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

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The mesophotic coral ecosystems; refugia hypothesis

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

Prior knowledge
Training data

Detector
Classifier

Noise

Acoustic activity
Species diversity

Simultaneous sound sources
• 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
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
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

1. Feature extraction and visualization

2. Enhancement of biological sounds

3. Clustering of biological sounds

4. Modeling of bioacoustic diversity

Long duration recordings

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

Long duration recordings

5 min

$\text{STFFT}$

Long-term spectrogram of marine recordings

Fish chorus
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

Long-term spectrogram

Fish chorus

Noise

Clustering by sparse NMF

Reconstruction ($W^*H$)
3. Clustering of biological sounds

Long duration recordings

| 5 min | | | | | | | ...... |

Spectral features related to chorus (median spectrum)

Chorus 1  Chorus 2  Chorus 3...

Spectral features related to transient signals (mean-median spectrum)

Event 1  Event 2  Event 3...

Shannon entropy

Bioacoustic diversity
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
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
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
Higher diversity in mesophotic corals

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

![Graph showing Shannon entropy](image)

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

Coral Larvae Move toward Reef Sounds

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