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Estimated reduction in whale ship-strike risk during the 2025 Protecting Blue Whales and Blue Skies voluntary vessel speed reduction program in California waters

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Blue Whales
Blue Skies

Background and scope

Ship-strikes are a leading cause of mortality to large whales in California and around the world. One of the environmental objectives of the voluntary Vessel Speed Reduction (VSR) requests implemented by NOAA and supported by the Protecting Blue Whales and Blue Skies (BWBS) incentive program is to reduce ship-strike risk to threatened and endangered populations of whales off California, including blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus),* and humpback whales (*Megaptera novaeangliae)*.

In this analysis, we use encounter rate models to calculate the proportional reduction in risk of fatal strikes on whales associated with reducing vessel speeds compared to scenarios in which vessels maintained baseline speeds. To do this, we calculated baseline speed for vessels during the 2025 non-VSR season (January 15 - April 30), as well as baseline speeds from this same period of 2016 (January 15 - April 30). Vessel speeds in the region have been decreasing over time, so a historical comparison to vessel behavior in 2016 sheds light on the risk reduction benefits accrued over the life of the program relative to past vessel behavior. We calculated risk reduction both for vessels enrolled in the BWBS program, as well as for all vessels >108m transiting through the VSR zones. This assessment was done for all VSR zones combined, as well as separately for VSR zones in northern California (including Monterey Bay, Greater Farallones, and Cordell Bank National Marine Sanctuaries [NMS]) and southern California (including Chumash Heritage NMS and the area encompassing Channel Islands NMS and the Santa Barbara Channel).

Key takeaways

For vessels >108m enrolled in the BWBS program, speed reductions during the 2025 VSR season were associated with a 25.5% reduction in ship-strike risk to blue whales when compared to vessel speeds during the 2025 non-VSR season. When compared to speeds during the 2016 non-VSR season, risk was reduced by 39.7%. Risk reduction estimates were similar across species, and full results are presented in Table 1. Risk reduction was higher in the northern CA zones (28.7% compared to 2025 baseline, and 42.9% compared to 2016 baseline) relative to the southern CA zones (24.5% compared to 2025, and 38.2% compared to 2016), due to the higher vessel speeds during baseline periods in northern CA. The risk reduction benefit calculated across all vessels >108m (i.e., all vessel transits including those from companies not enrolled in the BWBS program) was less than estimates for enrolled vessels only - 19.8% compared to the 2025 baseline and 35.0% compared to the 2016 baseline, reflecting higher mean speeds during the VSR season.

Risk reduction estimates were lower for the 2025 season relative to prior years, reflecting an update in risk reduction modeling rather than changes in vessel cooperation. Specifically, a new model for the probability of mortality given that a collision occurred shows that for larger vessels, collisions even at slower speeds have a high probability of causing mortality (Garrison et al. 2025). While updating the model in accordance with best available science results in lower estimates of risk reduction, we still see a substantial reduction in risk, both within-year and compared to historic patterns of vessel behavior.

Methods

Encounter rate models predict mortality from whale-ship collisions based on whale and vessel density and characteristics, including vessel speed and size (Martin et al. 2016, Rockwood et al. 2017, Blondin et al. 2025) (Equation 1):

$$M = \lambda_e t P(Strike\ depth)(1 - P(Avoidance))P(Mortality)N_m N_b \quad \text{(Equation 1)}$$

Where for each grid cell, λ_e is the encounter rate between whales and ships and depends on vessel speed, whale swim speed, whale and vessel sizes, and study area size, t is the total time of vessel transits, *P(Strike depth)* is the probability that a whale will be within the depth susceptible to strike, *1-P(Avoidance)* is the probability that a whale will not avoid a ship and depends on vessel speed, *P(Mortality)* is the probability that a collision will be lethal and depends on vessel speed, N_m is the number of whales, and N_b is the number of vessels.

We are not able to utilize these full models because we lack temporally- and spatially-explicit information on whale densities for our study period. However, using these models, it is possible to evaluate the proportional risk reduction associated with reducing vessel speeds. To do this, we assume that all other components of the model besides vessel speed remain constant, meaning that those components cancel out. Terms that are not related to vessel speed, and thus which are assumed constant across the two scenarios, include *P(Strike depth)*, N_m, and N_b.

To calculate the reduction in ship-strike mortalities associated with a VSR, we can calculate the percent reduction in mortalities under different vessel speed scenarios based on the relative risk associated with vessel speed (Equation 2):

$$RelativeRisk = \lambda_e(1 - P(Avoidance))P(Mortality) \quad \text{(Equation 2)}$$

As in (Rockwood et al. 2017, 2020), the probability of avoidance is a logistic function related to vessel speed (Equation 3):

$$P(Avoidance) = 1 - \frac{0.9}{1 + e^{-0.15(v_b - 6.1)}} \quad \text{(Equation 3)}$$

The model of probability of mortality given that a collision occurred is from Garrison et al. (2025), and represents a major change relative to prior ship-strike risk reduction modeling for the Protecting Blue Whales and Blue Skies program. Previous risk reduction estimates used a model by Conn and Silber (2013), which was based on an analysis of 90 whale-ship collisions, in which larger ocean-going vessels were underrepresented (Conn and Silber 2013). The Garrison et al. (2025) model serves as an update to this model, by improving sample size (n=201), incorporating more data from larger vessels, and incorporating vessel length and whale species as additional predictors of probability of mortality. The Garrison et al. (2025) model predicts higher rates of mortality given collision for large vessels, even at lower speeds, which is consistent with a recent biophysical model of whale-ship collision outcomes (Kelley et al. 2021). As such, using the Garrison et al. (2025) model rather than the Conn and Silber (2013) model will result in higher risk of mortality overall, as well as a lower reduction in risk associated with VSR. Nevertheless, the Garrison et al. (2025) model should be considered the best available science for the probability of whale mortality given a vessel collision.

Percent reduction in risk between two scenarios (i.e. vessel speed reduction (VSR) and non-VSR periods) are calculated based on the relative risk in both scenarios (Equation 4):

$$Percent\ Reduction = 100 * \left(1 - \frac{RelativeRisk(VSR)}{RelativeRisk(nonVSR)}\right) \quad \text{(Equation 4)}$$

To evaluate the impact of the 2025 VSR on ship-strike risk, we used AIS data from all transits of vessels within the 2025 VSR zones in California, including Monterey Bay, Greater Farallones, and Cordell Bank National Marine Sanctuaries (northern CA zone), as well as

Chumash Heritage NMS and the area encompassing Channel Islands NMS and the Santa Barbara Channel (southern CA zone). We filtered out data from non-transitting vessels (< 0.2 knots). We calculated distance-weighted mean transit speed over ground for each vessel transit. We subset the data to include vessels >108m in length, corresponding to the "Extra Large" size class in the Garrison et al. (2025) model and representing the vast majority (>99.5%) of vessel traffic from BWBS-participating companies.

We used Equation 4 to evaluate the reduction in risk associated with (1) within-year speed reduction for BWBS-participating vessels, (2) within-year speed reduction for all vessels, (3) long-term reduction in vessel speeds for participating vessels, and (4) long-term reduction in vessel speeds for all vessels. For the within-year comparisons (1 and 2), mean speeds were compared between the VSR season (May 1, 2025 - January 15, 2026) and non-VSR season (January 15, 2025 - April 30, 2025). For the long-term comparisons (3 and 4), we compared mean speeds within the 2025 VSR season to the same off-season period during 2016 (January 15, 2016 - April 30, 2016). We conducted long-term comparisons because vessel speeds have been decreasing over time, due to a combination of the BWBS program and a variety of other regional factors (Morten et al. 2022). A historical comparison allows us to evaluate reduction in risk over the life of the BWBS program.

Results

For vessels enrolled in the BWBS program, reducing vessel speeds during the 2025 VSR season resulted in a 24.0-25.5% change relative to the 2025 non-VSR season across species across both regions (Table 1). By region, there was a 27.0-28.6% change in Northern CA and a 23.0-24.5% change in Southern California, which reflects the higher mean speed in Northern CA during the 2025 off-season. Relative to the non-VSR season in 2016, speed reduction by enrolled vessels resulted in risk reductions of 37.9 - 39.7% across regions, 41.0-42.9% in Northern California, and 36.3-38.2% in Southern California.

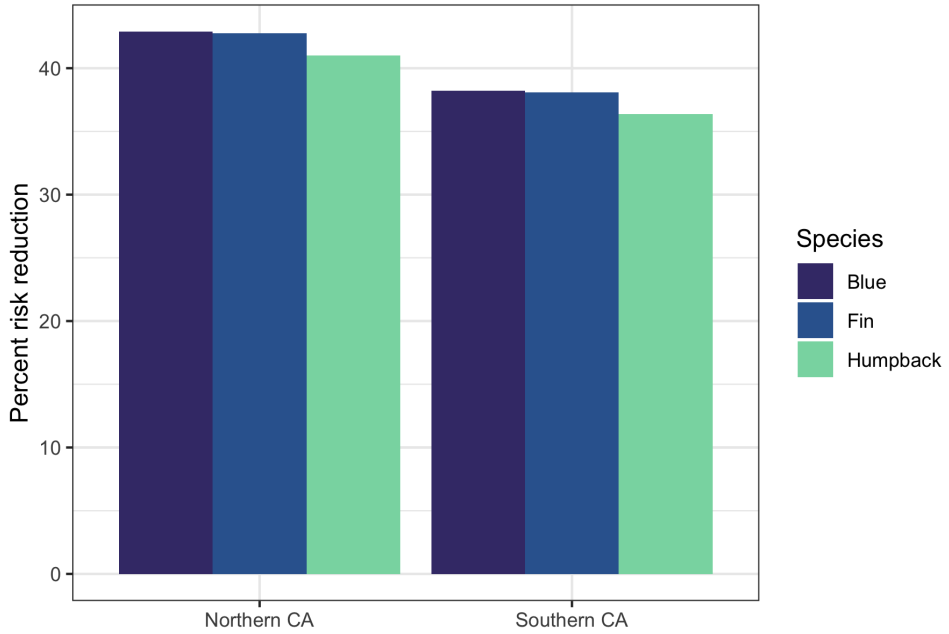

Figure 1. Reduction in ship-strike risk for BWBS-enrolled vessels based on reducing vessel speeds during the 2025 VSR season relative to vessel behavior in 2016, by species and region.

For all vessels, including enrolled vessels as well as vessels for companies not enrolled in the BWBS program, reducing vessel speeds resulted in a 19.7-19.8% reduction in risk across the entire region, with a 23.6-23.7% reduction in Northern California and a 18.5-18.6% reduction in Southern California, relative to the 2025 non-VSR season (Table 2). Relative to the non-VSR season in 2016, speed reduction across all vessels in the 2025 VSR period resulted in risk reductions of 34.9-35.0% across regions, 39.2-39.3% in Northern California, and 33.0-33.1% in Southern California.

Table 1. Vessel speeds and ship-strike risk reduction of participating vessels >108m in the 2025 BWBS vessel speed reduction program. Risk reduction is the proportional reduction in risk associated with traveling at reduced speeds relative to a scenario where speeds remained the same as a baseline period. Two baseline periods were considered: a historical baseline (the non-VSR period in 2016) and a within-year baseline (the non-VSR period in 2025).

	Mean speed (knots)			Percent change relative to 2016			Percent change within 2025		
Region	2016 non-VSR	2025 non-VSR	2025 VSR	Blue	Fin	Humpback	Blue	Fin	Humpback
Northern CA	13.403	11.650	9.391	42.902	42.779	41.016	28.569	28.463	27.019
Southern CA	12.711	11.204	9.354	38.205	38.084	36.381	24.476	24.379	23.076
Combined	12.921	11.311	9.361	39.732	39.611	37.883	25.517	25.417	24.076

Table 2. Vessel speeds and ship-strike risk reduction of all vessels >108m (both those enrolled in the BWBS program as well as vessels from non-enrolled companies) in the 2025 BWBS vessel speed reduction program. Risk reduction is the proportional reduction in risk associated with traveling at reduced speeds relative to a scenario where speeds remained the same as a baseline period. Two baseline periods were considered: a historical baseline (the non-VSR period in 2016) and a within-year baseline (the non-VSR period in 2025).

	Mean speed (knots)			Percent change relative to 2016			Percent change within 2025		
Region	2016 non-VSR	2025 non-VSR	2025 VSR	Blue	Fin	Humpback	Blue	Fin	Humpback
Northern CA	13.403	11.612	9.767	39.342	39.230	39.247	23.721	23.634	23.647
Southern CA	12.711	11.235	9.844	33.153	33.050	33.065	18.665	18.592	18.603
Combined	12.921	11.320	9.828	35.046	34.940	34.955	19.825	19.748	19.760

Discussion

By participating in the 2025 VSR program, enrolled vessels reduced ship-strike risk by 24.0-25.5% compared to what risk would have been had they maintained their off-season (non-VSR) speeds. Vessel speeds have been decreasing in this region over time, meaning that risk to whales during and outside of the VSR season has decreased compared to prior years – indeed, this analysis found that ship-strike risk was reduced by almost 40% during the 2025 VSR season relative to vessel behavior in 2016. Importantly, the VSR zones have increased in area over the course of the program, including in 2025 when Chumash Heritage NMS was added, resulting in a larger area in which risk is reduced and thus greater absolute benefit to whales.

It is important to note that the simplified version of the encounter rate models used to quantify the risk reduction does not account for spatial patterns in whale density. The only parameters that varied across whale species include species' size and mean swimming speed, which have negligible effects on mortality rate model components relative to other parameters (Rockwood et al. 2017). Additionally, our analysis excluded vessels <108m, corresponding to the extra large size category that mediates the probability of mortality given collision model. This corresponds to nearly all (>99.5%) of vessels enrolled in the BWBS program in 2025. However, it is important to note that traffic from high-speed craft <108m in length, which regularly operate in the region, were not included in the "all vessels" analysis.

Estimates in risk reduction for 2025 were lower than for prior years, due to advances in the scientific literature around ship-strike risk modeling. The updated model for the probability of mortality given that a collision occurs is built on a larger sample size overall, includes more data from large ocean-going vessels, and found that even at slower speeds, collisions with larger vessels are likely to result in mortality (Garrison et al. 2025). Updating the risk reduction modeling methods to reflect the best available science thus resulted in estimated risk reductions of lower magnitude relative to prior years. Nevertheless, this analysis still indicates substantial reduction in risk to endangered whale populations associated with the voluntary VSR program.

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