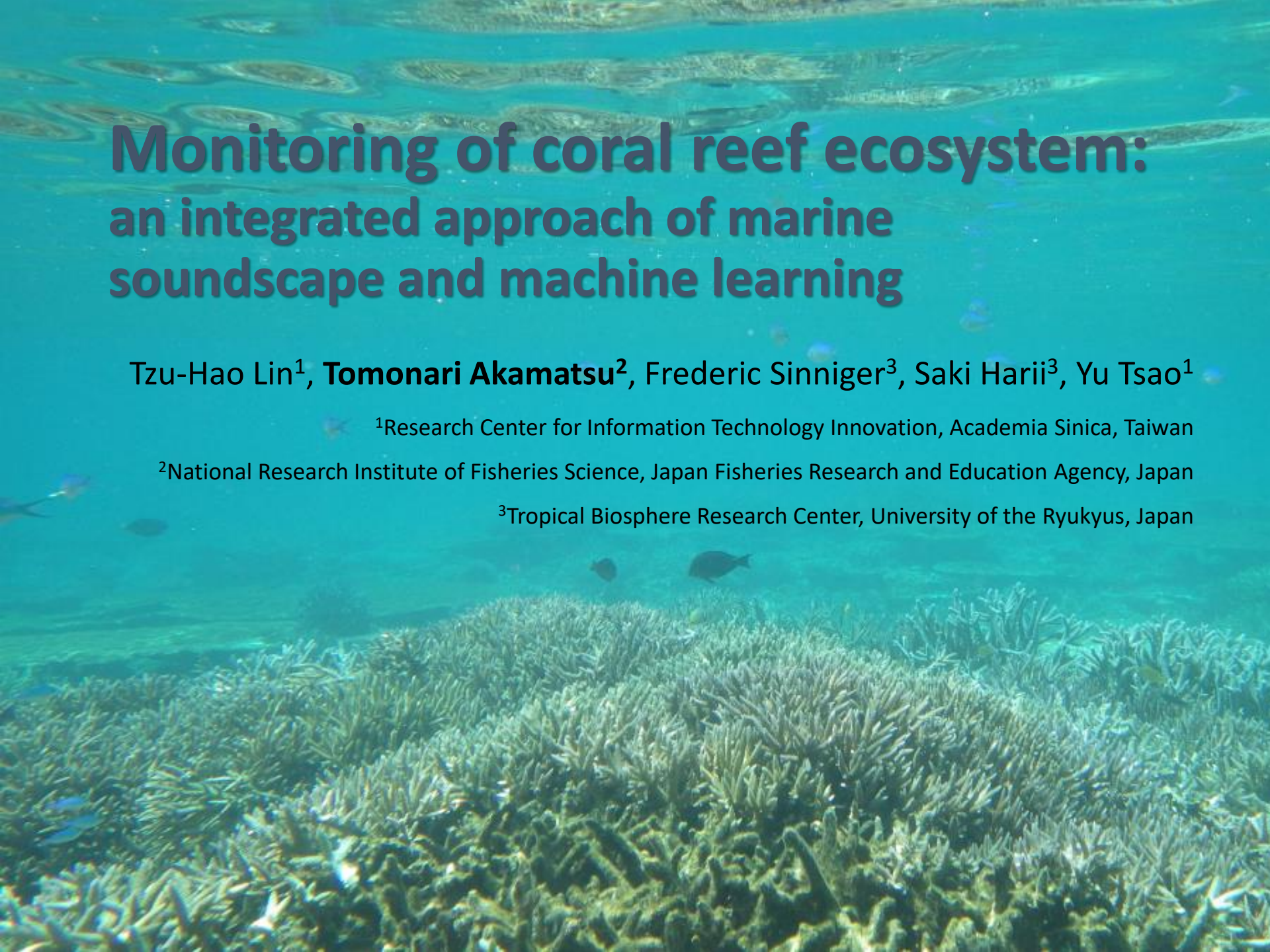
Monitoring of coral reef ecosystem:
an integrated approach of marine soundscape and machine learning

Tzu-Hao Lin[1], **Tomonari Akamatsu[2]**, Frederic Sinniger[3], Saki Harii[3], Yu Tsao[1]

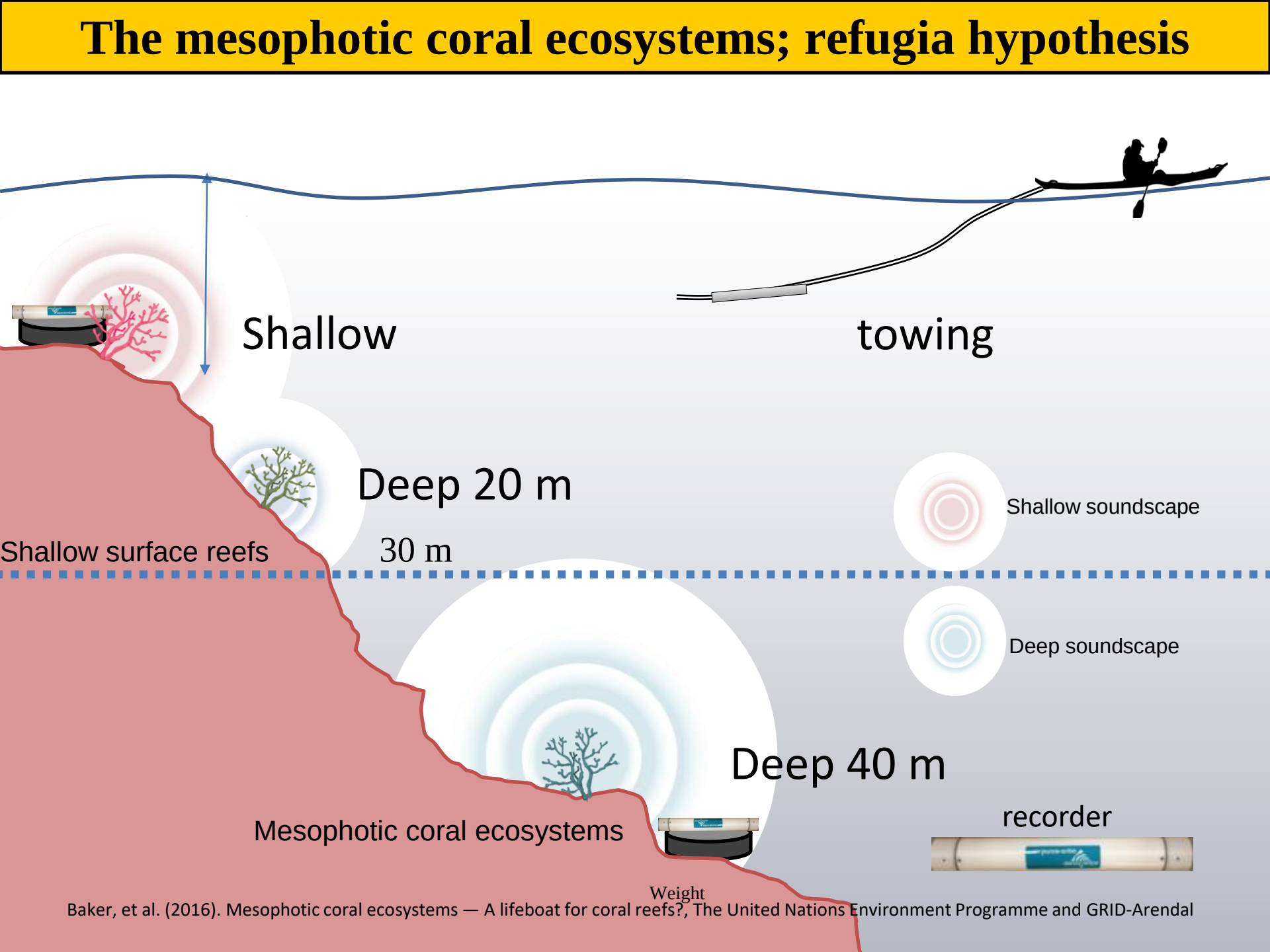
[1]Research Center for Information Technology Innovation, Academia Sinica, Taiwan

[2]National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency, Japan

[3]Tropical Biosphere Research Center, University of the Ryukyus, Japan



The mesophotic coral ecosystems; refugia hypothesis



Baker, et al. (2016). Mesophotic coral ecosystems — A lifeboat for coral reefs?, The United Nations Environment Programme and GRID-Arendal

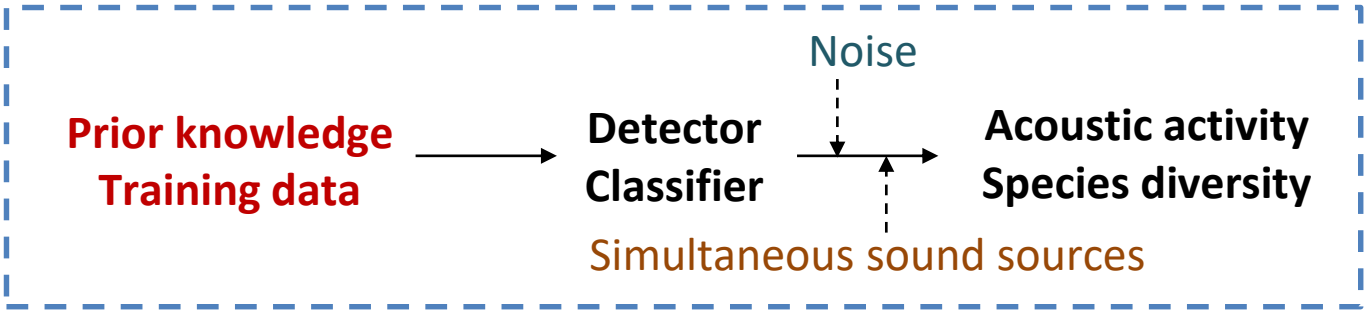
Monitoring of coral reef soundscape

Objectives

- Time spatial mapping of soundscape in coral reefs
- Testing refugia hypothesis

Challenges

- Quantify the soundscape and acoustic biodiversity
- Continuous recording at deep water



Soundscape analysis

- Supervised learning (training by labeled data) for spatial sound source mapping of range-wide recording.

- Unsupervised learning (learning structure from unlabeled data) for time sequential mapping of long-term recording

Target species for rule based detector

Damselfish

Abudefduf sexfasciatus
ロクセンスズメダイ

Chrysiptera cyanea
ルリスズメダイ

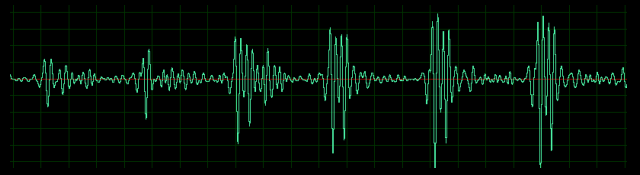
Dascyllus trimaculatus
ミツボシクロスズメダイ

http://www.aqua.stardust31.com

Frederic Sinniger

Platform

Survey lines

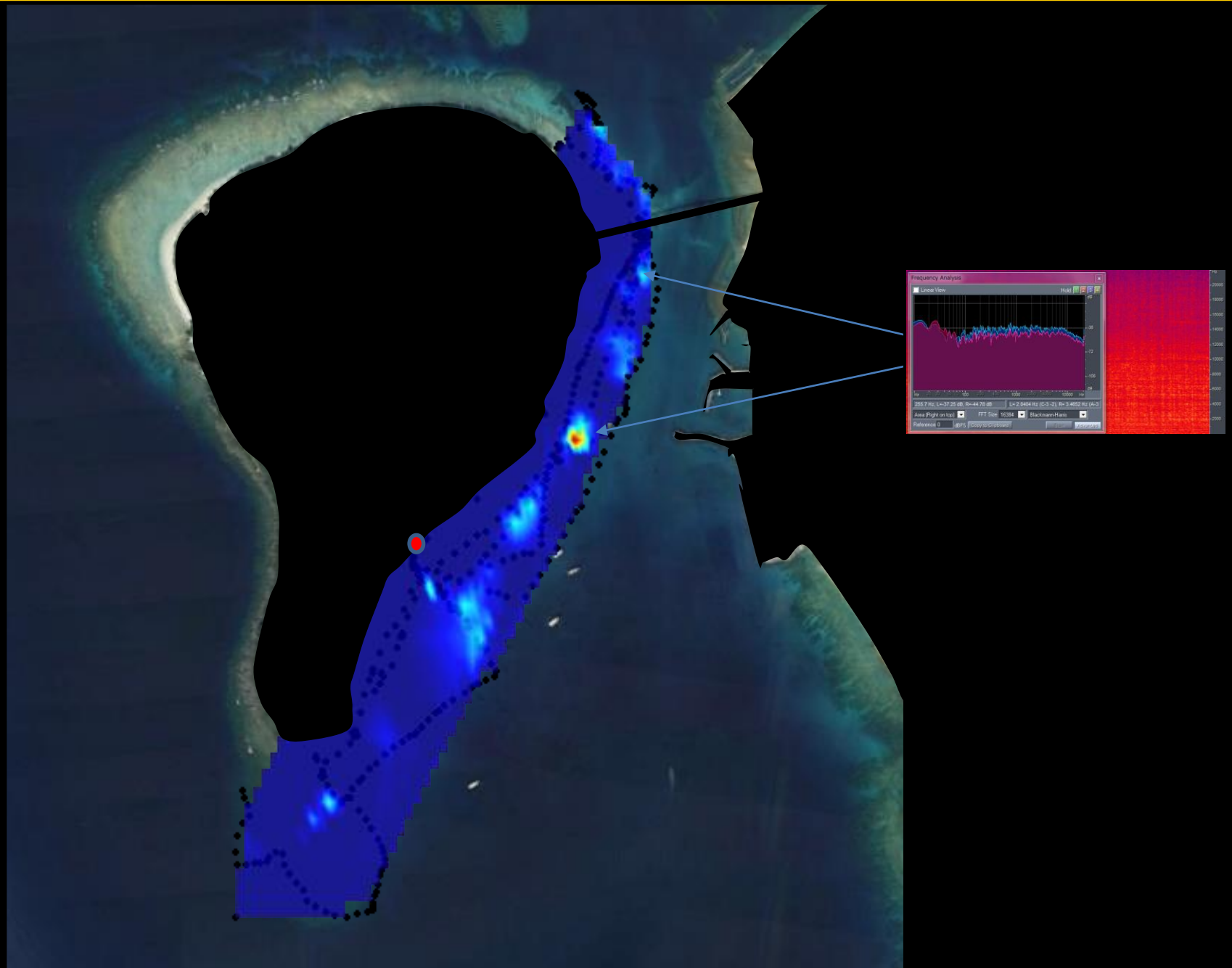


Rule-based detector

Frequency
Inter-pulse interval
Number of pulses in a train

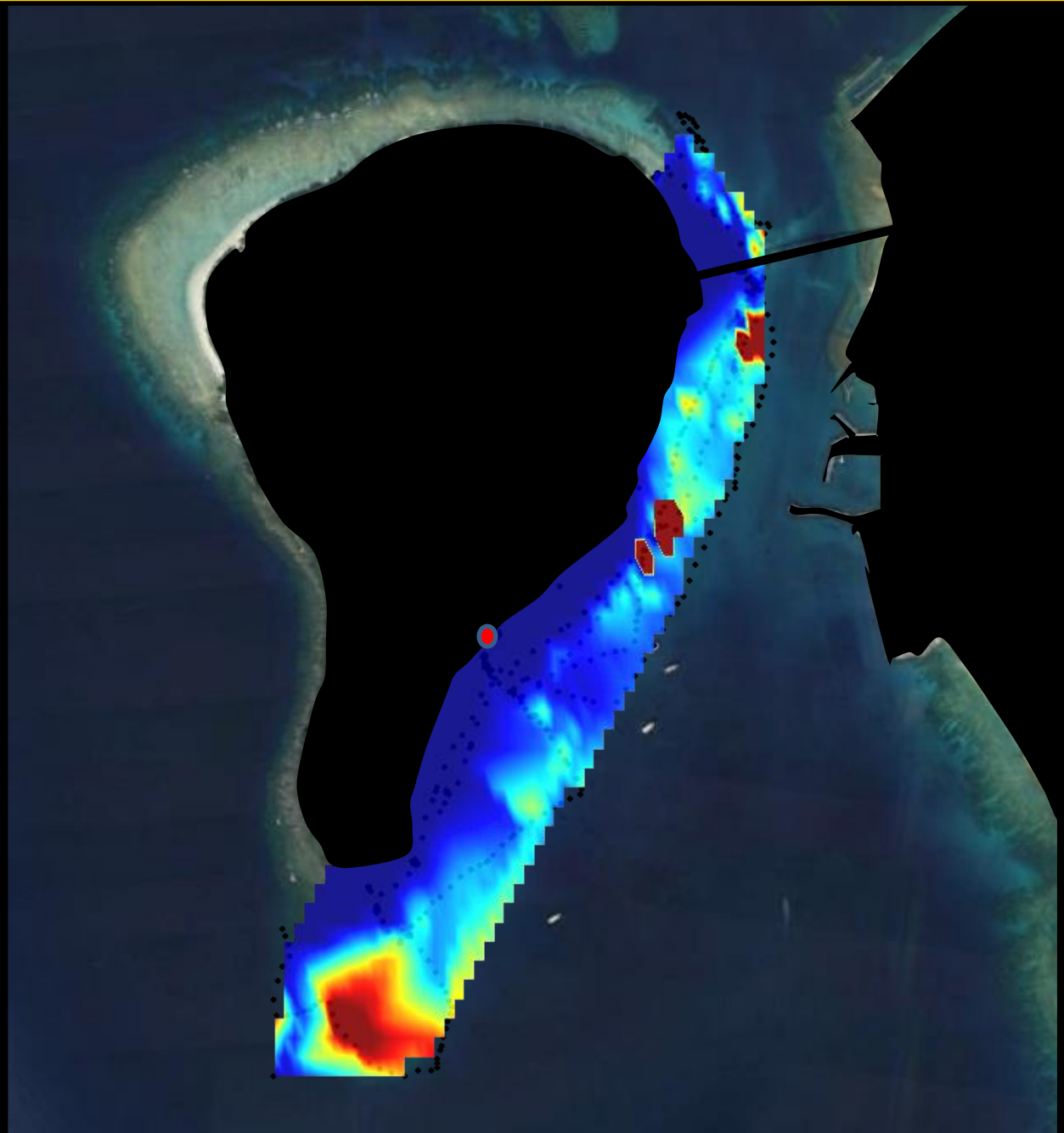
Av. & Std.

Acoustic distribution of damsel fish



Acoustic distribution of damsel fish

Acoustic distribution of crustaceans



Acoustic distribution of crustaceans

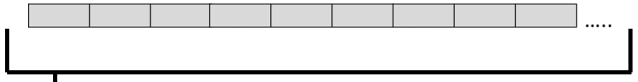
Soundscape analysis

- Supervised learning (training by labeled data) for spatial sound source mapping of range-wide recording.

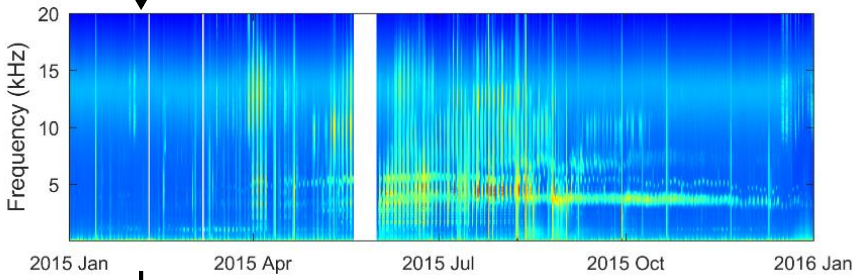
- Unsupervised learning (learning structure from unlabeled data) for time sequential mapping of long-term recording

Soundscape-based biodiversity monitoring

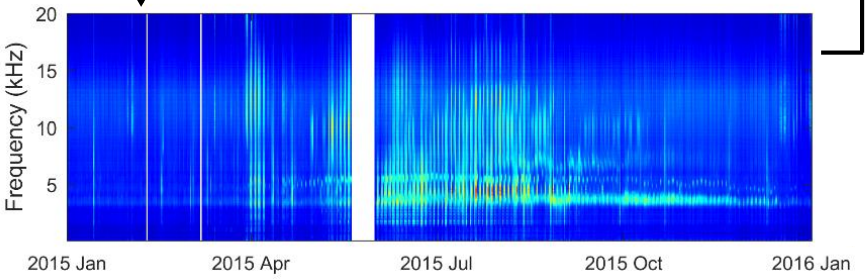
Long duration recordings



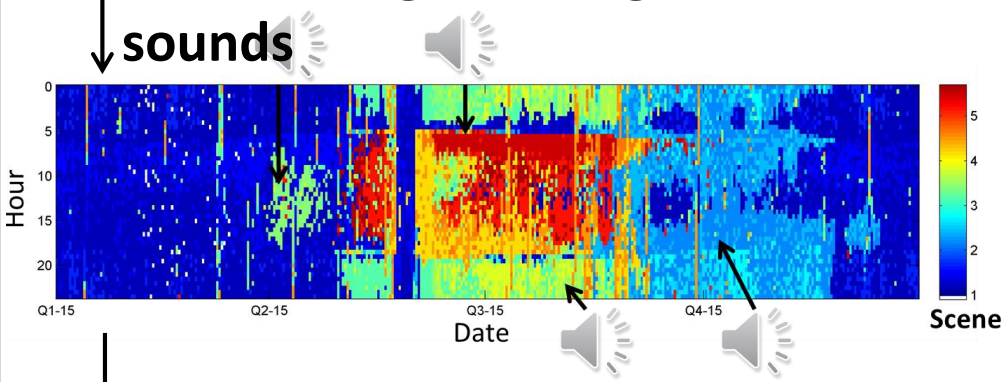
1. Feature extraction and visualization



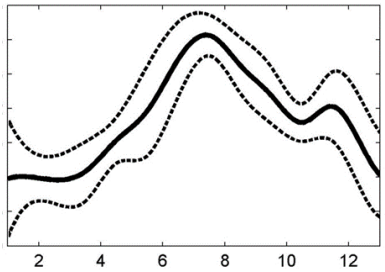
2. Enhancement of biological sounds



3. Clustering of biological sounds



4. Modeling of bioacoustic diversity

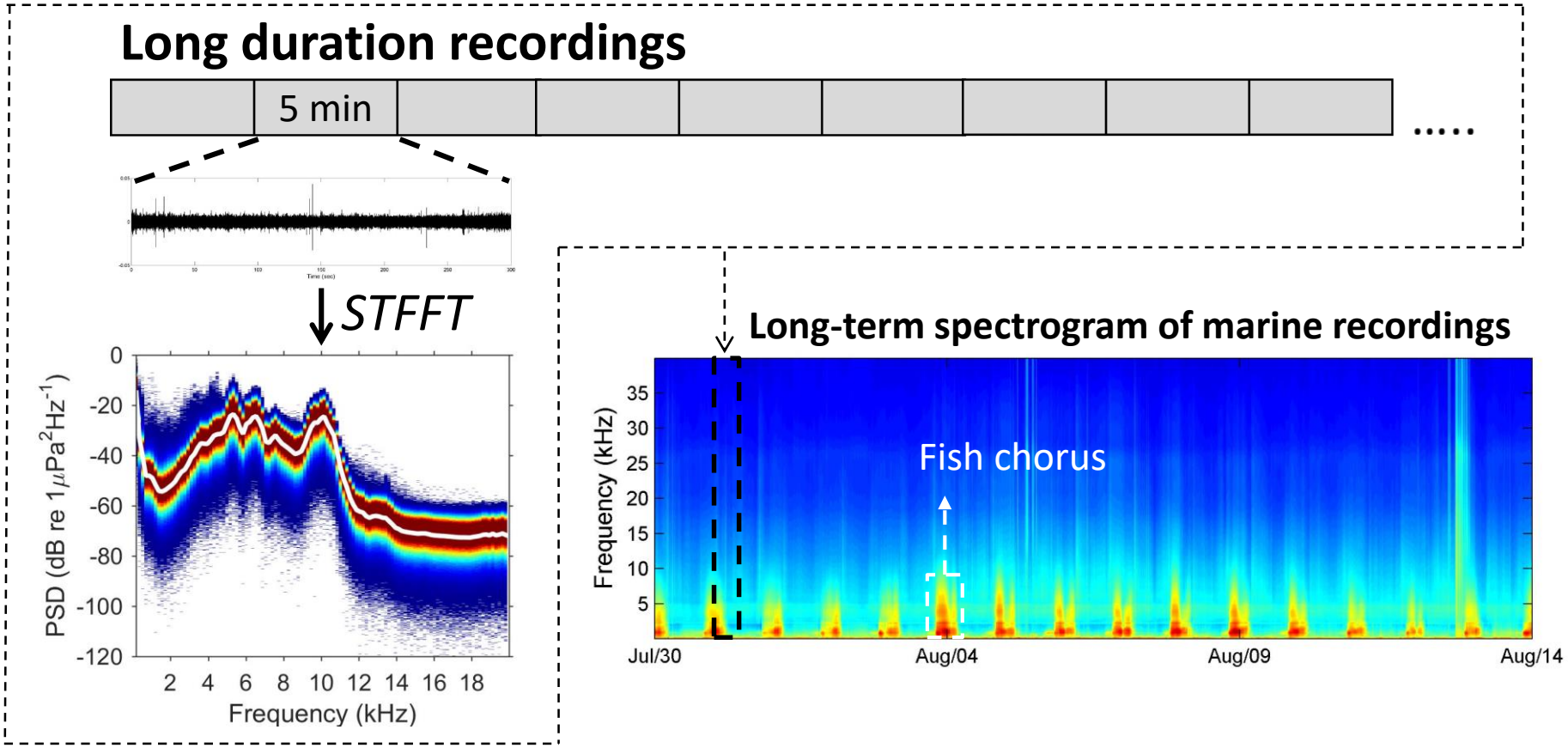


Lin et al. (2017) PNC 2017

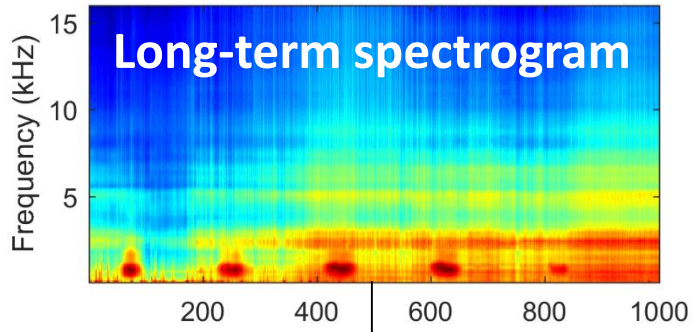
An example of terrestrial soundscape

1. Feature extraction and visualization

- Reduce the redundant information by measuring the median/mean power spectrum



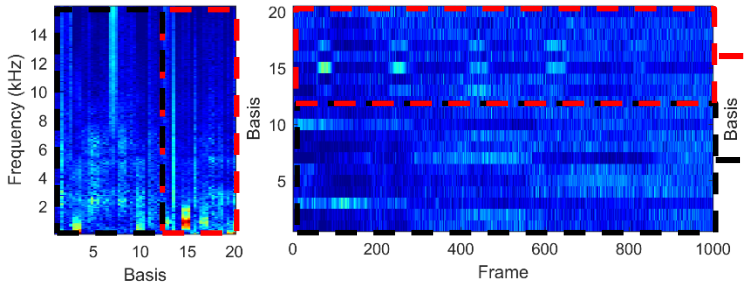
2. Enhancement of biological sounds using Periodicity-coded NMF



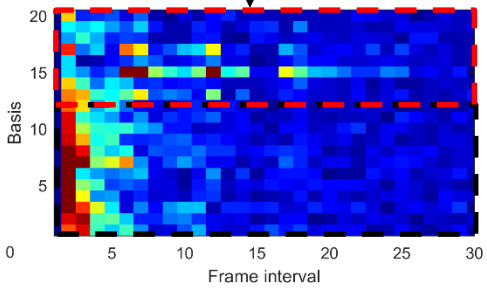
Lin et al. (2017) Scientific Reports

1. Source learning without prior information
2. Basis clustering based on periodicity
3. Spectrogram reconstruction

NMF

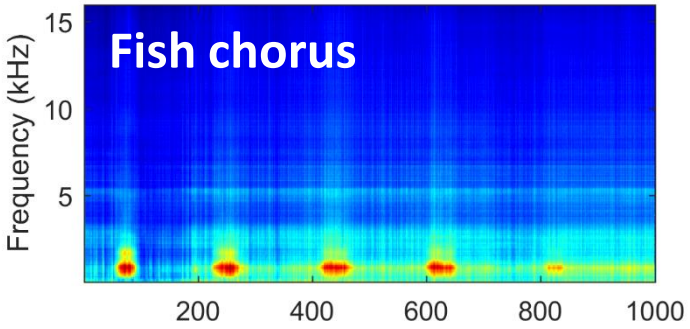


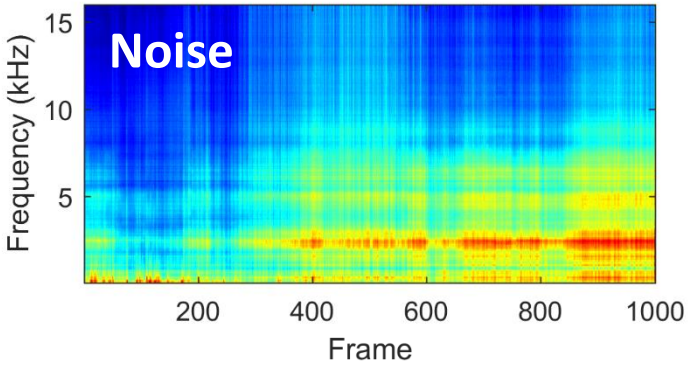
FFT



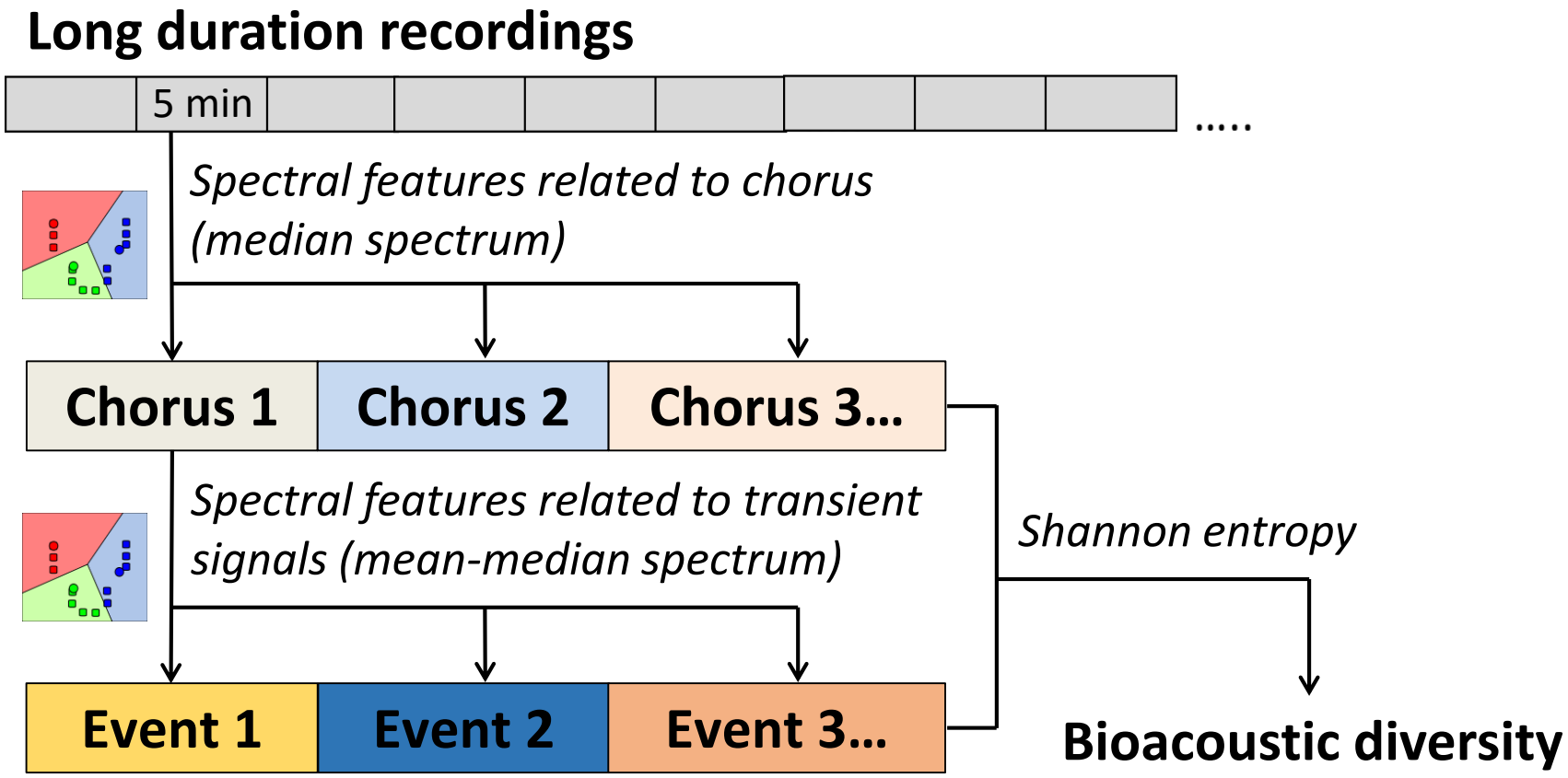
Clustering by sparse NMF

*Reconstruction (W*H)*



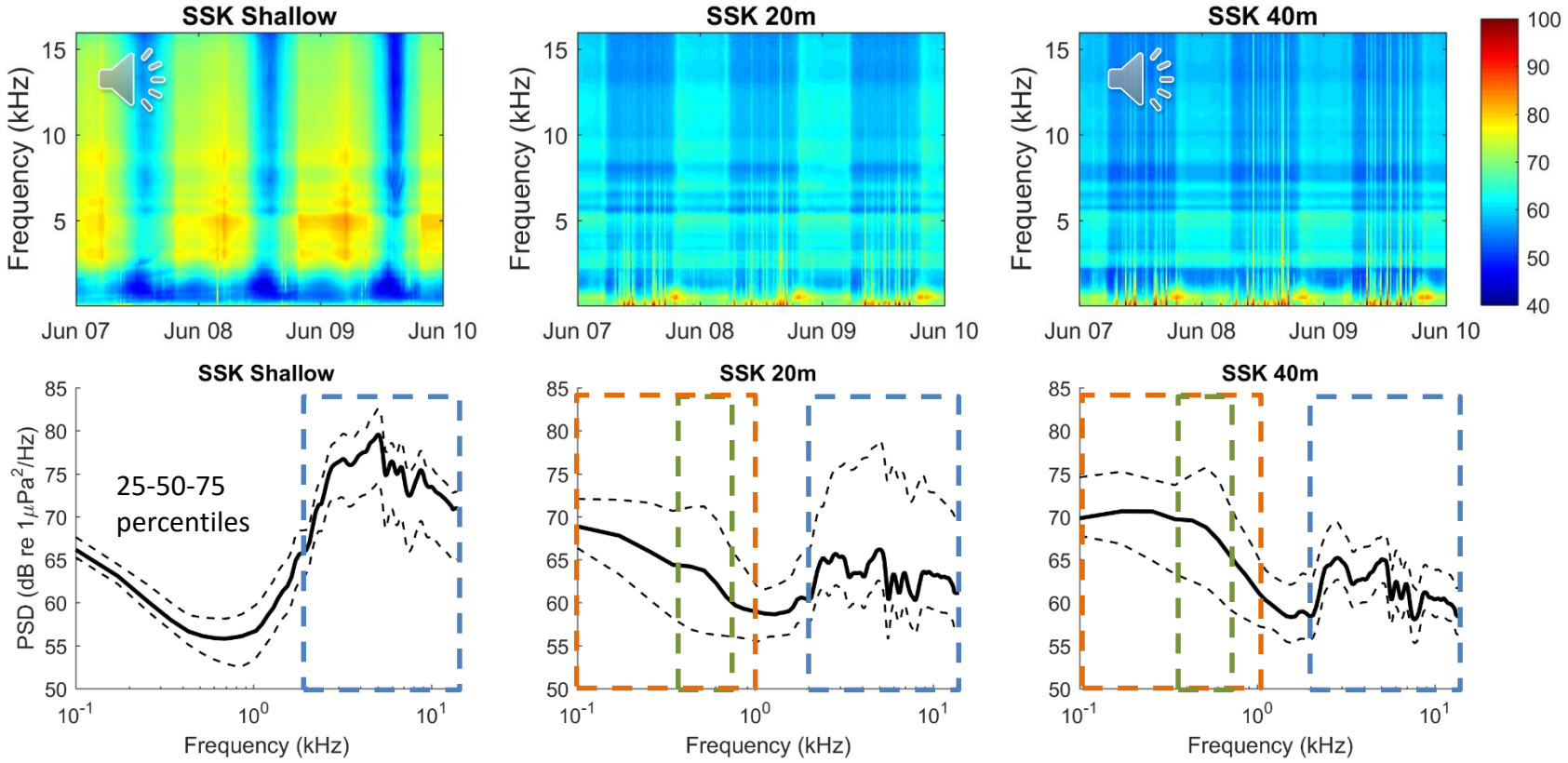


3. Clustering of biological sounds



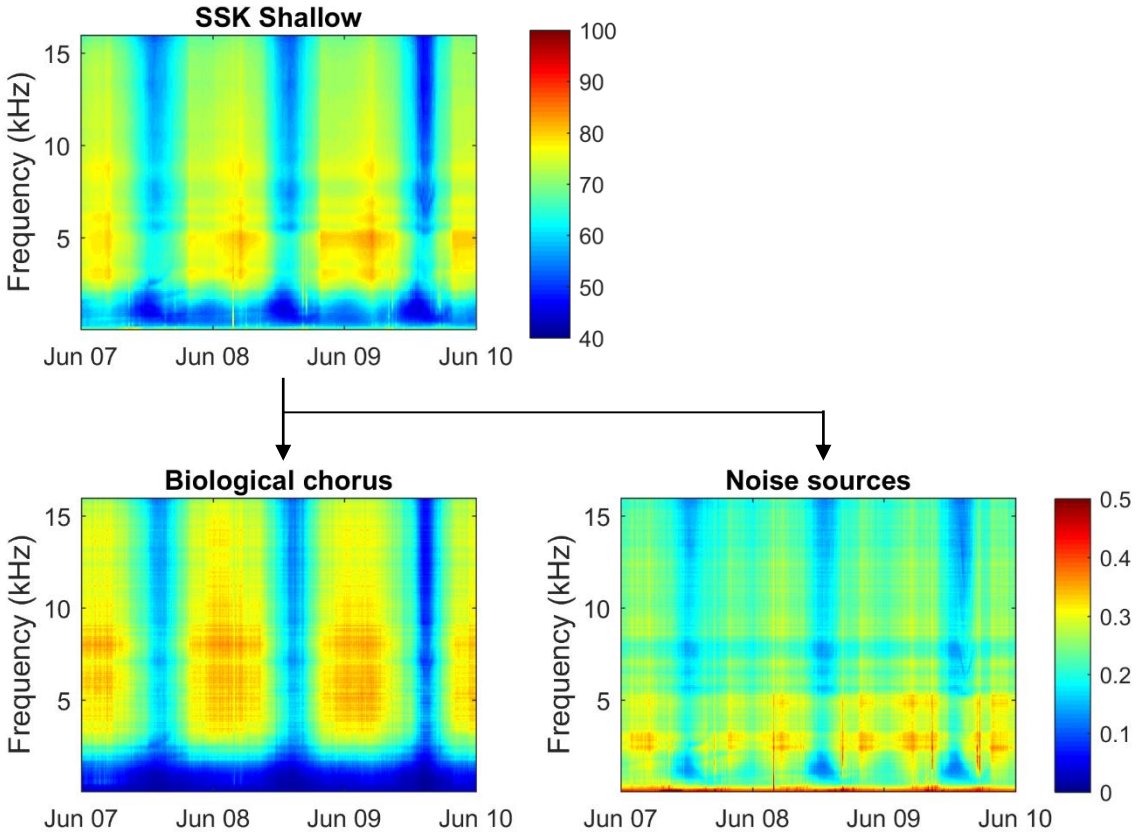
1. Feature extraction and visualization

- Various sound sources contributed the soundscape
  - **LTS-median:** snapping shrimps, fish chorus, shipping activities



Soundscape separation in shallow-water corals (1.5 m)

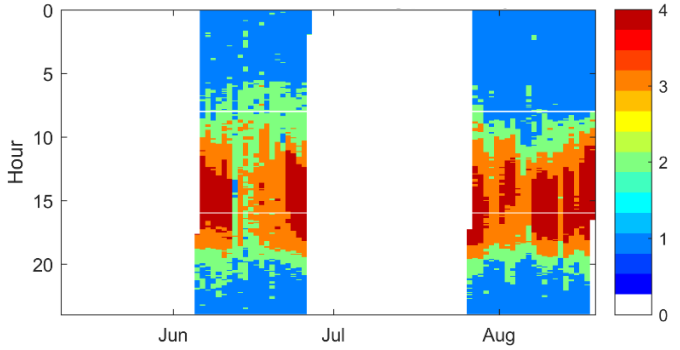
- **Biological chorus:** snapping shrimps
- **Noise:** environmental noise



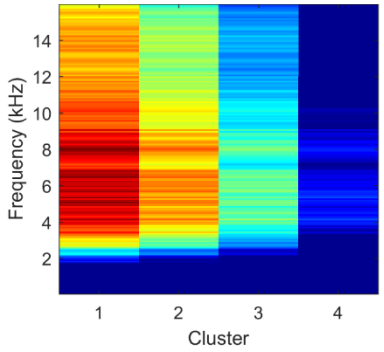
Soundscape clustering in shallow-water corals (1.5 m)

- **Biological chorus:** primary in nighttime
- **Environmental noise:** tide-related pattern

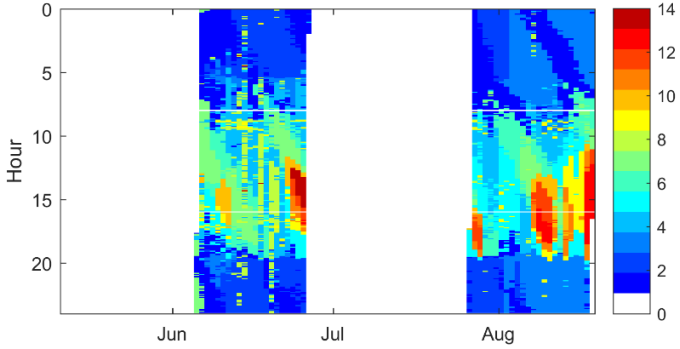
Temporal change of biological chorus



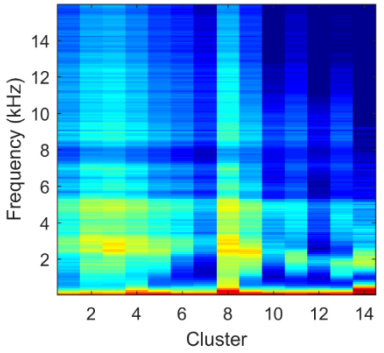
Spectral features of biological chorus



Temporal change of noise

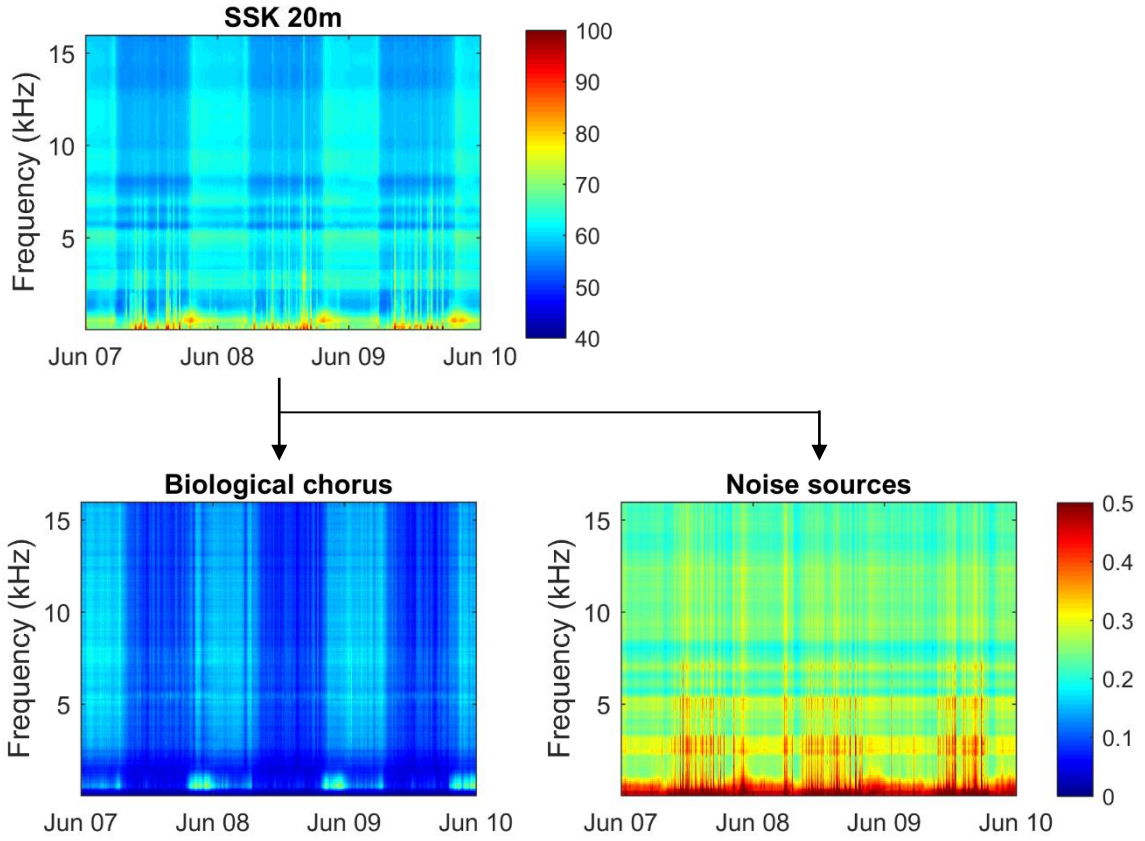


Spectral features of noise



Soundscape separation in deep-water corals (20 m)

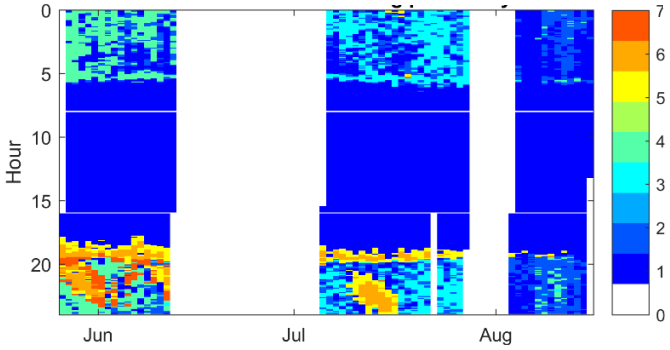
- **Biological chorus:** snapping shrimps & fish chorus
- **Noise:** environmental noise & shipping noise



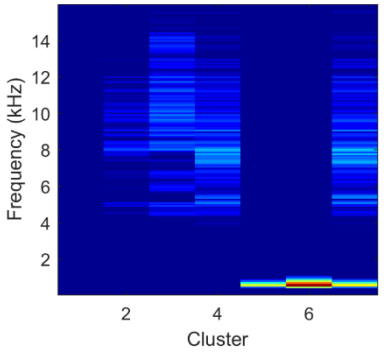
Soundscape clustering in deep-water corals (20 m)

- **Biological chorus:** primary in nighttime (snaps vs. fish chorus)
- **Environmental noise:** fixed shipping activities, weather noise

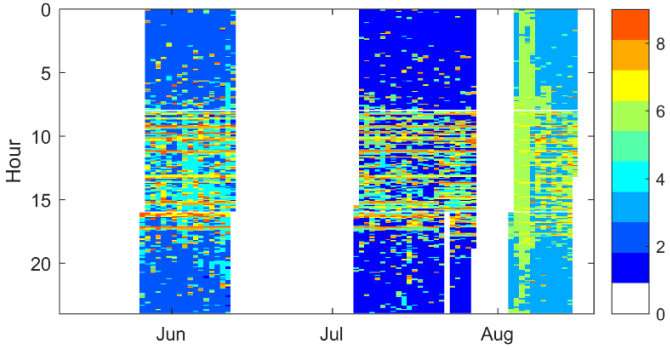
Temporal change of biological chorus



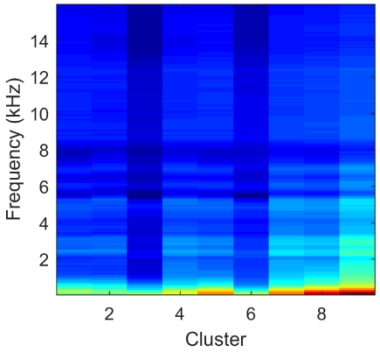
Spectral features of biological chorus



Temporal change of noise

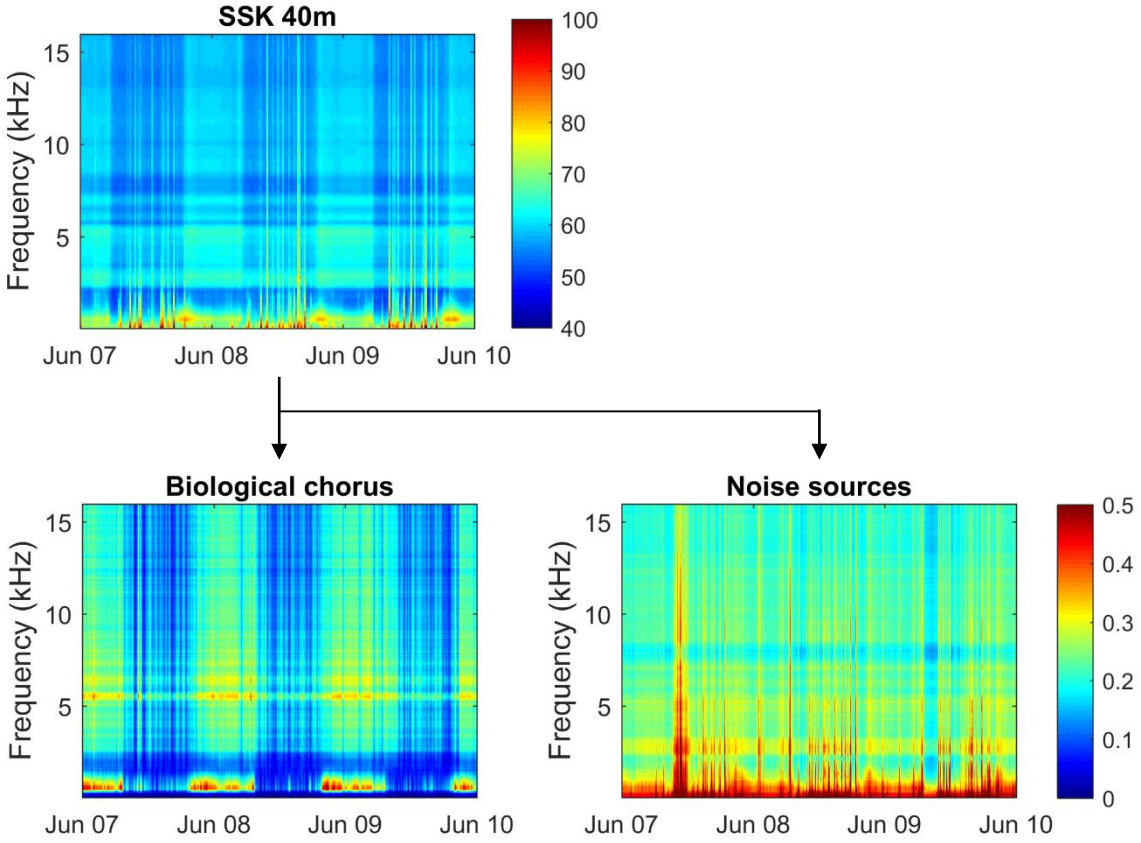


Spectral features of noise



Soundscape separation in mesophotic corals (40 m)

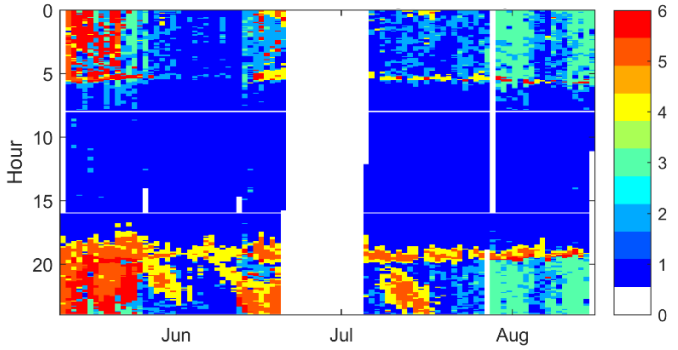
- **Biological chorus:** snapping shrimps & fish chorus (stronger)
- **Noise:** environmental noise & shipping noise



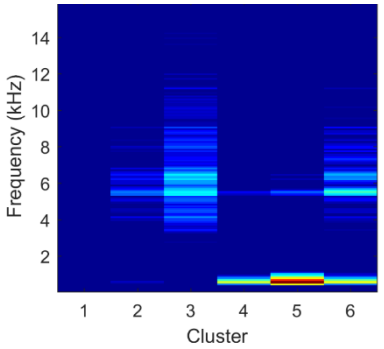
Soundscape clustering in mesophotic corals (40 m)

- **Biological chorus:** primary in nighttime (snaps vs. fish chorus)
- **Environmental noise:** fixed shipping activities, weather noise

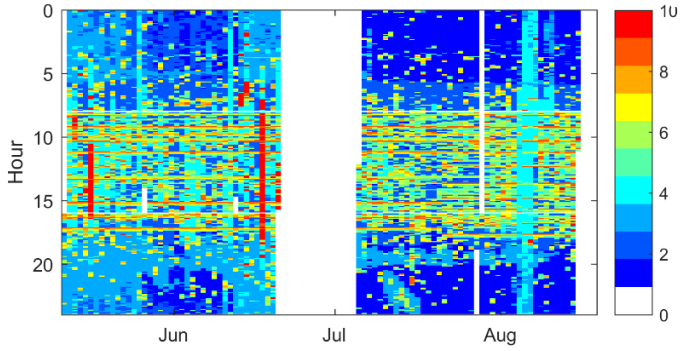
Temporal change of biological chorus



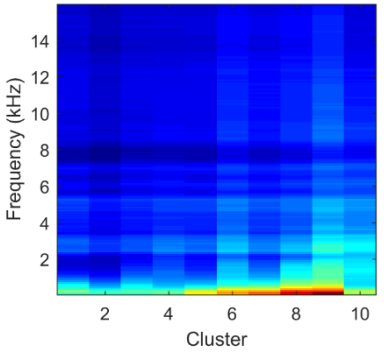
Spectral features of biological chorus



Temporal change of noise

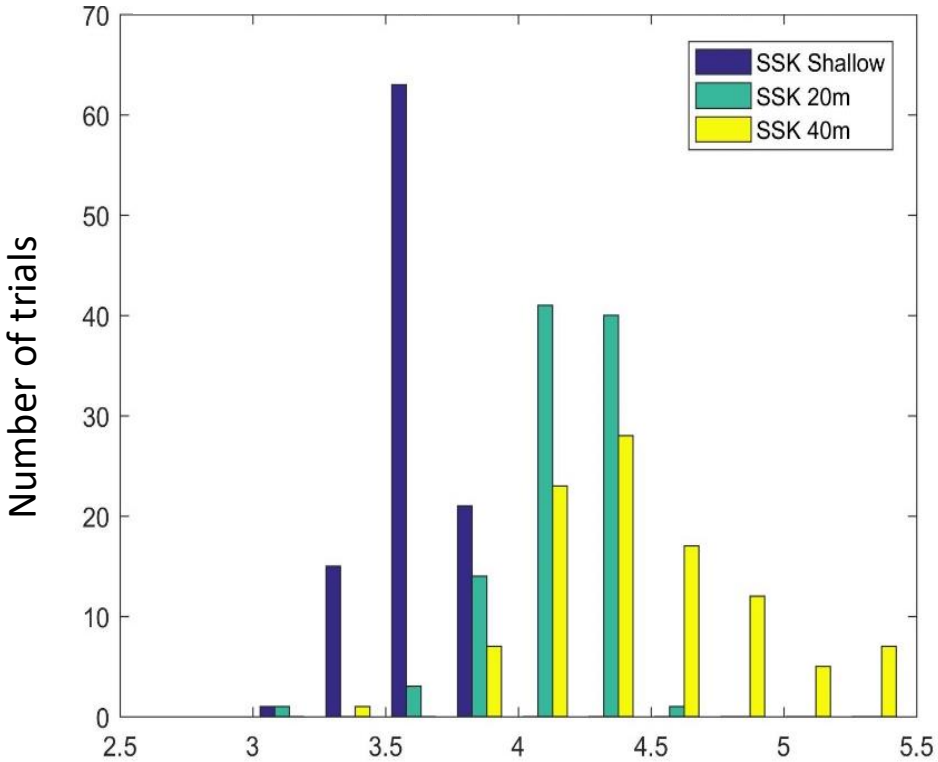


Spectral features of noise



Higher diversity in mesophotic corals

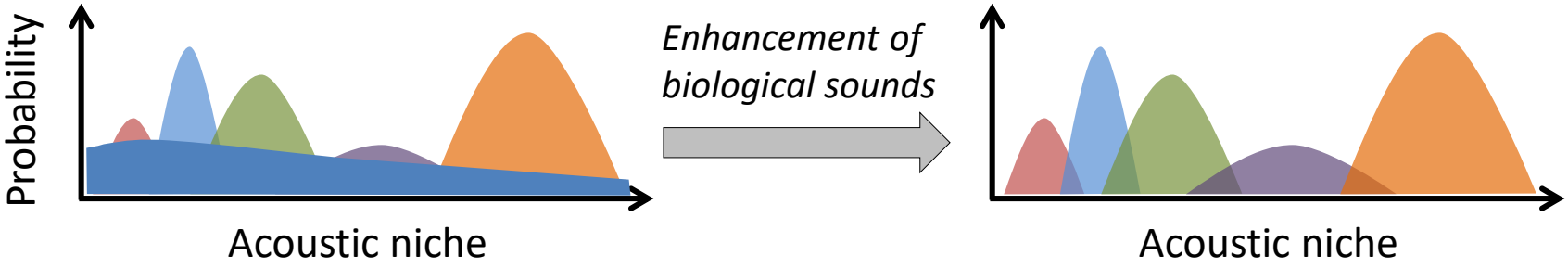
- Lots of unidentified fish sounds
- 100 trials were repeated due to the uncertainty of separation



$$H' = -\sum_{i=1}^{S} P_i \cdot \log_2 P_i$$

Machine learning-based soundscape information retrieval

- Improve the measurement of bioacoustic diversity by separating biological sounds and other noise sources



- **Caution: PC-NMF does not provide a closed-form solution**
  - Obtain a pre-train model by an experienced observer, then use the pre-trained model to analyze big acoustic data

Soundscape-based conservation management

- **Dynamics of bioacoustic diversity**
  - A potential indicator of coral reef biodiversity
  - Correlations with coral bleaching and recovery?
- **Change of anthropogenic noise**
  - Relative level of human activities (shipping, recreational activities…)
    - Noise induced physiological and behavioral impacts
    - Change of soundscape may affect the settlement of larvae

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Coral Larvae Move toward Reef Sounds

Mark J. A. Vermeij[1,2*], Kristen L. Marhaver[3], Chantal M. Huijbers[4], Ivan Nagelkerken[4], Stephen D. Simpson[5]