Detailed Project Plan: Separating Bioacoustic Sources from Non-Biological Ocean Soundscape Signals Using Mono-Aural Blind Source Separation (BSS)

1. Problem Statement & Objectives

Goal: Develop a mono-aural BSS framework to isolate biological sounds (e.g., marine mammals, fish vocalizations) from non-biological sources (e.g., ship noise, wind, seismic activity) in underwater recordings.
Key Challenges:

- Overlapping frequency ranges of biological and anthropogenic noise [2][14].
- Lack of labeled training data for unsupervised separation [2][12].
- Non-linear mixing of sound sources in real-world marine environments [5].

2. Literature Review & Foundational Concepts

Key Papers & Techniques

1. **Blind Source Separation (BSS) for Ocean Acoustics**:
    - **Nonlinear BSS with Slow Feature Analysis**: Effective for nonlinearly mixed signals (e.g., ship noise + cetacean calls) [5].
    - **Unsupervised Machine Learning**: Used in Indian Ocean soundscapes to separate anthrophony (human-generated noise) from biophony [2].
    - **Data-Driven Audio Source Separation**: Leverages periodicity of biological sounds (e.g., fish choruses) for factorization [12][14].
2. **Bioacoustic Signal Features**:
    - Biological sounds often exhibit species-specific frequency modulations (e.g., humpback whale songs) [47].
    - Fourier analysis and deep learning improve recognition of non-voiced, aperiodic signals [47].

3. Datasets & Tools

Primary Datasets

1. **NOAA Passive Acoustic Data Archive** [6]:
    - **Link**: NOAA Passive Acoustic Data
    - **Description**: Contains raw audio files from global marine environments, including biophony (marine mammals), geophony (waves), and anthrophony (ships).
    - **Use Case**: Download SanctSound project data for annotated soundscapes.
2. **South Virgin Islands Marine Soundscape** [47]:
    - **Link**: Springer Chapter
    - **Description**: Real-time recordings with non-voiced bioacoustic events (e.g., fish clicks).
3. **Northeastern Taiwan Deep-Water Recordings** [14]:

- **Link**: PubMed Study
- **Description**: Long-duration recordings with cetacean vocalizations and abiotic noise.

Additional Resources

- **Watkins Marine Mammal Sound Database**: Freely accessible repository of marine mammal vocalizations [47].
- **SanctSound Data Portal**: Hourly decidecade band metrics for noise analysis [6].

4. Methodology

Step 1: Preprocessing

- **Signal Conditioning**:
  - Resample audio to standard rates (e.g., 48 kHz) and apply bandpass filtering (50 Hz – 24 kHz) to focus on biological signals [6].
  - Use tools like `librosa` (Python) for noise reduction.

Step 2: Feature Extraction

- **Time-Frequency Representation**:
  - Compute spectrograms using Short-Time Fourier Transform (STFT) to highlight frequency modulations [47].
  - Apply wavelet transforms for multi-resolution analysis of transient sounds (e.g., dolphin clicks) [14].

Step 3: Blind Source Separation

- **Algorithm Selection**:
  - **Non-Negative Matrix Factorization (NMF)**: Separate sources by factorizing spectrograms into additive components [12][14].
  - **Deep Clustering (DC)**: Train a neural network to map time-frequency bins to source clusters [7].
  - **Slow Feature Analysis (SFA)**: For nonlinearly mixed signals (e.g., ship noise + whale songs) [5].

Step 4: Post-Processing & Validation

- **Source Identification**:
  - Compare separated sources with annotated datasets (e.g., SanctSound vessel detections) [6].
- **Performance Metrics**:
  - Signal-to-Interference Ratio (SIR), Scale-Invariant Signal-to-Distortion Ratio (SI-SDR) [14].

5. Implementation Tools

- **Programming**: Python (librosa, scipy, tensorflow).
- **Audio Tools**: Audacity (visual inspection), Praat (bioacoustic analysis).
- **Data Packaging**: NOAA's PassivePacker for standardized metadata [6].

6. Validation & Ecological Analysis

- **Biodiversity Metrics**:
  - Calculate acoustic diversity indices (ADI, NDSI) to quantify biophony dominance [14].
- **Case Study**:
  - Apply the pipeline to the Indian Ocean Region dataset [2] to assess seasonal variations in bioacoustic activity.

7. Timeline

Phase	Duration	Tasks
1	2 weeks	Dataset acquisition & literature review
2	3 weeks	Preprocessing & feature extraction
3	4 weeks	BSS algorithm implementation
4	2 weeks	Validation & ecological interpretation

8. Expected Deliverables

1. A Python-based BSS pipeline for mono-aural ocean soundscapes.
2. A comparative analysis of NMF vs. SFA for bioacoustic separation.
3. A report linking anthropogenic noise reduction to marine biodiversity trends [2][14].

9. References

- [1] IEEE Xplore: Blind Source Separation of Nonlinear Ocean Signals [5].
- [2] Taylor & Francis: Marine Soundscape Source Separation [2].
- [3] Springer: Bio-Acoustic Recognition with Deep Learning [47].
- [5] NOAA Passive Acoustic Data Archive [6].
- [8] PubMed: Source Separation for Ecosystem Dynamics [14].