Protecting Blue Whales and Blue Skies VSR Program
Air Emission Reduction Methodology & Results
2025 Season

Blue Whales Blue Skies

Background

The Protecting Blue Whales and Blue Skies (BWBS) Vessel Speed Reduction (VSR) Program began as a trial in 2014 and it has been growing with each successful iteration. For the first few years of the program, containerships and auto carriers were invited to participate if the historic, baseline speed of the specific vessel within the Santa Barbara Channel or San Francisco Bay Area zones was high (e.g. 14 knots or greater). At that time, limited funds were available for financial incentives, and so the focus of the program was on reducing the speed of the fastest ships in the region based on transit-specific data for the prior years.

With the expansion of the 2018 VSR season to include all vessel activities under an enrolled company, the time intensive process of determining emission reductions based on the historic, transit-specific speeds of each vessel was no longer practical. Furthermore, companies were introducing new vessels and new routes to California which didn't have transit-specific baseline speeds. Hence, the program transitioned to a fleet-based methodology, which accounts for the normal operating speed of all vessels within a ship sector using the 2016 and 2017 baseline speeds. Emission reductions are then calculated for each season by looking at the difference in emissions between the participating vessels at their estimated baseline speed and the actual emissions at their VSR-compliant speeds.

A summary table of the various program expansions is shown below which demonstrates the VSR request durations, the applicable vessels that have been invited to participate, and the additional zones that have been added to the program.

Table 1: Summary of BWBS VSR Expansions

<table>
<tr><th>VSR Season</th><th>Duration</th><th>Basis</th><th>Speed Target</th><th>Vessel Applicability</th><th>Zones</th></tr>
<tr><td>2014</td><td>4 months</td><td rowspan="3">Transit</td><td>12 knots</td><td rowspan="7">Containerships & Auto Carriers</td><td>Santa Barbara (SB) Channel</td></tr>
<tr><td>2016</td><td rowspan="3">4.5 months</td><td rowspan="2">10-12 knots</td><td>Add south of Channel Islands</td></tr>
<tr><td>2017</td><td>Add San Francisco (SF) lanes</td></tr>
<tr><td>2018</td><td rowspan="8">Fleet</td><td rowspan="8">10 knots</td><td>---</td></tr>
<tr><td>2019</td><td rowspan="3">6 months</td><td>---</td></tr>
<tr><td>2020</td><td>Add POLA/POLB zones</td></tr>
<tr><td>2021</td><td>---</td></tr>
<tr><td>2022</td><td rowspan="2">7.5 months</td><td>Add Bulk & General Cargo</td><td>Add Greater Farallones & Cordell Bank NMS (SF zones)</td></tr>
<tr><td>2023</td><td>Add Tankers</td><td>Add Monterey Bay NMS</td></tr>
<tr><td>2024</td><td>8 months</td><td>---</td><td>---</td></tr>
<tr><td>2025</td><td>8.5 months</td><td>---</td><td>Add Chumash Heritage NMS</td></tr>
</table>

This document will step through the various assumptions necessary to estimate the emission reduction benefits of the VSR program. The topics are broken up into sections, as shown below:

1) Ocean-Going Vessel Types, Maximum Rated Speeds, and Load-Factors
2) Baseline (Non-VSR) Speed Datasets
3) Speed Correction Factors
4) Emission Reduction Calculations
5) Emission Reduction Results - 2025 VSR Season
6) Areas of Further Research
7) Closing Thoughts

1) Ocean-Going Vessel Types, Maximum Rated Speeds, and Load-Factors

On an Ocean-Going Vessel (OGV), the main sources of emissions include the main propulsion engine, the auxiliary engines, and the boilers. In general, emissions are estimated as a function of the power demand from this equipment, with vessel speed being a driving factor in the calculation. Since the majority of the vessel's emissions are from the main propulsion engine, this methodology document will focus on the assumptions surrounding these engines.[1] Emissions from main propulsion engines are calculated using Equation 1 below, with the load factor estimated using the Propeller Law, as shown in Equation 2 below.

Equation 1: Main Propulsion Engine Emissions

Emissions = Maximum Continuous Rated (MCR) engine power * Load Factor * Emission Factor * Low-Load Adjustment Factors * Hours of Operation

Equation 2: Load Factor using Propeller Law

$$\text{Load Factor} = [(\text{VesselSpeed}_{\text{Actual}}) / (\text{VesselSpeed}_{\text{Maximum}})]^3$$

For this analysis, the IHS Markit database was used to determine the maximum rated speed of each vessel in the data sets. Table 2 below provides a summary of the average maximum rated speed for each vessel type analyzed by this program, with containerships further grouped into TEU (Twenty-foot Equivalent Unit) categories due to engine & operating differences between the ship sizes.

Table 2: Average Maximum Rated Speed, by Vessel Type

Vessel Type	Vessel Size	Avg. Max Rated Speed *(knots)*
Auto & RoRo	All	19.8
Containership (small)	1,000 - 5,999 TEU	22.5
Containership (medium)	6,000 - 9,999 TEU	24.8
Containership (large)	10,000+ TEU	24.1
Bulk	All	14.5
General Cargo	All	14.5
Tanker	All	14.8

[1] For the assumptions and calculation methods for the auxiliary engines and boilers, please refer to the San Pedro Bay Ports Emissions Inventory Methodology Report, found at: www.portoflosangeles.org/environment/air-quality/air-emissions-inventory.

2) Baseline (Non-VSR) Speed Datasets

To help determine the baseline operating speeds of the enrolled vessels, AIS (Automatic Identification System) data was obtained for all vessel activities within the Santa Barbara Channel and San Francisco Bay Area regions for calendar years 2016 and 2017. Vessel activities within the months of May through November were then removed to prevent any bias from the previous 2016 and 2017 BWBS VSR seasons and from the NOAA requests for all vessels 300 gross tons or larger to slow down to 10 knots or less.

In 2020, the BWBS program expanded to include the Port of Los Angeles (POLA) and Port of Long Beach (POLB) 40 nautical mile VSR zone in Southern California. Permission was obtained to analyze the 2016 and 2017 calendar year Southern California Marine Exchange AIS vessel speed data to help establish BWBS baseline speeds in these zones. Since these ports have existing VSR programs to slow down to 12 knots or less and the programs have been in effect year-round since 2001, no months were excluded from the baseline speed calculations for the port zones.

In 2022 and 2023, the BWBS program expanded to include the three National Marine Sanctuaries (NMS) in the San Francisco Bay Area. For these zones, a similar AIS analysis was performed using 2017 calendar year data. Data in the months of May through November were removed for the Cordell Bank and Greater Farallones NMS to prevent any bias from the NOAA requests to slow down to 10 knots or less. The Monterey Bay NMS did not participate in the NOAA requests in 2017, and so no data was excluded from the analysis for the MBNMS zone.

3) Speed Correction Factors

Speed Correction Factors (SCFs) represent the ratio of the normal operating speed for a vessel type compared to the maximum operating speed for the vessel type. SCFs are critical in this analysis as they allow us to estimate the baseline speeds for each enrolled vessel as it travels through the various zones along the California coast.

SCFs were calculated for all ships in the 2016 and 2017 data sets based on Equation 3 below. The SCFs were then grouped and averaged together to get vessel type and zone specific SCFs. The SCFs for the BWBS VSR zones are presented below in Tables 3 and 4, and the corresponding maps to demonstrate the zone boundaries are included in Appendices A and B at the end of this document.

Equation 3: Establishing SCFs, by Vessel

$$(\text{SCF})_{\text{vessel-zone}} = \frac{(\text{Non-VSR speed})_{\text{vessel-zone, in knots}}}{(\text{Maximum rated speed})_{\text{vessel, in knots}}}$$

Table 3: Southern California Average SCFs, by Vessel Type

Vessel Type	VSR Zone			
	Santa Barbara Channel	POLA/POLB IMO Lane Arrival	POLA/POLB Departure & Inside 40 nm	Open Waters/ Remainder Southern CA
Auto & RoRo	0.66	0.47	0.53	0.73
Containership (small)	0.63	0.47	0.50	0.69
Containership (medium)	0.62	0.43	0.47	0.59
Containership (large)	0.58	0.42	0.46	0.63
Bulk	0.82	0.73	0.75	0.82
General Cargo	0.76	0.70	0.74	0.80
Tanker	0.80	0.70	0.74	0.75

Table 4: Bay Area and Monterey Bay Average SCFs, by Vessel Type

Vessel Type	VSR Zone		
	SF IMO Lane Arrival	SF IMO Lane Departure	Open Waters/ Marine Sanctuaries
Auto & RoRo	0.57	0.77	0.73
Containership (small)	0.57	0.70	0.63
Containership (medium)	0.52	0.62	0.60
Containership (large)	0.52	0.62	0.59
Bulk	0.71	0.81	0.78
General Cargo	0.66	0.79	0.78
Tanker	0.71	0.75	0.79

Additional parameters for determining the zones and how they were analyzed are listed below:

- In the San Francisco Bay Area and POLA/POLB IMO-designated lanes, SCFs were analyzed based on trip direction (arrival vs. departure) since vessels in these zones tend to travel at higher speeds after departing from the nearby port (compared to the arrival leg).
    - SCFs within the POLA/POLB 40 nautical mile VSR zone were averaged for the entire Northern route, while SCFs for the Southern route were averaged out to 25 nautical miles to stay consistent with the boundaries of the BWBS VSR Program.
    - Due to the lack of IMO-approved shipping lanes for the POLA/POLB Western route, no adjustments were made to account for differences between inbound and outbound speeds on this route. All speed data for the Western route was comparable to and incorporated into the POLA/POLB departure routes.
- The Santa Barbara Channel and remaining VSR zones outside the POLA/POLB 40 nautical mile radius are in open water and cover a greater distance, so vessel speeds have not been observed to correlate to transit direction to nearby ports.
- There are some smaller zones, such as the SF Precautionary Area and the POLA/POLB Precautionary Area, in which the program records cooperation with the slow-speed requests, but speed correction factors and emission calculations are not performed because the BWBS program most likely did not change ship behavior in these zones.
- For the ATBAs (Areas To Be Avoided) in Southern California, emission reductions are not calculated because the program requests the vessels to avoid these areas.
- In 2023, vessels were requested to prioritize use of the Western IMO-designated lane of the San Francisco TSS (Traffic Separation Scheme). Due to this request and other routing behavior changes since 2017, the SCFs for the Northern, Western, and Southern IMO-designated lanes for the Bay Area were averaged together.

4) Emission Reduction Calculations

For each enrolled fleet that complies with the program parameters, the program estimates the baseline speed for each participating vessel in each zone using the SCFs defined in the previous section. The baseline speeds are calculated using the following equation:

Equation 4: Determining Vessel Baseline Speeds

$$(\text{Baseline Speed})_{\text{vessel-zone}} = (\text{Max Rated Speed})_{\text{vessel}} * (\text{SCF})_{\text{vessel-zone avg}}$$

The emissions for each participating vessel are then calculated at both the baseline speed and at the observed VSR speed for each zone that it passes through on its transit. Vessels often travel through multiple zones, and an example is provided in Table 5 below to demonstrate the various baseline and observed speeds for an entire trip through the region.

Table 5: Example SCFs and Speeds for the MSC Eleni

[IMO #9278143; Small Containership with a Max Rated Speed of 24.3 knots]

Transit Date	Zone	SCF	Baseline Speed	Observed VSR Transit Speed	Observed VSR Transit Distance
8/4/2025	SB Channel	0.63	15.3 knots	9.8 knots	97.3 nm
8/4/2025	POLA Arrival	0.47	11.4 knots	9.4 knots	41.9 nm
8/5/2025	POLA Departure	0.50	12.1 knots	9.7 knots	42.0 nm
8/5/2025	SB Channel	0.63	15.3 knots	9.7 knots	97.1 nm

Equation 5: Emission Reductions

$$\text{Emission Reductions} = \sum(\text{Emissions})_{\text{Baseline Speed}} - \sum(\text{Emissions})_{\text{VSR Transit Speed}}$$

Since the AIS data for the VSR analysis is consolidated into segments, all segments with an observed distance-weighted speed of 11 knots or less will be attributed to the program calculations to account for any short-term vessel maneuvers that slightly exceeded the 10-knot target. Any activity from vessels that slowed down from their baseline speed – but did not achieve 11 knots – were excluded as these instances were most likely influenced by other factors outside the VSR program. Additionally, segments where a vessel has been observed to be at anchor or loitering in a VSR zone have been removed.

Emission calculations are performed for Oxides of Nitrogen (NOx), Oxides of Sulfur (SOx), Diesel Particulate Matter (DPM), and Greenhouse Gases (GHGs - as carbon dioxide equivalent (CO_2E)). All emission calculations are performed by Starcrest Consulting using the same emission factors and adjustments used for the POLA/POLB emission inventory.[2]

[2] Please refer to the San Pedro Bay Ports Emissions Inventory Methodology Report, found at: www.portoflosangeles.org/environment/air-quality/air-emissions-inventory.

5) Emission Reduction Results - 2025 VSR Season

The Blue Whales and Blue Skies VSR Program resulted in an estimated reduction of 1,491 tons of NOx, 37 tons of SOx, 8.9 tons of DPM, and 55,771 metric tons of Greenhouse Gases during the 2025 season. Compared to baseline conditions, these reductions signify a 27% decrease in NOx, SOx, and GHG emissions and an 18% decrease in DPM. The 2025 season results are also broken down by ship type, as shown in Table 6 below, to show their relative contributions.

To compare the 2025 season results to prior seasons and to demonstrate the on-going success and benefits of the BWBS VSR Program, the results from all VSR seasons are included in Table 7 below.

Table 6: 2025 VSR Season Results – Total, By Ship Type, and By Region

	# Vessels	Baseline Emissions				2025 Emission Reductions			
		NOx *(tons)*	SOx *(tons)*	DPM *(tons)*	CO_2E *(tonnes)*	NOx *(tons)*	SOx *(tons)*	DPM *(tons)*	CO_2E *(tonnes)*
Results, Total	**775**	**5,683**	**136**	**48.1**	**205,119**	**1,491**	**37**	**8.9**	**55,771**
Results, by Ship Type									
Container	408	4,820	114	39.2	171,702	1,309	31	6.1	46,686
Auto	211	388	10	3.9	14,518	91	3	0.9	3,948
Tanker	77	341	9	3.5	13,387	59	2	1.1	3,435
Bulk/General	79	134	3	1.5	5,512	31	1	0.7	1,701

Table 7: Summary of BWBS Air Emission Reductions – By Year

VSR Season	Duration	Basis	# Vessels	Emission Reductions			
				NOx *(tons)*	SOx *(tons)*	DPM *(tons)*	CO_2E *(tonnes)*
2014	4 months	Transit	14	12	0.4	0.1	537
2016	4.5 months		25	26	0.7	0.3	1,007
2017			44	84	1.9	1.1	2,630
2018		Fleet	295	266	6	2.6	8,668
2019	6 months		349	536	12	4.8	17,026
2020			482	748	16	4.8	24,258
2021			545	650	15	2.7	22,201
2022	7.5 months		671	921	22	4.7	32,604
2023			709	1,256	30	6.3	45,784
2024	8 months		743	1,405	33	8.4	49,945
2025	8.5 months	Fleet	775	1,491	37	8.9	55,771
			Total:	**7,394**	**174**	**44.5**	**260,432**

6) Areas of Further Research

Alternative Fuels: For the 2025 season, approximately 6% of the participating vessels were equipped with dual-fuel engines, meaning that they were capable of using alternative fuels such as Liquefied Natural Gas (LNG) or methanol. However, at this time, all vessels are assumed to be combusting conventional, low-sulfur marine diesel fuel in the VSR zones. Additional data collection and analysis is being performed by Starcrest Consulting to refine the dual-fuel usage parameters for future VSR seasons.

Maximum Speed vs Service Speed: In April 2025, the California Air Resources Board (CARB) published an update to their OGV emission calculation methodology. One component of CARB's methodology is that they use a linear regression analysis to help determine a reasonable maximum speed for those vessels that do not have their maximum speed listed in the IHS database. Currently, the BWBS methodology uses the vessel's service speed as the reasonable maximum speed if the maximum speed isn't listed in the IHS database. These differences in assumptions will be more thoroughly vetted and analyzed for future VSR seasons.

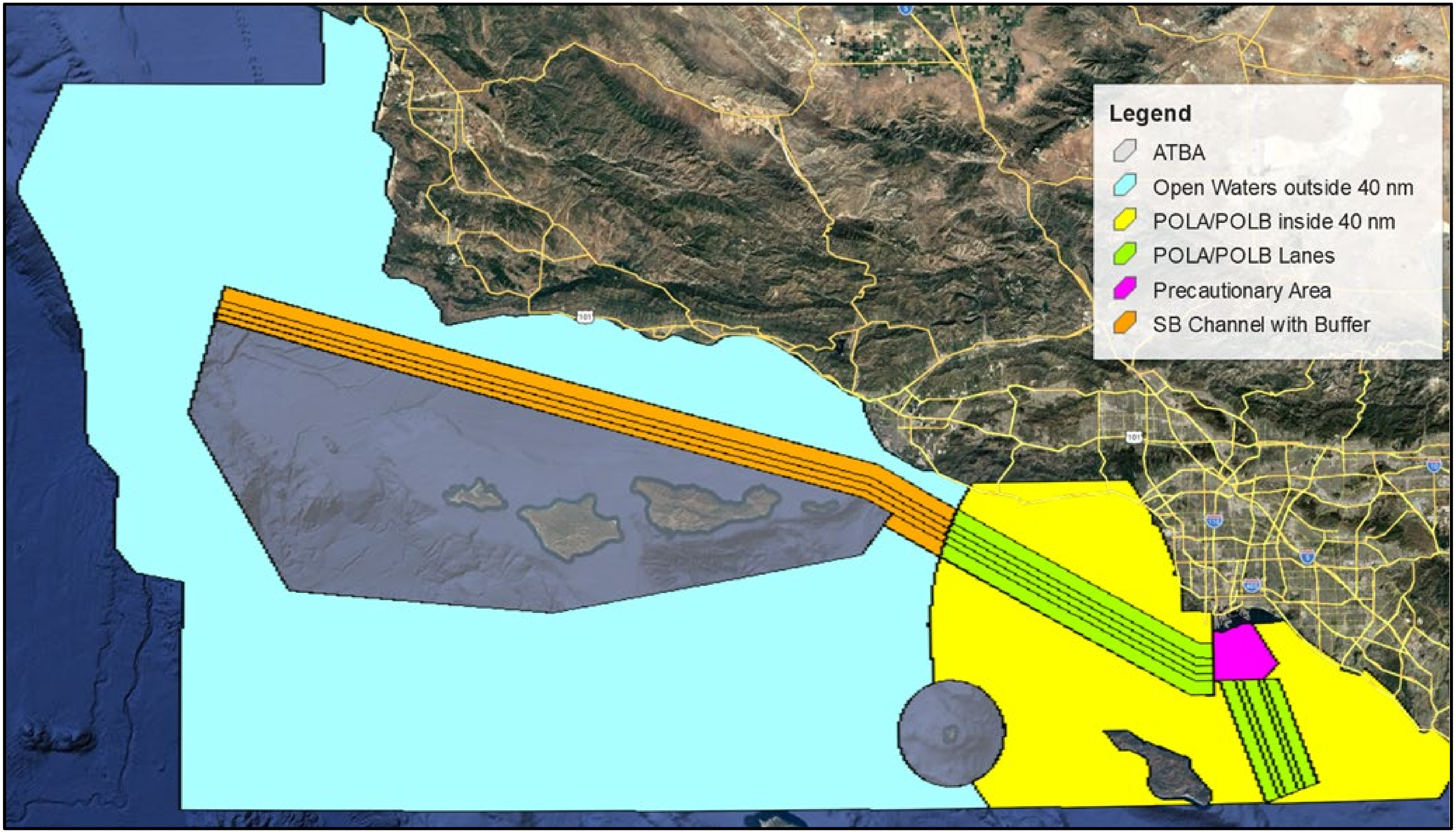
Low-Load Conditions: The low-load factors being used in the BWBS methodology are similar to those being used by both CARB and the U.S. EPA for their published OGV methodologies. However, the underlying data for these low-load factors are over 10 years old, and new studies are being performed to help further refine the factors, with some studies focusing on Tier 2 and Tier 3 OGV main engines at low-loads (<25%). These studies are being tracked, as they may lead to additional methodology improvements for future VSR seasons.

7) Closing Thoughts

The BWBS partners will continue to engage with technical experts, such as Starcrest Consulting and CARB, to make sure that the emission estimates presented in this methodology are defensible. Further collaboration with the technical experts can help refine the assumptions used in the methodology and allow for additional discussions on emerging data that reflect real-world emissions.

The BWBS partners also acknowledge that there are many competing factors that influence ship behavior in the region, such as fuel costs, timing restraints, and company-specific economic and environmental goals. However, using a 2016 - 2017 baseline speed comparison is still appropriate because the program has helped instill good environmental practices in the region over the last decade. Additional analyses performed by the BWBS partners show that participating companies are slowing down to VSR speeds more often during the off-season, resulting in additional benefits to air quality, whale risk, and ocean noise reduction. These additional benefits are not quantified in this analysis, but they provide further justification to maintaining the 2016 - 2017 baseline, as vessel operators are unlikely to slow down to 10 knots or less without the established BWBS zones.

Appendix A: Southern California Methodology Map



Appendix B: San Francisco Bay Area and Monterey Bay Methodology Map