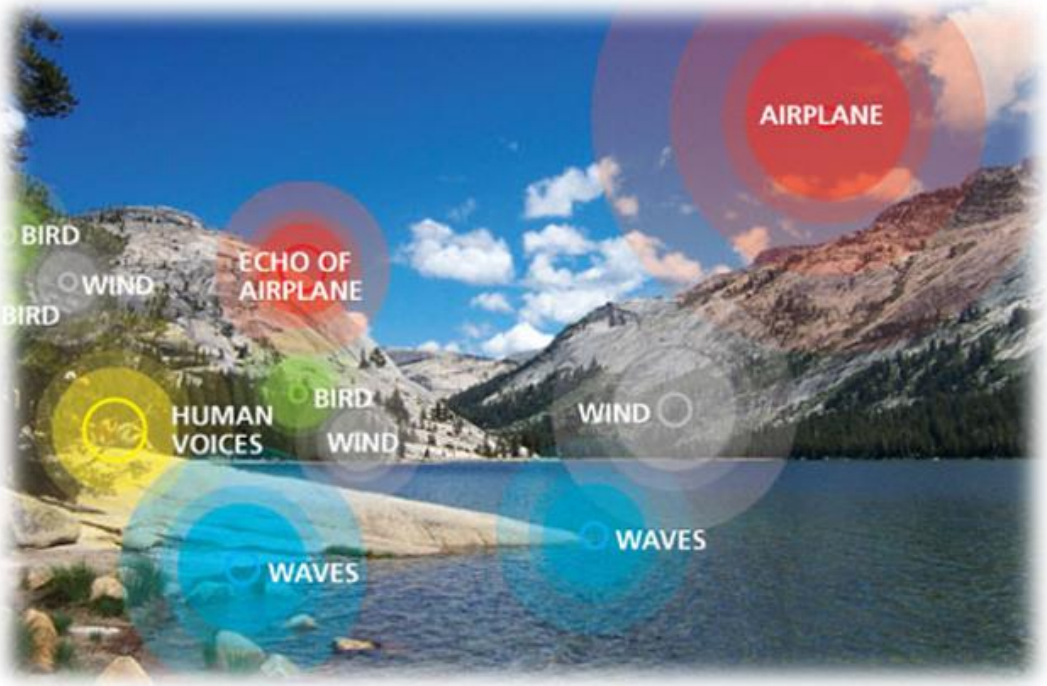


Sensor power. Networking satellite and airborne remote sensing with in situ sensing will allow changes in many elements of biodiversity to be tracked over time.

Image courtesy of SCIENCE

Soundscape

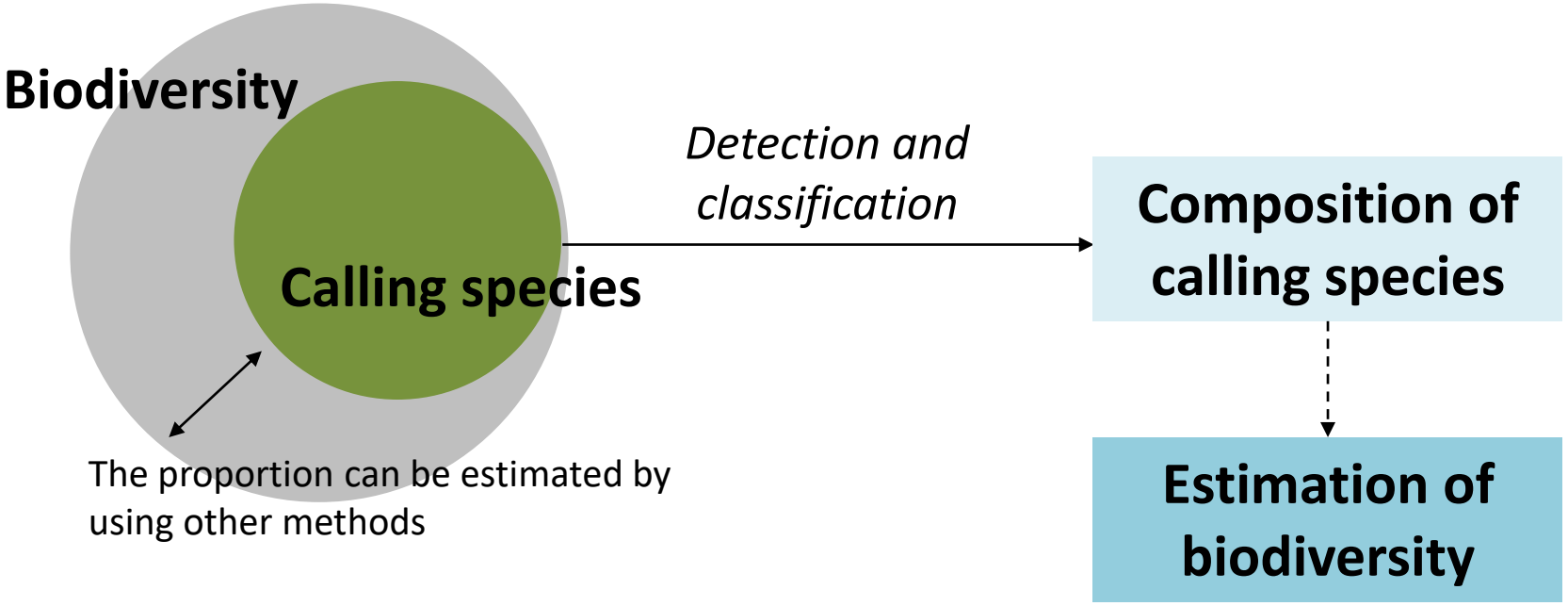
- **Geophony** (Nature sounds…)
- **Biophony** (Animal vocalizations…)
- **Anthrophony** (Human made noise…)



https://www.nps.gov/yose/learn/nature/soundscape.htm

Listening to biodiversity

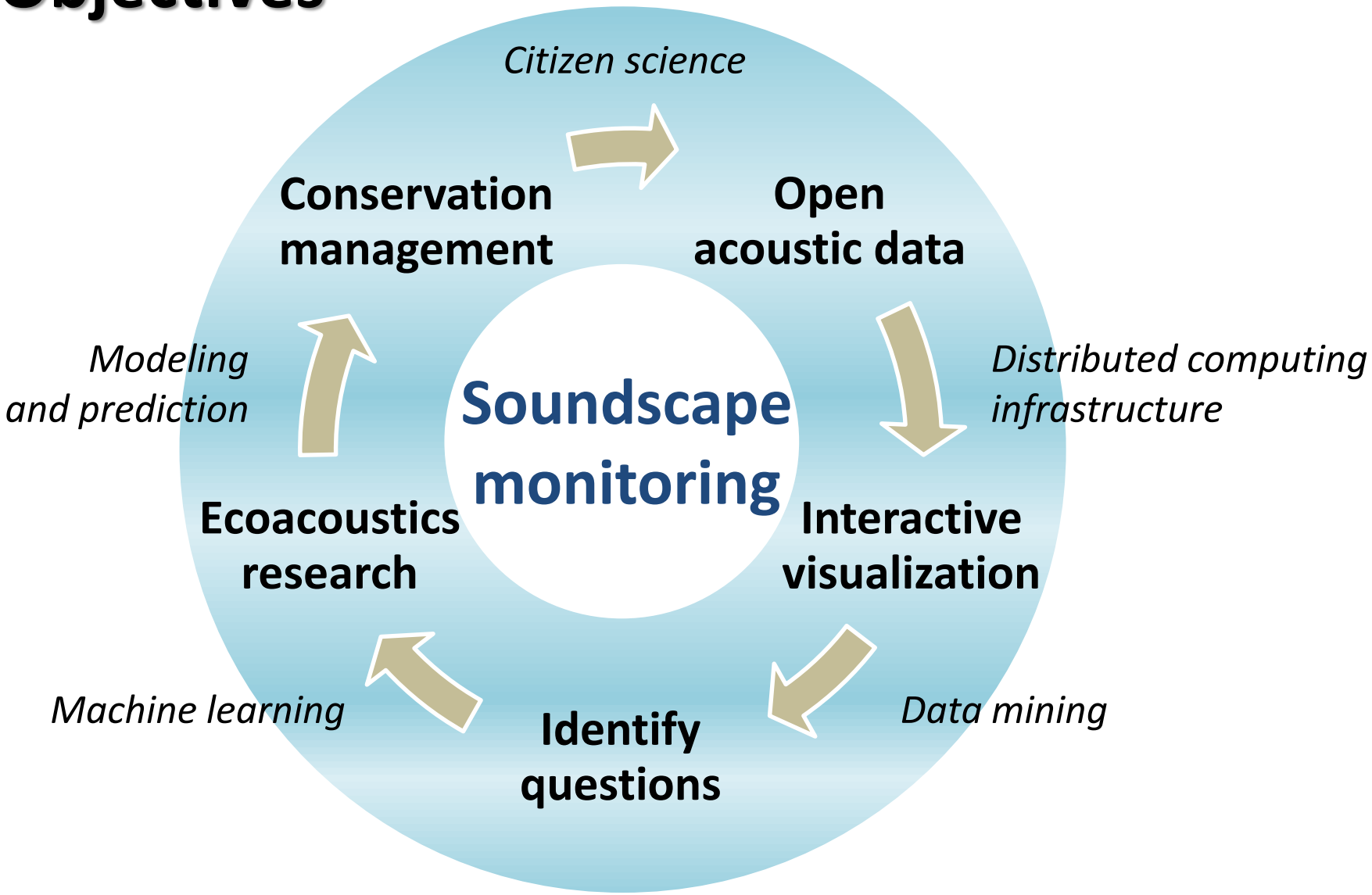
- Passive acoustic monitoring
  - Identify an animal by detecting its acoustic signals
  - Classify the species based on acoustic features



Challenge of soundscape monitoring

- **Data storage**
  - Large amount of data
  - Unlabeled data
- **Analysis**
  - Various types of animal vocalizations
  - Most users are not familiar with signal processing
  - Noise interference, multiple sound sources
- **Performance**
  - Sensitivity of recording devices
  - Uncertainty of detectors and classifiers

Objectives


Citizen science
Open acoustic data
Distributed computing infrastructure
Interactive visualization
Data mining
Identify questions
Machine learning
Ecoacoustics research
Modeling and prediction
Conservation management
Soundscape monitoring

Soundscape monitoring network

Missions:

- Evaluate the dynamics of soundscape and biodiversity
- Study the interactions between wildlife, habitat, and human activities

Current platform

Missions:

- Open data
- Service for ecological and environmental researches, citizen science, education

Cloud data center
Academia Sinica Grid Computing

Web-based management system (Pumilio)
Villanueva-Rivera & Pijanowski (2012)

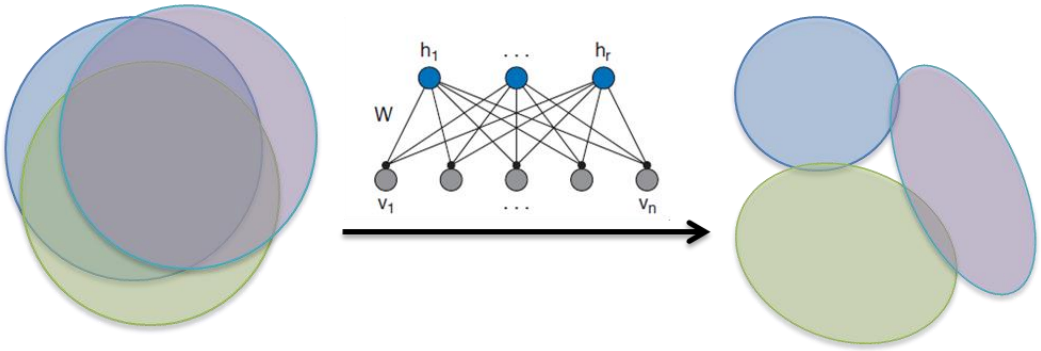
Detection and classification

Researchers

Visualization and interactive interface

Tools for analyzing field recordings (unlabeled data)

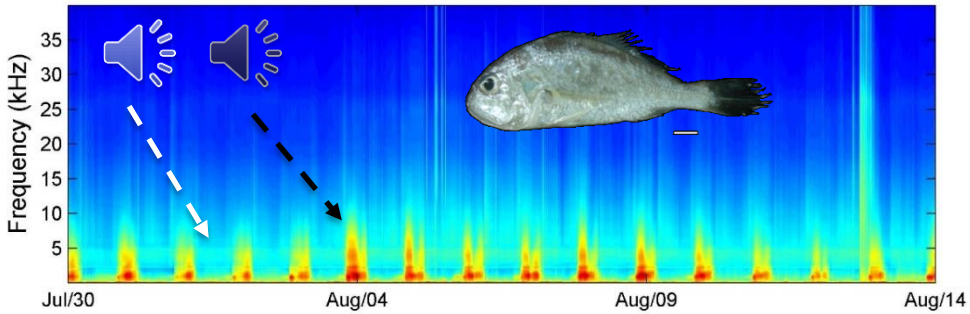
- Visualization of long-term acoustic data
- Unsupervised detection of biological chorus
- Clustering of soundscape scenes and events



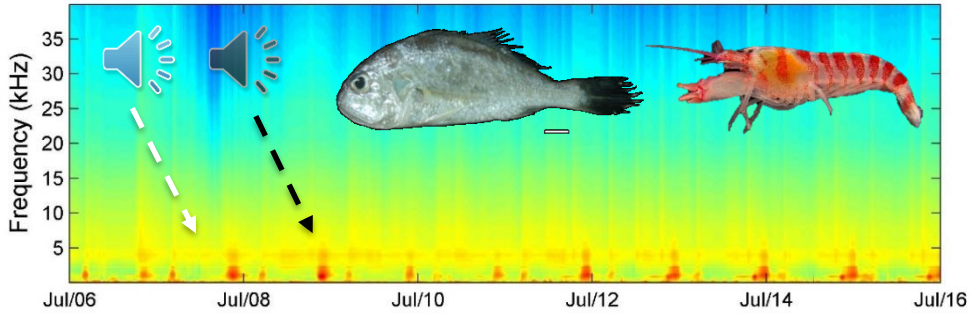
Marine soundscape

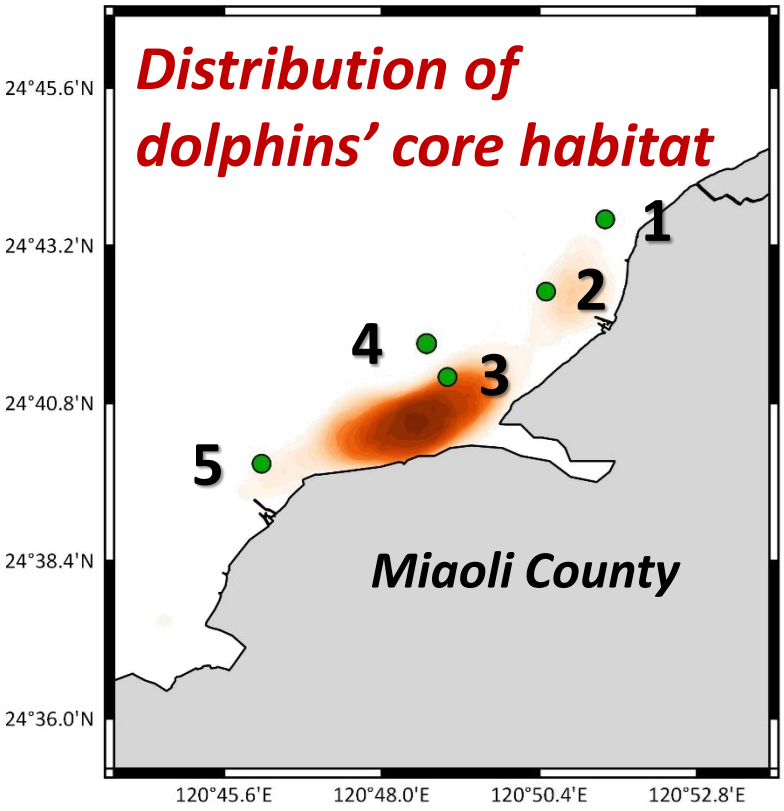
Indo-Pacific humpback dolphins & marine soundscape

3. Chunggang river estuary



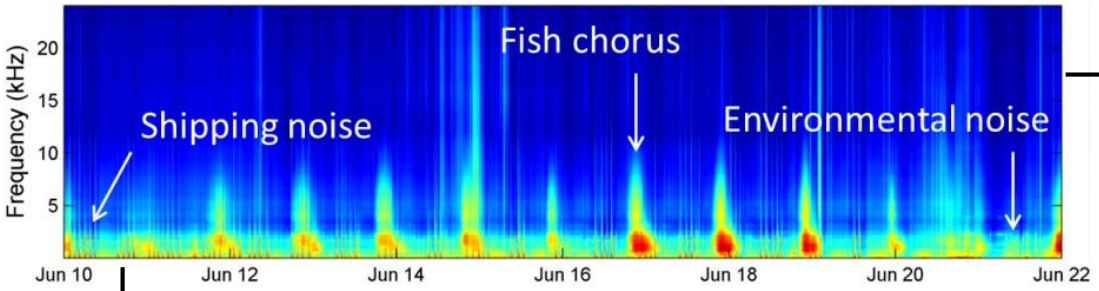
5. Waipu artificial reefs





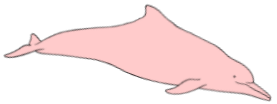
Data collected by Institute of Ecology and Evolutionary Biology, National Taiwan University

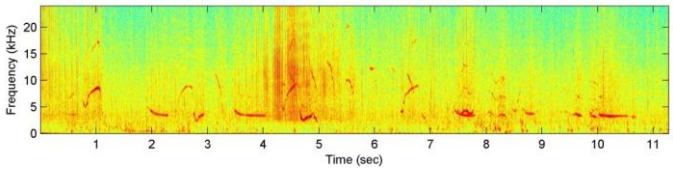
Analysis procedures



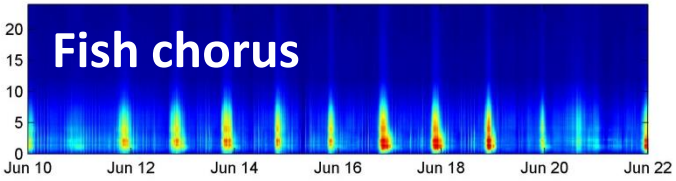
Biosonar detector

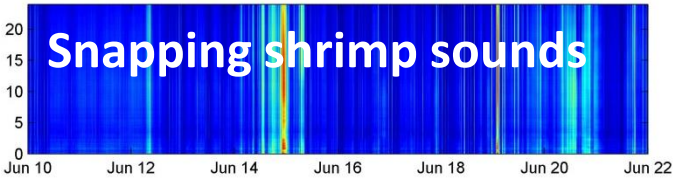
Tonal sound detector





Unsupervised separation of different sound sources



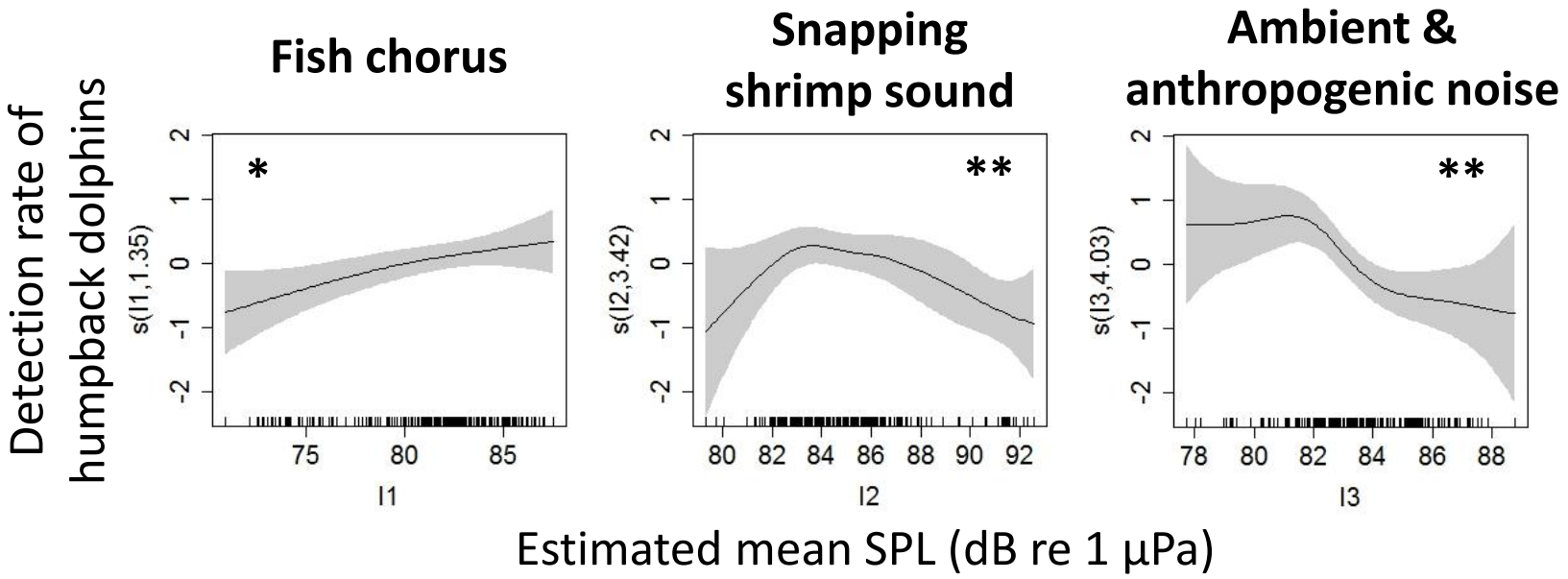


Modeling by GAM

- SPL of soundscape
- Clicking rate
- Whistle complexity
  - ✓ Sampling by 1 day interval

Behavior response to different sound sources

- Prey associated sound: **+**
- Competitor of acoustic space: **+ -**
- Environmental and anthropogenic noise: **-**



Forest soundscape

Forestry biodiversity

Sanyi (A) (500 m)

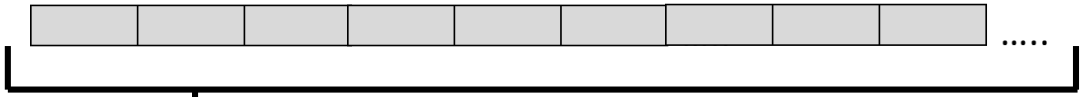
Lienhuachih (B) (800m)

Taiping Mt. (C) (1900m)

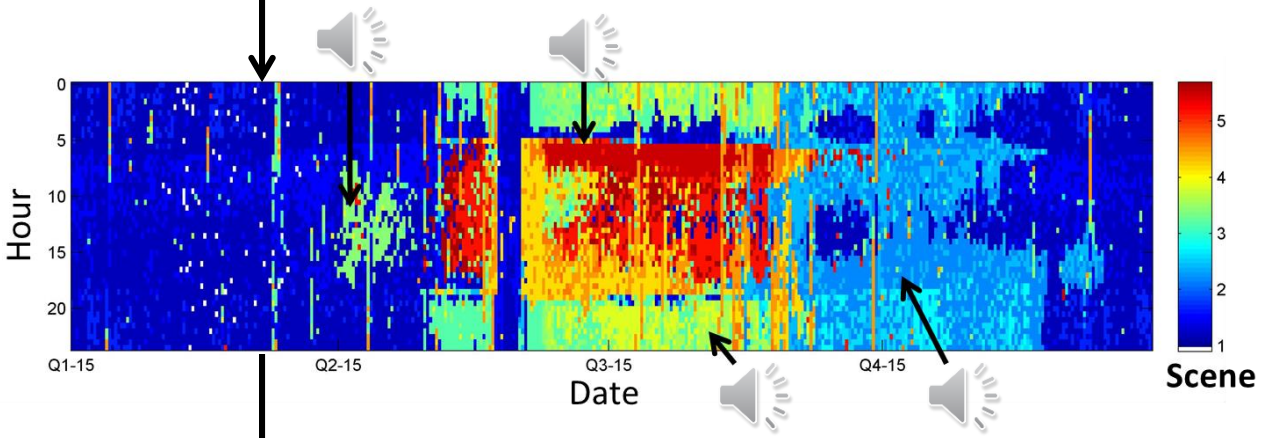
Data collected by Taiwan Forestry Research Institute

Analysis procedures

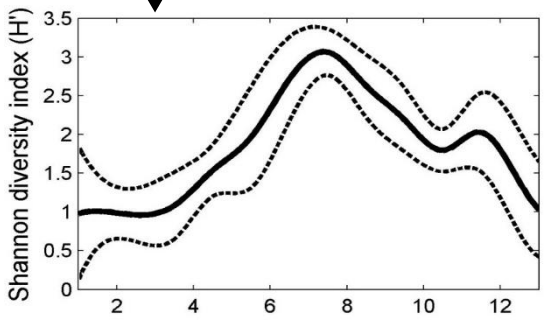
Long duration recordings



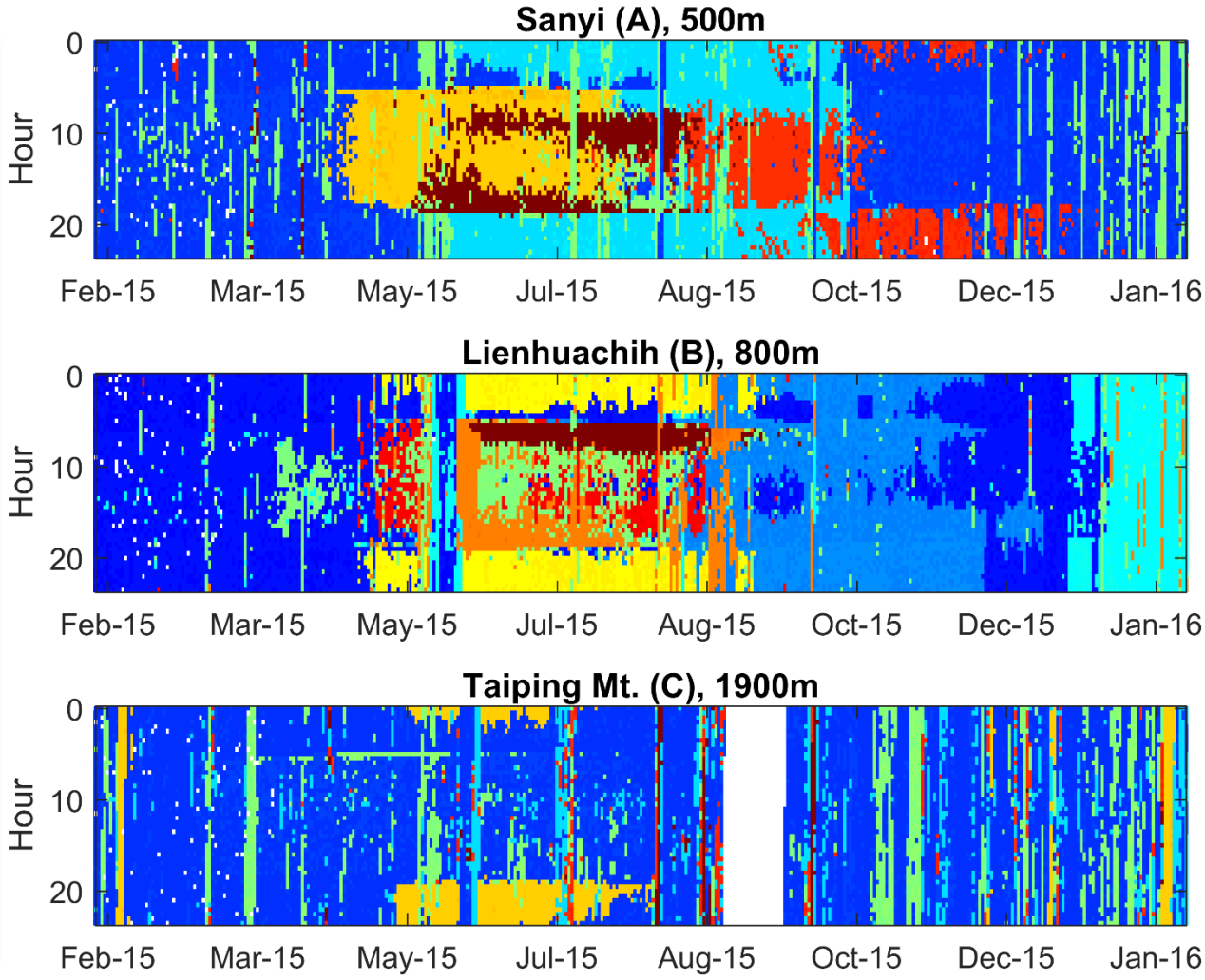
Unsupervised classification of soundscape scenes and events



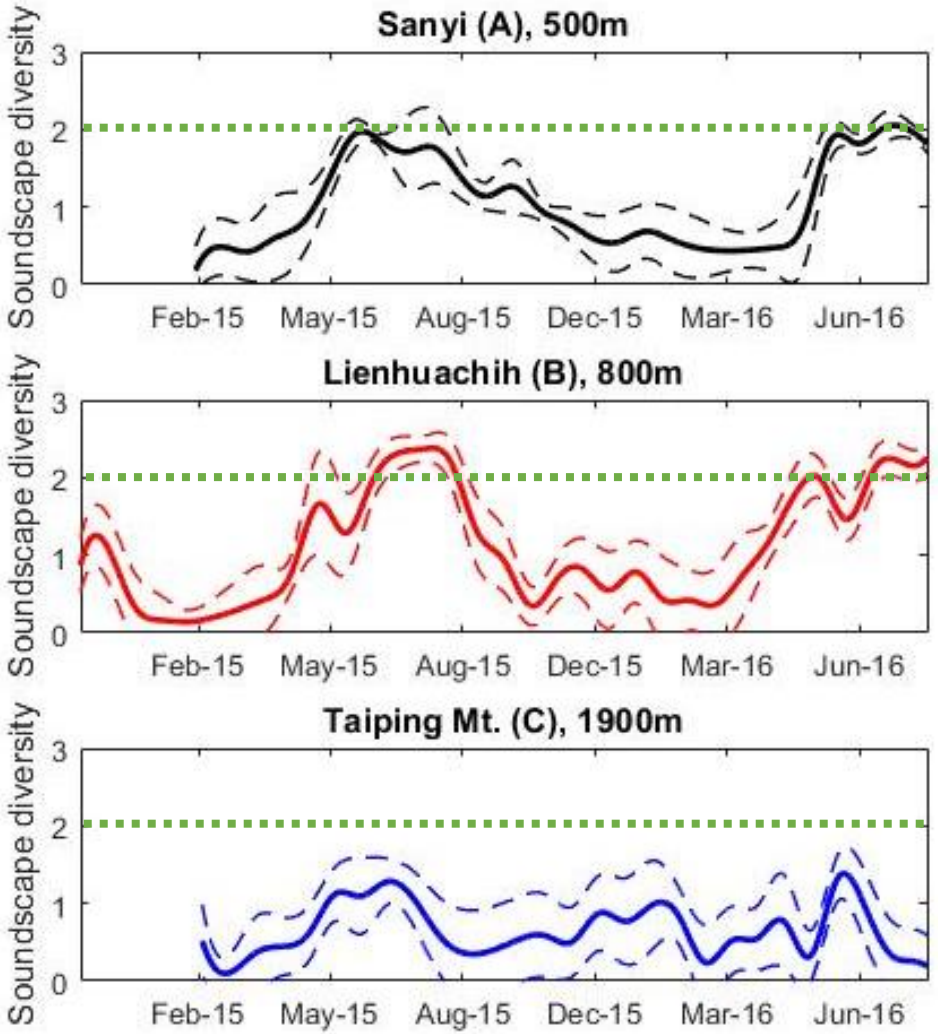
Measuring and modeling the change of diversity



Visualization of soundscape change



From soundscape to biodiversity



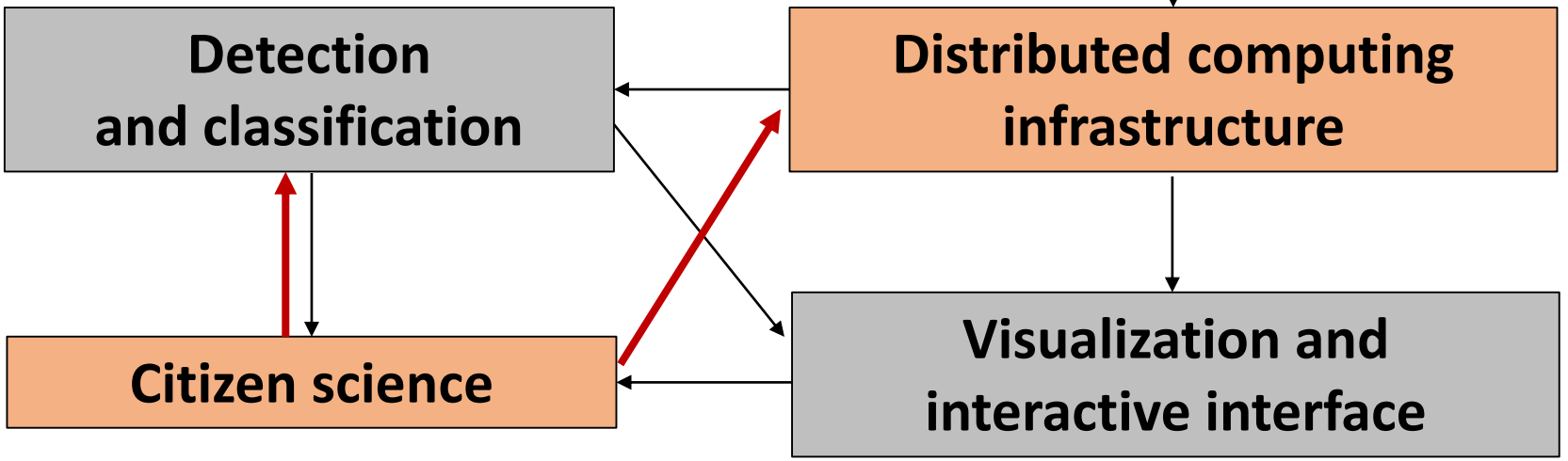
Machine learning facilitates acoustics-based biodiversity monitoring

- Supervised detection and classification
  - Search for specific targets
  - **Behavior and population size of keystone species**
- Unsupervised separation and classification
  - Labeling and evaluate the change of data structure
  - **Spatial and temporal change of biodiversity**
  - **Interactions between habitats, climates, human activities, and wildlife**
- **Require large scale computing resources**

Future platform

Open science:

- Evaluating classification results and labeling by publics
- Conducting ecoacoustics experienments through DCI



International collaborations on the remote sensing of biodiversity

- Sensor network of terrestrial and marine ecosystems
- Distributed data computing and services
  - Open data, open tools, open science

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Thanks for your attention!
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