
Advanced Skill Certificate in Marine Mammal Bioacoustics (Puerto Rico)

Pinniped Vocalizations

Pinniped vocalizations encompass a diverse suite of acoustic signals produced by seals, sea lions, and walrus. Mastery of the terminology associated with these sounds is essential for researchers and students enrolled in the Advanced Skill Certificate in Marine Mammal Bioacoustics (Puerto Rico). The following explanation provides a comprehensive glossary of key terms, organized thematically to facilitate learning, application, and critical analysis. Each entry includes a definition, acoustic characteristics, biological context, examples of usage in research, and common challenges encountered when measuring or interpreting the signal.

Acoustic signal – any sound wave generated by a pinniped that can be detected by a recording system. Acoustic signals are described in terms of frequency (Hz), amplitude (dB), duration (seconds or milliseconds), and modulation patterns. In field studies, distinguishing between biological signals and ambient noise is a primary challenge.

Frequency – the number of pressure cycles per second in a sound wave, measured in hertz (Hz). Pinniped vocalizations range from low-frequency barks below 200 Hz to high-frequency clicks exceeding 150 kHz in some species. Frequency analysis is performed with spectrograms and Fourier transforms.

Amplitude – the strength or intensity of a sound, expressed in decibels (dB) relative to a reference pressure. Amplitude provides insight into the source level of a vocalization and its potential communication range. Calibration of hydrophones is required to obtain accurate amplitude measurements.

Duration – the temporal length of a vocal event, from onset to offset. Short-duration sounds such as clicks may last less than 1 ms, whereas long-duration calls like the female vocalization can exceed several seconds. Duration is a key parameter for classifying call types.

Fundamental frequency – the lowest frequency component of a periodic sound, often perceived as the pitch. In pinniped vocalizations, the fundamental frequency may be accompanied by harmonics that shape the timbre of the call.

Harmonic – an integer multiple of the fundamental frequency. Harmonics create the tonal quality of a call. For example, the “seal bark” often exhibits a series of harmonics that give it a rich, resonant character.

Modulation – systematic variations in frequency, amplitude, or both over the course of a vocalization. Modulation patterns, such as frequency sweeps or amplitude envelopes, are diagnostic for certain call types (e.g., The “squeak” of harbor seals).

Spectrogram – a visual representation of a sound’s frequency content over time, with intensity indicated by

color or shading. Spectrograms are indispensable for identifying call structures, measuring parameters, and differentiating overlapping sounds.

Source level – the acoustic power emitted by a vocalizing animal, expressed in dB re 1 μ Pa at 1 m. Source level estimation requires knowledge of the distance to the animal and the transmission loss in the environment.

Transmission loss – the reduction in sound intensity as it propagates through water, governed by spreading, absorption, and scattering. Accurate modeling of transmission loss is essential for estimating source levels and detection ranges.

Call type – a classification of vocalizations based on shared acoustic features and presumed function. Common pinniped call types include bark, click, growl, moan, whistle, and trill. Researchers often develop species-specific call catalogs.

Vocal repertoire – the complete set of call types an individual or population can produce. The size and complexity of a vocal repertoire may reflect social structure, ecological pressures, and learning ability.

Contextual cue – environmental or behavioral information that accompanies a vocalization, such as breeding season, territorial defense, or mother-pup interaction. Contextual cues aid in interpreting the functional significance of a sound.

Territorial call – a vocalization used to advertise and defend a spatial area, typically produced by dominant males. In many sea lion species, the bark serves as a territorial call, often accompanied by visual displays.

Mother-pup call – a vocal exchange between a female and her offspring, crucial for maintaining contact and coordinating care. The pup whine is a high-frequency, low-amplitude call that mother seals can locate even in noisy environments.

Breeding call – a vocalization associated with reproductive activities, often produced by males to attract females. The “male display bark” in northern elephant seals is a classic breeding call, characterized by high source levels and low frequencies.

Social call – a vocalization used in non-reproductive interactions, such as group cohesion, alarm signaling, or coordination of foraging. The “group trill” of California sea lions is an example of a social call that facilitates collective movement.

Alarm call – a short, high-frequency vocalization emitted in response to perceived threats. Alarm calls may trigger avoidance behaviors in conspecifics and can be distinguished by rapid onset and high duty cycle.

Vocal plasticity – the ability of an individual to modify its vocal output in response to environmental or social changes. Evidence of vocal plasticity in pinnipeds includes changes in call frequency due to ambient noise (the Lombard effect) and learned modifications in captive settings.

Lombard effect – the involuntary increase in vocal amplitude and sometimes frequency when an animal vocalizes in a noisy environment. Pinnipeds exhibit the Lombard effect; for example, harbor seals raise the amplitude of their clicks when background ship noise intensifies.

Click train – a sequence of rapid clicks emitted by some pinnipeds, particularly during foraging or echolocation. Click trains can consist of dozens of clicks spaced milliseconds apart, and their inter-click intervals provide information about prey detection strategies.

Echolocation click – a high-frequency click used to probe the environment and locate prey. While true echolocation is more characteristic of cetaceans, some otariids produce clicks that function similarly during underwater foraging.

Pulse – a single, brief burst of sound energy. Pulses can be components of more complex calls, such as the initial burst of a “growl” or the terminal segment of a “squeak”.

Growl – a low-frequency, broadband vocalization with a rough quality, often associated with aggression or dominance. Growls in walrus can reach source levels above 170 dB and may be accompanied by body posturing.

Moan – a long, modulated, low-frequency call with a characteristic “wailing” quality. Moans are commonly observed in male elephant seals during the breeding season and can convey individual identity.

Whistle – a narrow-band, tonal call with a relatively pure frequency. Whistles are prevalent in sea lion communication, especially in juvenile interactions. Their frequency stability makes them useful for individual identification.

Trill – a rapid series of frequency-modulated tones, often produced in social contexts. Trills in California sea lions have been shown to vary with group size and can be used to assess social dynamics.

Frequency sweep – a call in which the frequency rises or falls continuously over its duration. Frequency sweeps are typical of the “squeak” call of harbor seals and may encode information about the caller’s emotional state.

Amplitude envelope – the overall shape of a sound’s amplitude over time, describing how the signal rises, sustains, and decays. The envelope can be used to differentiate call types; for example, a rapid rise and fall characterizes a “click”, whereas a gradual rise and sustained plateau typify a “growl”.

Duty cycle – the proportion of time a vocalization is active within a given period. High duty cycles are found in continuous vocalizations like “trill” sequences, while low duty cycles characterize brief calls such as “clicks”.

Signal-to-noise ratio (SNR) – the ratio of the level of a vocalization to the level of background noise, expressed in decibels. High SNR is essential for reliable detection and classification; low SNR poses

challenges for automated recognizers.

Passive acoustic monitoring (PAM) – the deployment of hydrophones to record ambient sounds without actively emitting signals. PAM is the primary method for studying pinniped vocalizations in the wild, allowing long-term data collection with minimal disturbance.

Hydrophone – an underwater microphone that converts pressure variations into electrical signals. Hydrophone specifications (sensitivity, frequency response, self-noise) directly affect the quality of recorded pinniped vocalizations.

Array – a spatial configuration of multiple hydrophones used to localize sound sources and estimate direction of arrival. Arrays enable researchers to track moving animals and separate overlapping calls.

Localization – the process of determining the position of a vocalizing animal relative to the recording system. Techniques include time-difference-of-arrival (TDOA) analysis and beamforming. Accurate localization is critical for linking calls to specific individuals.

Beamforming – a signal-processing method that combines data from an array to enhance sounds from a particular direction while suppressing others. Beamforming can isolate a single vocalizing seal from a noisy colony.

Time-frequency analysis – analytical methods that examine how frequency content changes over time, such as short-time Fourier transform (STFT) or wavelet transform. These techniques reveal modulation patterns and are fundamental for call classification.

Machine learning classifier – an algorithm that automatically assigns recordings to predefined call categories based on extracted acoustic features. Common classifiers include support vector machines (SVM), random forests, and deep neural networks. Training data must be carefully curated to avoid bias.

Feature extraction – the process of quantifying aspects of a sound (e.g., Spectral centroid, bandwidth, zero-crossing rate) for input into machine-learning models. Effective feature extraction improves classification accuracy for complex vocal repertoires.

Spectral centroid – the “center of mass” of a sound’s spectrum, indicating where most energy is concentrated. Higher spectral centroids are typical of high-frequency calls like whistles.

Bandwidth – the range of frequencies over which a call contains significant energy. Broadband calls such as growls have wide bandwidths, whereas tonal calls have narrow bandwidths.

Zero-crossing rate – the rate at which the waveform crosses the zero amplitude axis. This metric is useful for distinguishing impulsive sounds (high zero-crossing rate) from tonal sounds (low zero-crossing rate).

Call duration variability – the degree to which the length of a call type varies across individuals or contexts.

High variability may indicate flexibility in communication or influence of environmental constraints.

Individual signature – unique acoustic features that allow discrimination of calls from different individuals. In many pinniped species, subtle differences in fundamental frequency, harmonic structure, or temporal pattern serve as signatures.

Vocal learning – the ability to acquire new vocal patterns through imitation or practice. While pinnipeds are not as vocal-learning proficient as dolphins, documented cases of call modification in captivity suggest some capacity for learning.

Playback experiment – a research method in which recorded vocalizations are broadcast to animals to assess behavioral responses. Playback experiments help infer the function of specific call types and test hypotheses about communication.

Acoustic masking – the phenomenon where background noise interferes with the detection of a vocalization. Anthropogenic noise (e.g., Ship traffic) can mask low-frequency pinniped calls, reducing effective communication range.

Anthropogenic noise – sound generated by human activities, such as vessel propulsion, sonar, and coastal construction. Its impact on pinniped vocal behavior includes altered call rates, frequency shifts, and increased stress.

Ambient noise – the natural background sound in the marine environment, including wind, waves, and biotic sources. Ambient noise levels fluctuate with weather and season, influencing detection probabilities.

Noise floor – the lowest level of background noise that a recording system can reliably detect. A low noise floor is essential for capturing faint calls, such as pup whines.

Signal attenuation – the reduction in sound intensity due to absorption, scattering, and spreading. Attenuation coefficients vary with frequency; high-frequency clicks attenuate more rapidly than low-frequency barks.

Absorption coefficient – a parameter quantifying the loss of acoustic energy per unit distance due to conversion into heat. In seawater, absorption increases with frequency, affecting the propagation of high-frequency calls.

Scattering – the redirection of sound energy by particles, bubbles, or organisms. Scattering can create reverberation that complicates call analysis, especially in shallow, turbulent waters.

Reverberation – the persistence of sound due to multiple reflections, producing a “tail” of energy after the original call. Reverberation can obscure temporal features of short calls and must be accounted for in signal processing.

Time of arrival (TOA) – the exact moment a sound reaches a hydrophone. Precise TOA measurements across an array enable accurate localization of vocalizing animals.

Inter-click interval (ICI) – the time between successive clicks in a click train. ICIs can reveal foraging strategies; shorter intervals may indicate close-range prey detection.

Call rate – the number of vocalizations emitted per unit time. Call rate can be modulated by social context, mating status, or disturbance level.

Vocal activity budget – the proportion of time an animal spends vocalizing versus being silent. Activity budgets help quantify the energetic costs of communication.

Energetic cost – the metabolic expenditure associated with producing vocalizations. Low-frequency, high-amplitude calls often have higher energetic costs than brief, high-frequency clicks.

Acoustic niche hypothesis – the proposition that sympatric species partition the acoustic spectrum to reduce interference. Pinniped communities may exhibit niche partitioning, with different species favoring distinct frequency bands.

Species-specific frequency band – a range of frequencies predominantly used by a particular species. For example, the “seal bark” of harbor seals typically occupies 200–600 Hz, whereas sea lion whistles are centered around 2–5 kHz.

Cross-species call overlap – situations where two or more species produce vocalizations in the same frequency range, potentially leading to acoustic interference. Researchers must consider overlap when designing PAM studies.

Call repertoire overlap – the degree to which call types are shared among different populations or subspecies. Comparative analyses of call repertoires can illuminate evolutionary relationships.

Temporal patterning – the arrangement of calls over time, including rhythmic sequences, alternating call types, or periodic bursts. Temporal patterning may encode additional information beyond individual call characteristics.

Rhythm – a regular, repeating temporal structure in vocal sequences. Some sea lion trills display rhythmic patterns that may facilitate group cohesion.

Phase – the position within a sound wave’s cycle at a given moment. Phase information can be exploited in beamforming and source localization algorithms.

Phase shift – a change in the phase of a wave relative to a reference point. In array processing, phase shifts between hydrophones are used to calculate direction of arrival.

Signal processing – the suite of computational techniques applied to raw acoustic data to extract

meaningful information. Common steps include filtering, denoising, segmentation, and feature extraction.

Bandpass filter – a filter that allows frequencies within a specified range to pass while attenuating frequencies outside that range. Researchers often apply a bandpass filter to isolate pinniped vocalizations from low-frequency ship noise and high-frequency equipment hiss.

High-pass filter – a filter that removes frequencies below a chosen cutoff, useful for eliminating low-frequency ambient noise when studying high-frequency clicks.

Low-pass filter – a filter that removes frequencies above a chosen cutoff, employed when focusing on low-frequency barks or moans.

Notch filter – a filter that suppresses a narrow band of frequencies, often used to remove power-line hum (e.G., 60 Hz) or specific tonal interference.

Signal clipping – distortion that occurs when a recording system is overloaded, causing the waveform to be truncated at the maximum amplitude. Clipping can obscure fine acoustic details and must be avoided through proper gain setting.

Dynamic range – the ratio between the largest and smallest detectable signal amplitudes. A wide dynamic range is essential for capturing both soft pup calls and loud adult barks within the same recording session.

Calibration tone – a known acoustic signal used to verify the performance of a hydrophone system. Calibration ensures that measured amplitudes are accurate and comparable across deployments.

Data logger – a device that records acoustic data, often with integrated GPS and environmental sensors. Data loggers enable simultaneous collection of sound, location, temperature, and depth information.

Metadata – descriptive information about a dataset, including time, location, sensor specifications, and observer notes. Comprehensive metadata is critical for reproducibility and data sharing.

Annotation – the process of labeling portions of an audio file with information such as call type, individual identity, and behavioral context. High-quality annotations are the foundation for training reliable machine-learning models.

Inter-annotator agreement – a measure of consistency among multiple annotators. Low agreement may indicate ambiguous call definitions and necessitates refinement of the annotation protocol.

Ground-truth data – verified observations that serve as reference for validating acoustic analyses. Ground-truth may involve visual confirmation of vocalizing animals, GPS tracking, or synchronized video recordings.

Synchronization – aligning multiple data streams (e.G., Audio, video, GPS) in time. Precise synchronization is required to correlate vocalizations with observed behaviors.

Acoustic tag – a device attached to an animal that records its vocal output and sometimes environmental parameters. Acoustic tags provide insight into individual vocal behavior and movement patterns.

Tag attachment – the method used to secure an acoustic tag to a pinniped, typically via suction cups or temporary adhesives. Tag attachment must minimize stress and be designed for rapid removal.

Tag detachment – the process by which a tag releases from the animal, either by design (e.G., Timed release) or after a set duration. Successful detachment ensures data retrieval without harming the animal.

Data retrieval – the act of recovering recorded acoustic data from a deployed system. Retrieval can be performed via physical recovery of the device or through remote telemetry.

Telemetry – the transmission of data from a remote sensor to a receiving station. Real-time telemetry enables monitoring of vocal activity without the need for physical retrieval.

Data archiving – the long-term storage of acoustic datasets in repositories that preserve data integrity and accessibility. Archiving supports future reanalysis and meta-studies.

Data sharing – the distribution of acoustic recordings and associated metadata to the scientific community. Open data sharing promotes collaboration and advances knowledge of pinniped communication.

Ethical considerations – the set of guidelines that govern the treatment of animals during acoustic research. Ethical protocols include minimizing disturbance, obtaining permits, and ensuring that tagging procedures do not impair normal behavior.

Permit requirements – legal authorizations required to conduct marine mammal research, often issued by national wildlife agencies. Researchers must comply with permit conditions, which may dictate allowable recording durations and equipment specifications.

Acoustic disturbance – the unintended impact of research equipment (e.G., Active sonar) on animal behavior. Studies must evaluate and mitigate acoustic disturbance to avoid biasing results.

Behavioral assay – an experimental design that quantifies changes in animal behavior in response to acoustic stimuli. Assays can measure metrics such as approach distance, vocal response latency, and movement speed.

Statistical power – the probability that a study will detect a true effect. Adequate sample sizes and robust experimental designs increase statistical power in vocalization research.

Null hypothesis – a default assumption that there is no effect or difference. In vocal studies, the null hypothesis might state that “ambient noise has no effect on call frequency”.

Alternative hypothesis – the statement that contradicts the null hypothesis, proposing a specific effect. Researchers test the alternative hypothesis using appropriate statistical tests.

p-value – the probability of observing data as extreme as those collected, assuming the null hypothesis is true. A p-value below a predetermined threshold (commonly 0.05) Leads to rejection of the null hypothesis.

Confidence interval – a range of values within which the true parameter is expected to lie with a given probability (e.G., 95 %). Confidence intervals provide insight into the precision of estimated acoustic parameters.

Effect size – a quantitative measure of the magnitude of a difference or relationship. Effect size complements p-values by indicating the practical significance of findings, such as the degree of frequency shift due to noise.

Multivariate analysis – statistical techniques that examine multiple dependent variables simultaneously, such as principal component analysis (PCA) applied to a suite of acoustic features.

Cluster analysis – a method for grouping similar calls based on feature similarity, often used to discover natural call categories without prior labeling.

Discriminant function analysis (DFA) – a classification technique that determines which variables best separate predefined groups, useful for testing whether call types differ significantly.

Cross-validation – a technique for assessing the performance of a predictive model by partitioning data into training and testing subsets. Cross-validation prevents overfitting in machine-learning classifiers.

Overfitting – a modeling error where a classifier captures noise rather than underlying patterns, resulting in poor generalization to new data. Regularization and proper validation mitigate overfitting.

Under-sampling – reducing the number of instances in a majority class to balance class distribution. Under-sampling may be employed when certain call types dominate the dataset.

Over-sampling – increasing the number of instances in a minority class, often through synthetic generation (e.G., SMOTE), to address class imbalance.

Signal-to-reverberation ratio (SRR) – the ratio of direct signal energy to reverberant energy. Low SRR complicates extraction of precise call parameters, especially in shallow, reflective environments.

De-reverberation – processing techniques aimed at reducing reverberant components, thereby enhancing the clarity of the direct signal.

Noise reduction – algorithms that suppress background noise while preserving the target signal. Common methods include spectral subtraction and Wiener filtering.

Time-frequency masking – a technique that isolates regions of a spectrogram associated with the target signal, improving detection in noisy conditions.

Acoustic index – a quantitative metric summarizing acoustic activity, such as the Acoustic Complexity Index (ACI) or Bioacoustic Index (BI). Indices can be used to monitor temporal trends in vocal activity.

Acoustic diversity – a measure of the variety of call types present in a dataset, often calculated using Shannon or Simpson diversity indices adapted for acoustic data.

Temporal resolution – the smallest time interval that can be distinguished in a recording, determined by sampling rate. High temporal resolution is needed to resolve rapid click sequences.

Sampling rate – the number of audio samples captured per second, expressed in Hz. To accurately record high-frequency clicks, sampling rates of at least 500 kHz are recommended.

Nyquist frequency – half of the sampling rate, representing the maximum frequency that can be accurately represented. Frequencies above the Nyquist limit alias into lower frequencies, corrupting the signal.

Aliasing – distortion that occurs when a signal contains frequencies above the Nyquist frequency, leading to erroneous spectral content. Proper anti-aliasing filters prevent this problem.

Dynamic range compression – a signal-processing technique that reduces the amplitude difference between loud and soft sounds, facilitating listening and analysis. Compression must be applied cautiously to avoid obscuring biologically relevant amplitude variations.

Automatic call detector – a software tool that scans recordings to identify candidate vocalizations based on predefined acoustic criteria (e.G., Frequency band, amplitude threshold). Detectors accelerate data processing but may produce false positives.

False positive – an event incorrectly identified as a vocalization when it is actually noise or an artifact. Reducing false positives improves the efficiency of downstream analyses.

False negative – a missed detection where a genuine vocalization is not identified by the detector. High false-negative rates can bias estimates of call rates and activity patterns.

Receiver operating characteristic (ROC) curve – a plot that illustrates the trade-off between true-positive rate and false-positive rate for a detector. The area under the ROC curve (AUC) quantifies detector performance.

Threshold setting – the selection of a detection level above which a signal is considered a call. Thresholds must balance sensitivity and specificity, often determined empirically for each dataset.

Training dataset – a collection of annotated calls used to teach a machine-learning model how to recognize patterns. The quality and representativeness of the training dataset directly affect model accuracy.

Testing dataset – a separate set of annotated calls used to evaluate the performance of a trained model. The testing dataset must be independent to provide an unbiased assessment.

Generalization – the ability of a model to perform well on unseen data. Generalization is essential for applying a classifier trained on one colony to another geographic region.

Acoustic behavior – the suite of actions associated with sound production, including posture, breathing, and movement. Understanding acoustic behavior provides context for interpreting vocalizations.

Breathing pattern – the rhythm of inhalations and exhalations associated with vocal production. In many pinnipeds, vocalizations occur during exhalation, influencing the timing and intensity of sounds.

Postural display – a body posture that accompanies a vocalization, such as the “head-up” stance during a bark. Postural cues can reinforce the communicative intent of a call.

Territorial marking – the combination of vocal and visual signals used to delineate a defended area. In sea lions, territorial marking often includes a series of barks accompanied by flank displays.

Social hierarchy – the rank order of individuals within a group, often reflected in vocal dominance. Dominant males may produce louder, lower-frequency barks, while subordinates emit higher-frequency calls.

Acoustic signaling network – the pattern of information flow among individuals mediated by sound. Network analysis can reveal central individuals (e.G., “Vocal hubs”) that play key roles in group cohesion.

Call sequencing – the order in which different call types are emitted. Certain sequences, such as a bark followed by a trill, may have specific communicative meanings.

Contextual inference – the process of deducing the likely function of a call based on surrounding environmental and behavioral cues. Contextual inference is a cornerstone of ethological interpretation.

Cross-modal integration – the combination of acoustic information with other sensory modalities (visual, tactile). For example, a seal may integrate a mother’s bark with visual cues of the pup’s location.

Acoustic adaptation hypothesis – the idea that vocal signals evolve to optimize transmission in a given acoustic environment. Pinniped calls may shift frequency or timing to mitigate the effects of surface noise or water depth.

Bioacoustic monitoring protocol – a standardized set of procedures for deploying equipment, collecting data, and processing recordings. Protocols ensure consistency across studies and facilitate comparative analyses.

Seasonal variation – changes in vocal activity patterns that correspond to seasonal cycles, such as increased breeding calls in winter. Seasonal variation must be accounted for when interpreting long-term datasets.

Diurnal variation – fluctuations in vocal behavior over the course of a day, often linked to foraging cycles or predator activity. Recording schedules should capture both day and night periods to avoid bias.

Geographic variation – differences in call characteristics among populations separated by distance. Geographic variation can reflect genetic divergence, environmental adaptation, or cultural transmission.

Population monitoring – the use of acoustic data to estimate abundance, distribution, and trends of pinniped populations. Call rate, detection probability, and occupancy models are common tools.

Acoustic abundance index – an estimate of population size derived from the number of detected vocalizations per unit effort. Calibration against visual counts improves the reliability of abundance indices.

Occupancy modeling – a statistical framework that estimates the probability of a species being present at a site, accounting for imperfect detection. Acoustic occupancy models incorporate detection covariates such as noise level and sensor range.

Detection probability – the likelihood that a vocalization present in the environment will be recorded and correctly identified. Detection probability varies with source level, distance, and environmental conditions.

Effective detection range – the maximum distance at which a vocalization can be reliably detected, given ambient noise and equipment sensitivity. Effective range calculations inform array design and deployment density.

Survey design – the planning of spatial and temporal coverage for acoustic data collection. Survey design considerations include transect spacing, deployment duration, and replication.

Replication – the repetition of measurements across time or space to assess variability. Adequate replication enhances the robustness of conclusions about vocal behavior.

Data quality assurance – procedures that verify the integrity and reliability of recorded data, including checks for sensor malfunction, timing errors, and data corruption.

Data preprocessing – the initial steps of cleaning and preparing raw recordings for analysis, such as removing corrupted segments, normalizing amplitude, and segmenting into individual calls.

Segmentation – the process of dividing a continuous recording into discrete units (calls) based on acoustic criteria. Automated segmentation algorithms speed up this step but may require manual refinement.

Annotation software – specialized programs that facilitate labeling of calls, such as Raven, Audacity, or custom MATLAB scripts. Annotation software often includes spectrogram display, playback control, and export functions.

Inter-species comparison – the examination of vocal characteristics across different pinniped species to identify convergent or divergent patterns. Comparative studies can reveal evolutionary pressures shaping communication.

Phylogenetic signal – the tendency for related species to share similar vocal traits. Detecting a phylogenetic

signal requires integrating acoustic data with genetic or morphological phylogenies.

Acoustic plasticity index – a metric quantifying the degree to which an individual or population alters its vocal parameters in response to environmental change. High plasticity may indicate resilience to anthropogenic noise.

Behavioral resilience – the capacity of animals to maintain normal behaviors despite disturbances. Acoustic studies assess resilience by monitoring changes in call rates, repertoire usage, and movement patterns.

Acoustic exposure level (AEL) – the cumulative energy received by an animal over a given time period, expressed in dB re 1 $\mu\text{Pa}^2\cdot\text{s}$. AEL calculations are used to evaluate potential hearing damage from persistent noise.

Hearing threshold – the minimum sound level at which an animal can detect a tone of a given frequency. Pinniped hearing thresholds vary across species, with some capable of detecting frequencies up to 100 kHz.

Auditory masking threshold – the level at which background noise prevents detection of a target signal. Determining masking thresholds helps predict communication breakdown under noisy conditions.

Acoustic habitat – the acoustic properties of a physical environment, including depth, substrate, and ambient noise. The acoustic habitat influences the evolution and usage of vocal signals.

Substrate reverberation – the reflection of sound off the seafloor or ice, which can amplify or distort certain frequencies. Substrate type (sand, rock, kelp) modulates reverberation characteristics.

Ice-associated vocalization – calls produced by pinnipeds inhabiting ice environments, such as the “ice-bark” of bearded seals. Ice can both reflect sound and generate unique acoustic cues.

Foraging call – a vocalization emitted during prey capture or handling. Some sea lions produce “snorts” that may coordinate group foraging or signal successful capture.

Predator alarm call – a rapid, high-frequency call emitted when a predator is detected. Alarm calls can trigger immediate escape responses in conspecifics.

Human-induced disturbance – alterations in vocal behavior caused by human activities, such as increased call rates near research vessels or altered frequency bands in response to ship traffic.

Acoustic mitigation – strategies implemented to reduce the impact of anthropogenic noise on marine mammals, including vessel speed restrictions, quieting technologies, and seasonal exclusion zones.

Noise abatement measures – specific actions taken to lower noise emissions, such as propeller modifications or the use of bubble curtains during construction.

Regulatory framework – the set of laws and guidelines governing marine acoustic activities, often

encompassing noise limits, monitoring requirements, and impact assessments.

Impact assessment – the systematic evaluation of potential effects of a proposed activity on marine mammals, incorporating acoustic modeling, field observations, and risk analysis.

Risk mitigation plan – a document outlining steps to minimize identified risks, including real-time monitoring of noise levels and adaptive management protocols.

Stakeholder engagement – the process of involving local communities, industry, and regulatory agencies in the planning and execution of acoustic research. Effective engagement fosters compliance and shared stewardship.

Data sovereignty – the principle that data generated within a jurisdiction belongs to that region's stakeholders. Researchers must respect data sovereignty when sharing recordings from Puerto Rican waters.

Open-access repository – a publicly available archive that hosts acoustic datasets, such as the Marine Mammal Sound Database. Open access facilitates collaboration and meta-analysis.

Metadata standards – agreed-upon formats for describing data, such as the Darwin Core schema. Adhering to standards ensures interoperability between datasets.

Version control – the practice of tracking changes to data and analysis scripts, often using systems like Git. Version control enhances reproducibility and collaborative development.

Reproducible workflow – a documented sequence of steps that enables other researchers to replicate results, encompassing data acquisition, processing, analysis, and visualization.

Visualization tools – software for creating spectrograms, call rate plots, and spatial maps. Effective visualization aids interpretation and communication of findings.

Spatial mapping – the representation of vocal activity across geographic space, often using GIS platforms. Spatial maps can reveal hotspots of breeding or foraging vocalizations.

Temporal trend analysis – statistical examination of changes in vocal activity over time, detecting patterns such as increasing call rates in response to climate change.

Phenological shift – alterations in the timing of vocal events (e.g., Earlier onset of breeding calls) that may be linked to environmental changes.

Acoustic niche partitioning – the segregation of call frequencies among co-occurring species to reduce interference. Empirical evidence of niche partitioning supports the acoustic niche hypothesis.

Signal redundancy – the presence of multiple, overlapping calls that convey the same information. Redundancy can increase robustness of communication in noisy environments.

Signal reliability – the degree to which a vocal signal accurately reflects the sender’s internal state or intent. Reliable signals are less likely to be deceptive.

Honest signaling theory – a framework suggesting that costly signals (e.G., Loud barks) are difficult to fake, thereby ensuring honesty. In pinnipeds, energetic costs of large source level calls support honest signaling.

Deception in vocal communication – the intentional production of signals that mislead receivers.