Literature Summary: Emerging Seismic Sources - Characterization and Regulatory Tiering (Caplinger et al. 2026)

Caplinger, J. E., Martin, M. J., Conrad, A. S., and E.R. Staaterman. 2026. Categorizing Alternative Seismic Sources Based on Their Potential to Affect Marine Mammals. *Journal of Marine Science and Engineering* 14(15): 1379. https://doi. org/10.3390/jmse14151379

THE BOTTOM LINE

Caplinger et al. demonstrate that emerging seismic source technologies can be assigned to U.S. Operational National Mitigation Protocol for Geophysical Surveys (ONMP) Tier 1, Tier 2, and Tier 3 categories using comprehensive acoustic characterization. This acoustically based tiering approach provides a scientifically defensible basis for integrating those technologies into the existing ONMP framework and supporting marine mammal incidental take authorization decision-making.

WHY IT MATTERS

- **Provides an Objective Framework for Evaluating Emerging Technologies.** As seismic source technologies continue to be developed, regulators require scientifically defensible approaches for evaluating technologies that differ substantially from conventional sources. This study demonstrates how comprehensive acoustic characterization can provide an objective basis for assigning emerging technologies within the existing ONMP framework.
- **Supports Science-Based Authorization Decisions.** By evaluating technologies using multiple acoustic characteristics rather than traditional engineering measures alone, the methodology provides an objective basis for assigning technologies to ONMP tiers, supporting consistent U.S. marine mammal incidental take authorization decisions.

INDUSTRY IMPLICATIONS

- **Provides a Clear Regulatory Pathway for Innovation.** The methodology establishes an objective process for evaluating emerging seismic source technologies, reducing uncertainty about how new technologies may be assessed within the existing ONMP framework.
- **Supports Proportionate Mitigation Requirements.** By assigning technologies to ONMP tiers on the basis of their acoustic characteristics rather than engineering descriptors alone, the methodology provides a scientific basis for mitigation requirements that are proportionate to the acoustic characteristics of the source being used, with less stringent levels of mitigation for sources in lower tiers.
- **Encourages Continued Technology Development.** The framework allows future seismic source technologies to be evaluated using consistent scientific criteria without requiring the creation of new regulatory approaches for each innovation.
- **International Relevance.** While the framework is based on U.S. regulatory requirements, the ONMP and the findings of Caplinger et al. have broader implications for the treatment of seismic source technologies and the development of regulatory approaches in other jurisdictions.

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Project Objectives

As seismic source technologies continue to be developed, regulators require scientifically defensible methods to evaluate how those technologies compare with how conventional seismic sources have been regulated.

The study evaluated the acoustic characteristics of four emerging seismic source technologies—Tuned Pulse Source™ (TPS™), Gemini Source™, Harmony™, and a representative marine vibroseis (MV) system—to assess their relative potential to affect marine mammals and determine whether they could be assigned to the existing ONMP Tier 1, Tier 2, and Tier 3 based on comprehensive acoustic characterization rather than traditional engineering descriptors such as air chamber volume or source type.

Researchers compiled the best available acoustic characterizations from published literature, direct industry communication, and information submitted in federal petitions and authorization applications. They then compared these technologies with representative conventional arrays using NMFS auditory injury and behavioral disturbance thresholds together with a 60-second M-weighted sound exposure level metric to evaluate their relative placement within the existing ONMP framework.

Source Characterization

- Conventional engineering descriptors, such as air chamber volume or source type, did not consistently reflect the acoustic characteristics of the seismic source technologies evaluated.
- Evaluated seismic technologies exhibited distinct acoustic signatures that differed in spectral content, temporal characteristics, duty cycle, and hearing-weighted sound exposure.
- Comprehensive acoustic characterization provided a more informative basis for comparing seismic source technologies than air chamber volume or source type alone.

ONMP Tier Assignment (Table 1)

- All of the source technologies evaluated demonstrated reduced higher-frequency (>200 Hz) output compared with conventional seismic sources, although their individual acoustic footprints differed.
- Several seismic source technologies aligned more closely with lower ONMP tiers than conventional higher-energy arrays when evaluated using multiple acoustic characteristics.
- The authors demonstrate that source technologies can be systematically classified within the existing ONMP framework based on their acoustic characteristics rather than source type alone. Individual tier assignments were specific to the representative configurations evaluated.

ENERGEO EXPERT EVALUATION

Caplinger et al. (2026) addresses one of the most important regulatory challenges associated with the continued development of seismic source technologies: *how should technologies that differ substantially from conventional sources be evaluated within the existing marine mammal 'take' authorization process?* Because ONMP tiers are used to inform the mitigation measures applied during marine mammal incidental take authorizations for geophysical surveys, assigning emerging technologies to the appropriate tier requires a scientifically defensible basis.

The study provides that scientific foundation by demonstrating that comprehensive acoustic characterization offers a more appropriate basis for ONMP tier assignment than traditional engineering descriptors such as air chamber volume or source type alone. By evaluating multiple acoustic characteristics that are directly relevant to sound exposure and potential marine mammal sound exposure, the authors establish a standardized, objective methodology for assigning emerging technologies within the existing ONMP framework.

From an industry perspective, this approach is particularly significant because it creates a scientifically defensible pathway for innovative seismic source technologies to be evaluated on the basis of their acoustic characteristics rather than being treated as conventional sources by default. By enabling technologies to be assigned to the ONMP tier that best reflects their acoustic performance, the methodology helps ensure that mitigation requirements associated with marine mammal incidental take authorizations are proportionate to the characteristics of the source being used. As additional seismic source technologies become commercially available, this approach provides regulators with a consistent method for integrating innovation into the existing authorization framework without requiring entirely new regulatory frameworks for each technology.

The study should also be interpreted within the context of its methodology. The revised ONMP tier assignments are based on comparative acoustic analyses and modeled auditory injury metrics rather than empirical observations of marine mammal responses under operational conditions. Consequently, the study should be viewed as providing the scientific foundation for acoustically based ONMP tier assignment rather than demonstrating differences in biological impacts among seismic source technologies.

Study Strengths

- Establishes a scientifically defensible methodology for assigning emerging seismic source technologies to ONMP tiers.
- Addresses an emerging regulatory issue with direct relevance to U.S. marine mammal incidental take authorizations and permitting.
- Evaluates multiple acoustic characteristics rather than relying solely on traditional engineering descriptors such as air chamber volume or source type.
- Provides a transparent pathway for integrating emerging technologies into the existing marine mammal authorization framework.
- Supports proportionate mitigation by providing an objective basis for matching ONMP tier assignments to the acoustic characteristics of emerging technologies.

Study Limitations

- Comparisons were based primarily on modeled acoustic characteristics and auditory injury metrics rather than operational field validation.
- Revised ONMP tier assignments were not validated using observed marine mammal behavioral or physiological responses.
- Only selected representative technologies were evaluated; additional technologies will require future acoustic characterization.
- Regulatory implementation will ultimately depend on acceptance by management agencies and continued validation as additional technologies become available.