Underwater Radiated Noise Levels along the California Coast for Participating Vessels in the 2025 Protecting Blue Whales and Blue Skies Program

Mia Conti[1], Lindsey Peavey Reeves[2,3], Samara Haver[4], Kaitlin Frasier[1], Vanessa ZoBell[1]

Scripps Institution of Oceanography, University of California San Diego[1]
National Marine Sanctuary Foundation[2]
NOAA's Office of National Marine Sanctuaries[3]
Cooperative Institute for Marine Ecosystems and Resources Studies, Oregon State University[4]

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1. Summary

The Scripps Machine Listening Lab at Scripps Institution of Oceanography partnered with the Protecting Blue Whales and Blue Skies Program (BWBS) to analyze potential changes in underwater radiated noise (URN) levels of participating vessels for the 2025 incentive-based vessel speed reduction (VSR) initiative along the California coast. This report summarizes the study of sound metrics (source level and noise level) at five acoustic monitoring sites along the California coast, including the Santa Barbara Channel (Site B), Chumash Heritage National Marine Sanctuary (Site C), Morro Bay (Site WEA), Monterey Bay (Site MB) and Cordell Bank National Marine Sanctuary (Site CB). The VSR program was active during the 2025 season from January 1st-15th, and May 1st, 2025 through the end of the year and was open to all vessels 300 gross tons and larger that pass through the VSR zones.

The specific goals of this study were to quantify vessel source levels (MSL) and ambient noise levels (NL) during transits of participating vessels at acoustic monitoring sites along the California coast; compare URN during the active 2025 VSR program with a 2016–2017 baseline when the program was inactive; compare NLs during the active 2025 VSR program with the inactive 2025 VSR period; and identify BWBS program-associated changes.

The key results of this study are:

- Average broadband source levels were reduced during the VSR program active period compared to the 2016/2017 baseline at each site by 6.5 (Site B), 6.1 (Site C), 5.0 (Site MB), and 3.1 dB (Site CB).
- The overall program reduction in broadband source levels for 2025 compared to the 2016/2017 baseline was <u>**5.2 dB**</u>. This equates to a <u>**70%**</u> reduction in acoustic intensity (or 45% reduction in sound pressure amplitude).
- Average noise levels during transits were reduced by 3.8 (Site B), 4.8 (Site C), and 1.4 dB (Site CB) during the 2025 program active period compared to the same year inactive period. This results in an average NL reduction of 3.4 dB.

2. Introduction

URN from commercial shipping has emerged as a globally recognized pollutant that alters the natural marine soundscape and can negatively affect marine species that rely on sound for daily life functions such as communication, navigation, and foraging (Erbe et al. 2019). Extensive policy and scientific bodies have highlighted URN as a priority conservation issue, including the UN Convention on the Conservation of Migratory Species, the International Union for Conservation of Nature, the International Whaling Commission, and the Convention on Biological Diversity, all of which have issued resolutions or workplans calling for measurement and mitigation of shipping noise (Harding & Cousins 2022, Chou et al. 2021, International Whaling Commission 2018, Convention on the Conservation of Migratory Species of Wild Animals 2020, International Union for Conservation of Nature 2021).

The International Maritime Organization (IMO), the primary global authority on shipping practices, has also prioritized mitigating noise from vessels. In 2023, the IMO published revised guidelines for the Reduction of Underwater Radiated Noise from Shipping, with implementation and capacity-building reinforced through the Global Environment Facility-funded GloNoise Partnership. Within the guidelines, the IMO identifies VSR as a principal mitigation strategy, along with prioritizing speed reductions below the Cavitation Inception Speed (CIS) and implementing incentivization strategies (IMO 2024, IMO 2023). In 2024, the European Union's Marine Strategy Framework Directive became the first regulation to adopt mandatory threshold values for continuous underwater noise, establishing limits on the proportion of habitat that may exceed levels associated with biologically adverse effects (European Commission 2024). This milestone marks a shift in international policy capacity from voluntary guidance and recommendations toward mandated standards for noise exposure in marine ecosystems. In 2025, the High Ambition Coalition for a Quiet Ocean was launched at the UN Ocean Conference as the first high-level political initiative to address ocean noise at a global scale. Highlighted in the Coalition's declaration are effective solutions to reduce vessel impacts on sensitive ocean wildlife, including VSR (High-Ambition Coalition for a Quiet Ocean 2025).

2.1 Vessel Speed Reduction as a Mitigation Strategy

VSR programs have been implemented internationally during the past decade and have proven to be a successful and cost-efficient way to reduce noise levels for many vessel types (MacGillivray et al. 2019, ZoBell et al. 2021, Findlay et al. 2023, Hatch et al. 2025). VSR programs target operational changes in commercial shipping to achieve multiple conservation benefits: reducing greenhouse gas emissions, lowering the risk of lethal collisions with whales, and mitigating URN. As propeller cavitation from vessels dominates low-frequency underwater soundscapes, and ambient sound levels have risen globally with the growth of commercial vessel traffic, VSR applied in key biological and traffic corridors can reduce vessel source levels and, under appropriate propagation and traffic conditions, lower received levels experienced by acoustically sensitive species (MacGillivray et al. 2019, ZoBell et al. 2021, Findlay et al. 2023).

The Vancouver Fraser Port Authority's Enhancing Cetacean Habitat and Observation (ECHO) Program has coordinated voluntary slowdowns in key Southern Resident killer whale habitat on the west coast of Canada for multiple seasons. In 2019, it achieved 82% vessel participation in voluntary slowdowns, associated with broadband sound level reductions of approximately 3.0-3.5 dB relative to baseline conditions (Chou et al. 2021, Vancouver Fraser Port Authority 2019). Similarly, the Quiet Sound voluntary slowdown in Puget Sound reduced median broadband sound levels by about 2.8 dB (which equated to a ~45 % reduction in sound intensity) for participating large commercial vessels during slowdown periods (Quiet Sound 2023). The proliferation of voluntary VSR programs reflects their broad adoption as effective operational measures that are actively monitored to benefit marine species.

2.2 Protecting Blue Whales and Blue Skies Program (BWBS)

In 2014, the Channel Islands National Marine Sanctuary (CINMS) partnered with the Santa Barbara County Air Pollution Control District, Ventura County Air Pollution Control District, National Marine Sanctuary Foundation, and the Environmental Defense Center to implement a voluntary, incentive-based vessel speed reduction (VSR) initiative known as the Protecting Blue Whales and Blue Skies Program (BWBS). BWBS was initiated to encourage VSR in and around the Santa Barbara Channel (SBC), a biologically productive region that also serves as a major shipping corridor into the Ports of Los Angeles and Long Beach, the first and second busiest shipping ports in the United States, respectively. Enrollment was made available to companies operating container ships or vehicle carriers within the VSR zone. In 2024, the VSR zone was expanded along the California coast to include the Central and Northern California regions, reflecting increased industry participation and conservation ambition. In 2025, the VSR zones were expanded to include the Chumash Heritage National Marine Sanctuary to protect more of the Central Coast regions.

Participation agreements for the 2025 VSR season require vessels to travel at ≤10 knots for at least 30% of the distance within designated VSR zones. Incentivization is promoted via an award program which is tiered by cooperation level. In 2025, the award category thresholds were also increased to support greater conservation impact: Sapphire (≥90%), Gold (70-89%), or Blue Sky (50-69%) distance traveled within the VSR at or below 10 knots.

2.3 Acoustic Monitoring and Analysis

For two decades, the Scripps Institution of Oceanography's Marine Bioacoustic Research Collaborative, in collaboration with the California Marine Sanctuary Foundation, National Marine Sanctuary Foundation, the Navy, and the National Oceanic and Atmospheric Administration (NOAA) has monitored underwater noise at a variety of locations along the California coast and across the United States using High-frequency Acoustic Recording Packages (HARPs; Wiggins & Hildebrand, 2007, ZoBell et al. 2025, Figure 1). Additionally, the NOAA National Marine Fisheries Service, Office of National Marine Sanctuaries, and Pacific Marine Environmental Laboratory have maintained a series of monitoring sites in California as part of the NOAA/NPS Noise Reference Station Network (Haver, et al. 2025). One of the 13 U.S.-wide NRS monitoring sites is located in Cordell Bank National Marine Sanctuary offshore of San Francisco (Haver et al, 2020), and included here as site CB. These long-term acoustic datasets reflect the variability in the ambient noise levels of the regional soundscape. The data capture the cyclicity and volatility of maritime traffic patterns, which are influenced by factors such as seasonal shipping demand, holidays, economic conditions, and port operations (ZoBell et al. 2025). Historical events affecting vessel activity, including regulatory changes and periods of anchorage congestion, are also evident in the soundscape record. Time-series analysis of the data provides context for interpreting changes in underwater noise associated with vessel operations and mitigation efforts (Figure 2).

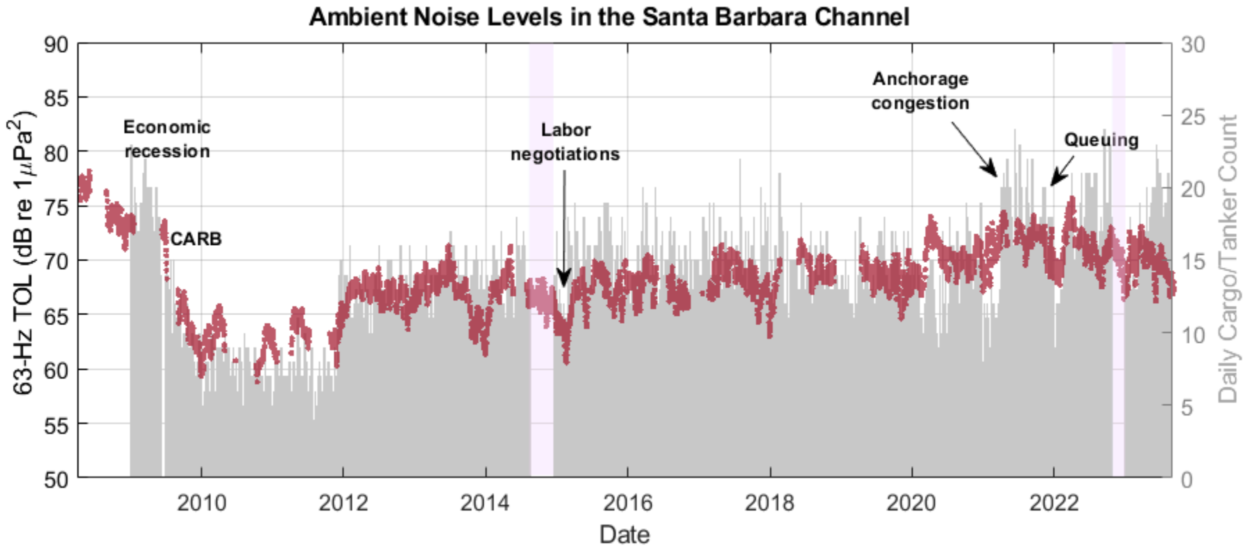

Figure 1: Daily ambient sound levels at a HARP site within the Santa Barbara Channel with associated daily count of unique cargo ships and tankers. Socioeconomic events, such as economic recessions and labor negotiations are defined in the time series. This figure is modified from ZoBell et al. (2025).

In 2019, the Marine Bioacoustic Research Collaborative at Scripps Institution of Oceanography (SIO) began quantifying reductions in broadband (5-1000 Hz) MSLs and sound exposure levels associated with participation in BWBS (ZoBell et al. 2021). Reporting of MSL and transit NL reductions in the Southern California region is continued annually by the Scripps Machine Listening Lab, with mean MSL reductions during the 2024 active season compared to the 2024 inactive season of: 5.4 dB (Site B), 4.6 dB (Site CB), 2.3 dB (Site MB), equating to a percent reduction in sound pressure of 46%, 41%, and 23%, respectively. Comparatively, the original findings pre-2019 yielded a result of 1.0 dB reduction in broadband MSLs in the SBC when comparing within the same year (ZoBell & Frasier, 2024).

3. Methods

The 2025 assessment evaluates two primary acoustic metrics: vessel monopole source levels (MSLs) and transit-based noise levels (NLs). Vessel MSL quantifies the acoustic output of individual vessels by correcting for propagation effects between the vessel and the receiver. Vessel NL quantifies received sound pressure levels at fixed monitoring locations when a vessel is within a specified radius of the acoustic sensor.

Vessel MSLs were compared to a 2016/2017 inactive-period baseline to ensure comparability across analysts (e.g., greenhouse gas emissions and whale-strike risk). This differs from the within-year baseline used in previous BWBS reporting years. For NL metrics, however, within-year comparisons were maintained because not all monitoring sites had acoustic data available for 2016/2017.

3.1 Data Sources

Automatic Identification System (AIS) data were obtained from the United States Coast Guard for areas extending 25–50 km around each recording site. The following AIS attributes were retained: vessel name, IMO identification number, vessel type, speed over ground (SOG), draft, vessel length, and position (latitude and longitude).

Acoustic data were collected using High-frequency Acoustic Recording Packages (HARPs) and a NOAA Noise Reference Station mooring (Site CB) deployed at several locations along the California coast (Figure 2, Table 1). Moorings were deployed at varying depths and recording durations. Acoustic recordings were collected at sampling rates of 200 kHz, 320 kHz (Site C), or 5 kHz (Site CB).

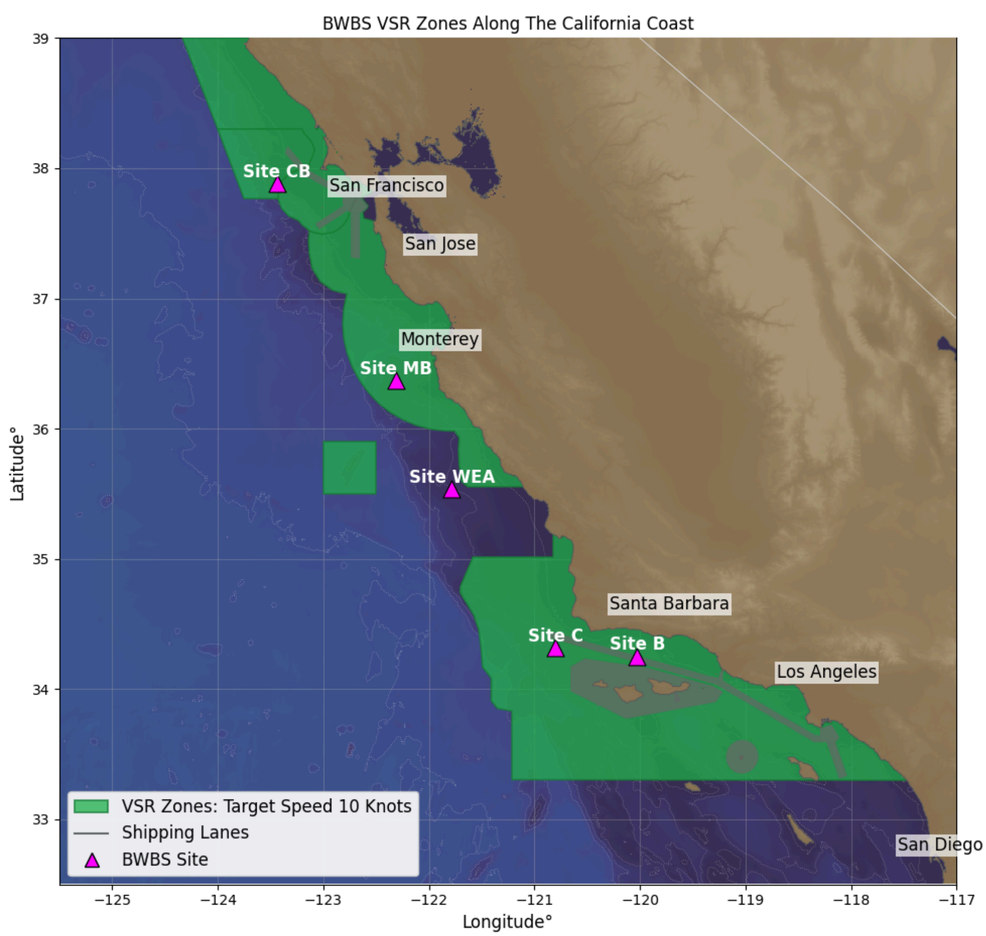

Figure 2: 2025 vessel speed reduction zone along the California coast for the Protecting Blue Whales and Blue Skies Program. Acoustic monitoring sites where source levels and noise levels were either measured or estimated are denoted by triangles.

Prior to analysis, recordings sampled at 200 kHz and 320 kHz were decimated for computational efficiency. Data were low-pass filtered using an 8th-order Chebyshev Type I IIR filter to prevent aliasing during decimation. Recordings were screened for data quality, and vessel transits contaminated by low-frequency hydrophone cable strumming were excluded. Data from Site MB were excluded from the 2025 analysis due to an instrument malfunction upon deployment. Data from this site will be used in future analyses.

Table 1: Table with acoustic monitoring site information including location, name, and lead organizations. Acoustic monitoring sites are equipped with a High-frequency Acoustic Recording Package (HARP), except for NRS11 which is equipped with a Noise Reference Station (NRS).

Location	Site Name	BWBS Abbrev	Lat (DD)	Lon (DD)	Depth (m)	Sample Rate (kHz)	Organization
Santa Barbara Channel	CINMS_B	Site B	34.25	-120.03	585	200	Scripps Oceanography
Chumash Heritage	CINMS_C	Site C	34.32	-120.80	780	320	Scripps Oceanography
Morro Bay	WEA_MBA	Site WEA	35.54	-121.8	986	200	Scripps Oceanography
Monterey Bay	MB-03	Site MB	36.37	-122.31	926	200	Naval Postgraduate School
Cordell Bank	NRS11	Site CB	37.88	-123.44	550	5	NOAA

3.2 Vessel Source Levels (MSL)

Acoustic monitoring sites that were suitable for vessel MSL analysis were Site B, Site C, and Site WEA, due to their data quality and proximity to nearby vessel transits, AIS data were restricted within one water depth of the sensor location. Sound pressure levels for each vessel transit were averaged over a data window equal to the time required for the vessel to travel its own length, as defined in ANSI/ASA (2009). Within this window, a Fast Fourier Transform was used to compute power spectral densities in 1-Hz frequency bins. Frequency-dependent hydrophone calibration was then applied to obtain SPL values in dB re 1 $\mu Pa^2/Hz$.

MSLs were calculated by applying propagation loss (PL) between the source and the receiver at the vessel's closest point of approach (CPA). The propagation loss model accounts for the Lloyd's mirror effect, which represents interference between the direct acoustic path and reflections from the sea surface (ISO 17208-2:2019). The model incorporates the distance from the source to the receiver, the distance from the image source to the receiver, and the acoustic wave number (rad/m). Sound refraction in the water column and reflections from the seafloor were not included in the model.

Vessel MSLs were computed using continuous acoustic recordings from HARPs at:

- Santa Barbara Channel (Site B);
- Chumash Heritage National Marine Sanctuary (Site C);
- Morro Bay - Wind Energy Area (Site WEA).

Vessel MSLs for sites that were too distant from vessels to compute MSL, had data quality issues, or had too few measured MSLs (Site C) were cross-referenced with the SIO Vessel Underwater Radiated Noise Database. Vessel MSL values were only used when the same vessel was recorded traveling within 1 knot of the speed documented in the database. The selected database MSLs were measured at the following locations:

- Chumash Heritage NMS (Site C)
- Monterey Bay NMS (Site MB)
- Cordell Bank NMS (Site CB)

The difference in MSLs between the 2025 program active period and the baseline 2016–2017 inactive period was calculated as the difference between the mean broadband (5-1000 Hz) MSL of participating vessels during the 2025 active period and the mean MSL of all vessels with type codes 70–89 during the 2016–2017 inactive period. Vessel types 70–89 were included in the baseline because the participating vessel list alone did not provide sufficient historical data. The inactive baseline period spans November 16, 2016 through June 30, 2017.

3.3 Noise Levels for 2025:

NL metrics were computed at sites with usable acoustic data and were constrained to periods when a vessel transit was confirmed within a specified distance of the sensor and the vessel was the closest AIS-broadcasting vessel to the hydrophone. Only times when vessels participating in BWBS were the closest vessel to the acoustic sensor were included in the noise reduction analysis to minimize confounding effects from other vessels.

NL metrics were computed for the 63-Hz one-third-octave band level (TOL) at one-minute resolution for the following sites:

- Santa Barbara Basin (Site B) – 10 km radius
- Chumash Heritage National Marine Sanctuary (Site C) – 10 km radius
- Wind Energy Area – Morro Bay (Site WEA) – 10 km radius
- Cordell Bank (Site CB) – 25 km radius

A larger radius was used for the Cordell Bank site due to the limited number of BWBS-participating vessels transiting within 20 km of the sensor. NL metrics could not be computed for Site MB due to data quality issues.

For periods meeting the above criteria, power spectral densities (PSDs) were calculated using 1-second time windows and 1-Hz frequency bins. The 63-Hz TOL was computed by summing sound pressure levels in linear space across the frequency bounds of the band. Minute-level mean noise levels were then calculated as the linear mean of the 1-second resolution 63-Hz TOL values. Finally, the average minute-level mean NL during the 2025 active period was compared to the average NL during the 2025 inactive period.

4. Results

4.1 Source Level Analysis

4.1.1 Santa Barbara Channel

Of the usable MSL measurements from Site B, 431 transits from BWBS participating vessels were identified, including 339 during program active dates and 92 during program inactive dates. For transits with paired AIS and acoustic data, the mean speed over ground during the active and inactive periods was 9.8 and 12.7 knots, respectively. The mean MSL of participating vessels during the active and inactive periods was 180.7 and 184.5 dB re 1 µPa·m, respectively. Relative to the 2016–2017 baseline, the mean MSL was reduced by 6.5 dB re 1 µPa·m (Table 2).

4.1.2 Chumash Heritage NMS

There were minimal transits from BWBS participating vessels within one water depth of the hydrophone at the Chumash Heritage National Marine Sanctuary site (Site C). Therefore, MSLs for vessels transiting within 10 km were estimated using the Vessel Underwater Radiated Noise Database. Using this approach, 555 transits were identified during active program dates and 160 during inactive program dates. The mean speed over ground during the active and inactive periods was 9.6 and 12.0 knots, respectively (Table 2). The mean source level of participating vessels during the active and inactive periods was 180.0 dB re 1 µPa·m and 182.3 dB re 1 µPa·m, respectively (Figure 7). Relative to the 2016–2017 baseline, the mean source level at Site C was reduced by 6.1 dB re 1 µPa·m.

4.1.3 Monterey Bay NMS

Source levels for Site MB were estimated by identifying transits of the same vessels in the Site B dataset operating within 1 knot of the speed observed during the Site MB transit. A total of 151 transits from BWBS participating vessels that occurred during the program active period had corresponding observations in the database within the 1-knot speed criterion. During the program inactive period, 73 transits met this matching criterion.

For the matched transits, the mean speed over ground during the active and inactive periods was 10.1 and 12.2 knots, respectively. The mean MSL of participating vessels during the active and inactive periods was 181.1 and 184.7 dB re 1 µPa·m, respectively (Table 2). Relative to the 2016–2017 baseline, the 2025 season exhibited a mean MSL reduction of 5.0 dB at Site MB.

4.1.4 Cordell Bank NMS

Because no BWBS participating vessels transited within 10 km of the site, the analysis radius was extended to 25 km. A total of 55 transits from BWBS participating vessels that occurred during the program active period had corresponding observations in the database within the 1-knot speed criterion. During the program inactive period, 29 transits met this matching criterion.

For the matched transits, the mean speed over ground during the active and inactive periods was 9.5 and 10.5 knots, respectively. The mean MSL of participating vessels during the active and inactive periods was 181.1 and 182.2 dB re 1 μPa·m, respectively (Table 2). Relative to the 2016–2017 baseline, the 2025 season exhibited a mean MSL reduction of 3.1 dB at Site CB.

4.1.5 Morro Bay

Site WEA is located outside of a VSR zone, in contrast with the other sites. MSLs at Site WEA were measured for the 2025 period and estimated from the database for the 2016–2017 baseline. During 2025, there were 47 transits from BWBS participating vessels during active program dates, and 38 transits during program inactive dates. The mean speed over ground during 2025 active versus inactive periods was 11.6 and 11.9 knots, respectively (Figure 8, 9). The mean MSL of participating vessels while the program was active versus inactive was 183.6 and 184.2 dB re 1 μPa·m, respectively (Table 2).

Table 2: Vessel source level (MSL) measurements and estimates during the 2025 Protecting Blue Whales and Blue Skies Program and the 2016–2017 baseline period. Sites shaded in green represent locations with measured MSLs, while sites shaded in blue represent locations where MSLs were estimated using the Scripps Machine Listening Lab's Vessel Noise Database. The Morro Bay site (WEA) was measured despite not being located within a Vessel Speed Reduction (VSR) zone.

Site	**2016-2017 Inactive (Baseline)** (Speed | Source level)	**2025 Inactive** (Speed | Source level)	**2025 Active** (Speed | Source level)	**Baseline - 2025 Active** (Speed | Source level)
Santa Barbara Channel (Site B)	14.4 | 187.2 (n = 226)	12.7 | 184.5 (n = 92)	9.8 | 180.7 (n = 339)	4.6 | 6.5
Chumash Heritage (Site C)	14.5 | 186.1 (n = 692)	12.0 | 182.4 (n = 160)	9.6 | 180.0 (n = 555)	4.9 | 6.1
Monterey Bay (Site MB)	14.3 | 186.1 (n = 811)	12.2 | 184.7 (n = 73)	10.1 | 181.1 (n = 151)	4.2 | 5.0
Cordell Bank (Site CB)	12.5 | 184.1 (n = 254)	10.5 | 182.2 (n = 29)	9.5 | 181.0 (n = 55)	3 | 3.1
All BWBS Regions	**13.9 | 185.9**	**11.9 | 183.5**	**9.8 | 180.7**	**4.1 | 5.2**
Morro Bay Non-VSR (Site WEA)	14.9 | 186.6 (n = 620)	11.9 | 184.2 (n = 38)	11.6 | 183.6 (n = 47)	3 | 3.3

*4.2 Noise Level Analysi*s

Noise level (NL) metrics were calculated using the 63-Hz one-third-octave band (TOL) during periods when a BWBS participating vessel was the closest AIS-broadcasting vessel to the acoustic sensor within the defined analysis radius. Noise levels were compared between the 2025 program inactive and active periods for sites with usable acoustic data.

Across all sites within the BWBS zone combined, the mean NL during the inactive period was 95.9 dB re 1 µPa, compared to 92.5 dB re 1 µPa during the active program period. This represents an average reduction of 3.4 dB in ambient noise levels during transits of BWBS participating vessels (Table 3).

4.2.1 Santa Barbara Channel

At the Santa Barbara Channel site (Site B), the mean NL during the program inactive period was 92.7 dB re 1 µPa (n = 507 minutes). During the program active period, the mean NL decreased to 88.9 dB re 1 µPa (n = 1594 minutes), representing an average reduction of 3.8 dB (Figure 3, Table 3). The stacked one-minute transit spectra illustrate elevated low-frequency vessel noise during the inactive period and reduced acoustic energy during the active program period, particularly below ~100 Hz (Figure 3).

Marine mammal vocalizations may be intermittently present within the stacked spectra. However, because the spectrograms represent aggregated one-minute transit windows, individual calls are difficult to resolve. Humpback whale vocalizations may be intermixed within the spectra, though distinct blue whale (~40–50 Hz) or fin whale (~15–25 Hz) call patterns were not clearly identifiable in the stacked transit spectra.

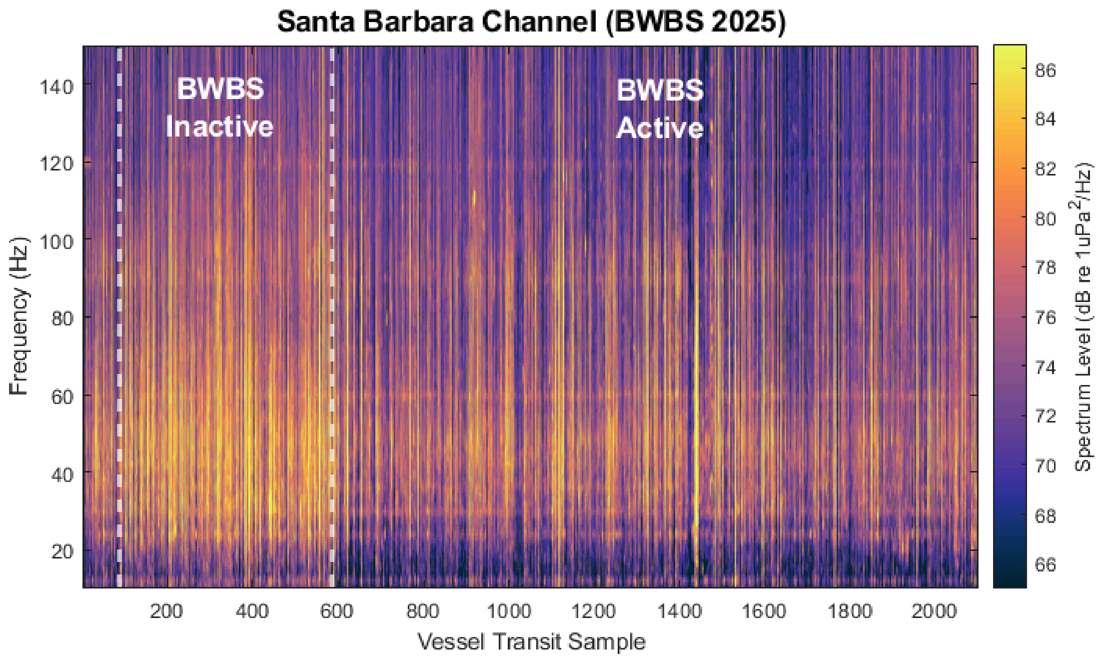

Figure 3. Stacked one-minute vessel transit (< 10 km) spectra at the Santa Barbara Channel site during BWBS 2025. Color indicates spectrum level (dB re 1 μPa²/Hz), with warmer colors representing higher acoustic energy. The dashed vertical line separates BWBS inactive and active periods.

4.2.2 Chumash Heritage National Marine Sanctuary

At the Chumash Heritage National Marine Sanctuary site (Site C), the mean NL during the program inactive period was 96.7 dB re 1 μPa (n = 253 minutes). During the program active period, the mean NL decreased to 91.8 dB re 1 μPa (n = 741 minutes), representing the largest site-level reduction of 4.8 dB (Table 3). The stacked one-minute transit spectra show a reduction in low-frequency acoustic energy during the BWBS active period compared to the inactive period, particularly below ~100 Hz (Figure 4).

Distinct marine mammal vocalizations are visible in portions of the stacked spectra. Energy bands corresponding to blue whale calls (~40–50 Hz) and fin whale calls (~15–25 Hz) are evident within the spectrogram during several transit samples. These frequency bands overlap with the dominant frequencies of vessel noise, illustrating how shipping activity can mask biologically important communication frequencies for baleen whales in this region.

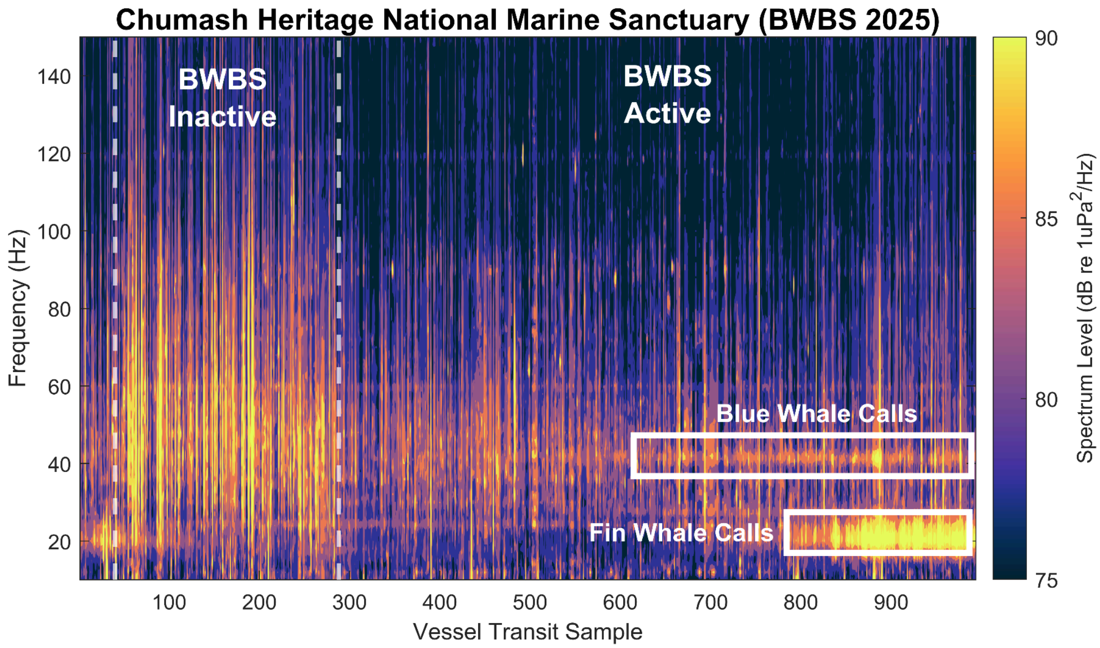

Figure 4. Stacked one-minute vessel transit (< 10 km) spectra at the Chumash Heritage National Marine Sanctuary site during BWBS 2025. Color indicates spectrum level (dB re 1 µPa²/Hz), with warmer colors representing higher acoustic energy. The dashed vertical line separates BWBS inactive and active periods. Boxes indicate frequency bands of blue whale calls (~40–50 Hz) and fin whale calls (~15–25 Hz), highlighting overlap between vessel noise and whale communication frequencies.

4.2.3 Cordell Bank National Marine Sanctuary

At the Cordell Bank NMS site (Site CB), the mean NL during the program inactive period was 98.2 dB re 1 µPa (n = 68 minutes). During the program active period, the mean NL decreased to 96.8 dB re 1 µPa (n = 137 minutes), corresponding to a reduction of 1.4 dB. The stacked one-minute transit spectra show generally elevated low-frequency acoustic energy across both inactive and active periods, though slightly reduced levels are observed during the program active period during some transits.

Marine mammal vocalizations are visible within portions of the stacked spectra. Fin whale calls are evident during both the BWBS inactive and active periods, indicating that the BWBS active period does not include the full duration of time that fin whales are communicating in the region (Haver et al. 2020). Blue whale calls are also visible during some transit samples. These vocalizations occur within the same low-frequency band dominated by vessel noise, highlighting the potential for overlap between shipping noise and baleen whale communication frequencies in Cordell Bank NMS.

4.2.4 Morro Bay

At the Morro Bay site (Site WEA), which is located outside of the BWBS vessel speed reduction (VSR) zone, the mean NL during the program inactive period was 95.3 dB re 1 μPa (n = 161 minutes). During the program active period, the mean NL decreased to 92.9 dB re 1 μPa (n = 95 minutes), representing an average reduction of 2.4 dB (Figure 5, Table 3). Although a reduction in noise levels was observed, the magnitude of change was smaller than those measured at sites located within VSR zones. The stacked one-minute transit spectra show several high-energy vessel passages during the program active months, consistent with continued vessel traffic operating outside the speed reduction zones.

Marine mammal vocalizations are also visible within portions of the stacked spectra. Fin whale calls (~15–25 Hz) and blue whale calls (~40–50 Hz) are present within the same low-frequency bands that contain dominant vessel noise energy. These observations illustrate that baleen whale vocalizations persist in this region even in the presence of vessel traffic and highlight the overlap between shipping noise and biologically important communication frequencies.

The magnitude of NL reductions varied among sites and likely reflects differences in distance from vessels and the monitoring locations, propagation conditions, and sample size. The larger reductions observed at Sites B and C correspond with areas where vessels are closer to the monitoring location, whereas the smaller reduction at Site CB may be influenced by the greater distance between the monitoring sensor and major shipping lanes as well as lower sample sizes.

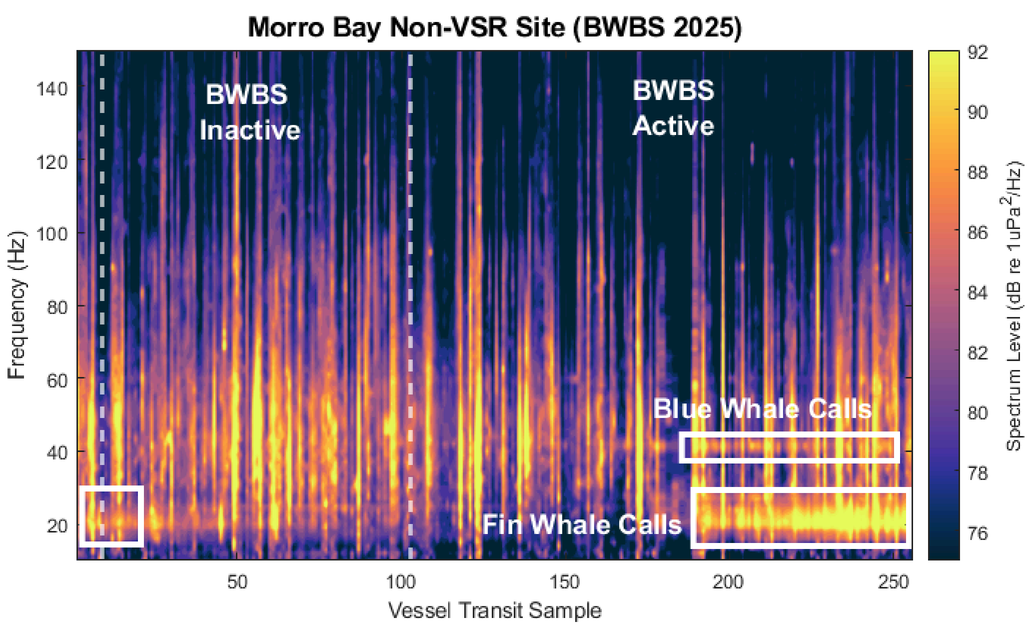

Figure 5. Stacked one-minute vessel transit (< 10 km) spectra at the Morro Bay site during BWBS 2025. Color indicates spectrum level (dB re 1 μPa²/Hz), with warmer colors representing higher acoustic energy. The dashed vertical line separates BWBS inactive and active periods. Boxes indicate frequency bands of blue whale calls (~40–50 Hz) and fin whales calls (~15–25 Hz), highlighting overlap between vessel noise and whale communication frequencies.

Table 3: Mean transit noise levels (NL; dB re 1 µPa) during the BWBS 2025 inactive and active periods at acoustic monitoring sites along the California coast. n indicates the number of one-minute observations used in each calculation. All sites were processed through measurements (green shading), no estimations were made in the NL analysis. Orange shading for Morro Bay indicates this site is not within a VSR zone.

Site	2025 Program Inactive (Noise Level dB re 1 µPa)	2025 Program Active (Noise Level dB re 1 µPa)	Inactive - Active (Noise Level dB re 1 µPa)
Cordell Bank NMS (25 km)	98.2 (n = 68)	96.8 (n = 137)	1.4
Chumash Heritage NMS (10 km)	96.7 (n = 253)	91.8 (n = 741)	4.8
Santa Barbara Channel (10 km)	92.7 (n = 507)	88.9 (n = 1594)	3.8
All BWBS Program	**95.9**	**92.5**	**3.4**
Morro Bay Non-VSR (10 km)	95.3 (n = 161)	92.9 (n = 95)	2.4

5. Discussion

This analysis demonstrates that participation in the 2025 Protecting Blue Whales and Blue Skies (BWBS) Program was associated with measurable reductions in vessel source levels and received noise levels across multiple regions of the California coast. Mean broadband source levels were reduced by an average of 5.2 dB relative to the 2016–2017 baseline across participating vessels. This reduction corresponds to approximately a 45% decrease in sound pressure amplitude and roughly a 70% decrease in acoustic intensity.

These findings are consistent with previous studies demonstrating that vessel speed reduction (VSR) can decrease underwater radiated noise. Propeller cavitation, which dominates low-frequency shipping noise, is strongly dependent on vessel speed; even modest reductions in speed can result in substantial reductions in source levels (MacGillivray et al. 2019, Findlay et al. 2023). Similar reductions in broadband noise associated with voluntary vessel slowdowns have been reported in other programs, including the Vancouver Fraser Port Authority's ECHO Program and the Quiet Sound initiative in Puget Sound, which documented reductions of approximately 3 dB during slowdown periods (Chou et al. 2021, Quiet Sound, 2023).

The reductions in received noise levels observed in this study further demonstrate that decreases in vessel source levels can translate into meaningful reductions in acoustic exposure within marine habitats. Across all monitoring sites, mean NL during vessel transits decreased by 3.4 dB during the 2025 program active period relative to the inactive period. Reductions were most pronounced at Sites B and C, where monitoring sensors are located closer to major shipping corridors.

The expansion of the BWBS program along the California coast in recent years underscores the importance of robust acoustic monitoring to evaluate mitigation effectiveness. In October 2024, California enacted Assembly Bill 14 (AB-14), which formally established the Protecting Blue Whales and Blue Skies Program as a statewide voluntary initiative aimed at reducing both air pollution and risks to endangered whale populations. This legislation represents the first statewide policy framework in the United States to support coordinated vessel speed reduction efforts across multiple regions of the California coast.

Globally, efforts to reduce underwater radiated noise from shipping are increasingly recognized as a critical conservation priority. International bodies including the International Maritime Organization (IMO), the Convention on Migratory Species, and the International Union for Conservation of Nature have all emphasized the need for monitoring and mitigation of anthropogenic underwater noise (Harding & Cousins, 2022, Chou et al. 2021, IUCN, 2021). The IMO's revised guidelines for the reduction of underwater radiated noise highlight operational measures such as vessel speed reduction as effective and immediately deployable mitigation strategies (IMO, 2023, IMO, 2024).

Recent scientific syntheses have also emphasized the need for standardized acoustic measurement approaches across VSR programs in order to enable comparisons among regions and mitigation strategies (Hatch et al., 2025). The methodology applied in this study, combining vessel source level measurements with transit-based noise level metrics, provides a framework for evaluating both the mitigation intent of vessel operators and the resulting changes in acoustic exposure within marine habitats.

As underwater noise mitigation continues to evolve as a global policy priority, monitoring programs such as the long-term HARP and NRS networks in U.S. waters, play an essential role in documenting the effectiveness of management actions and informing future policy decisions. Continued expansion of acoustic monitoring sites, particularly in northern California shipping corridors, would further improve the ability to empirically measure vessel noise and evaluate mitigation outcomes.

Overall, the results presented here demonstrate that voluntary vessel speed reduction programs can produce meaningful reductions in underwater radiated noise along major shipping corridors. These findings contribute to the growing body of evidence supporting operational vessel slowdowns as an effective strategy for reducing acoustic impacts on marine ecosystems.

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