



SONARPOINT • ARRAY DESIGN

How far apart can SonarPoint moorings be?

Species, terrain, mooring spacing and the size of the area you can map. Evidence from U.S. Navy LMR Deployment 1.3, Monterey Bay, California.

≈ 24 km

farthest mooring that still heard 90% of localized humpback and blue whale calls

≈ 13 km

the same distance for dolphins; their signals fade much faster with range

≈ 830 km²

predicted area mapped to better than 250 m by 11 moorings on an 8 km ring

1 Why spacing is the key design choice

A SonarPoint array locates a caller from the small differences in when its sound reaches each mooring. To do that, **the same call has to be heard by at least four moorings**. Spreading moorings out makes the mapped area larger and, inside the array, makes positions more accurate. But it also makes each call travel farther to the most distant moorings, and past some distance those moorings stop hearing it. The right spacing is therefore set by the animals you want to study, by the seafloor around the array, and by how much accuracy you need.

LMR 1.3 gave us a direct measurement of these limits. Four moorings (M1, M3, M4 and MARS, 2.3–8.2 km apart, hydrophones about 7 m above a 750–1000 m deep seafloor) recorded for 12 days in October–November 2025 and produced 166,000 positions from four groups of callers. Because there were only four moorings, every position required all four to hear the call. That makes the deployment a clean test: **the distance to the farthest mooring is a distance at which detection demonstrably worked**. This note updates our July 2026 spacing recommendations with the accuracy and terrain results obtained since.

2 How far each species can be heard

Figure 1A shows, for every localized call, how far the caller was from the farthest mooring. The species fall into two clear groups.

Caller	Main energy in LMR 1.3 recordings	Median	75%	90%	Max	Calls
● Humpback whale	song, about 80 Hz – 3 kHz	14.3 km	20.0 km	24.2 km	36 km	157,726
● Blue whale	about 15 – 45 Hz	11.2 km	19.2 km	24.7 km	36 km	1,083
● Fin whale	about 20 Hz pulses	9.5 km	12.9 km	18.3 km	36 km	996
● Dolphins (delphinids)	whistles and burst pulses, about 1 – 8 kHz and up	9.1 km	11.1 km	13.4 km	36 km	6,333

Distance from the localized caller to the farthest of the four moorings. Percentiles describe where calls were localized, not the probability of detecting a call at that distance.

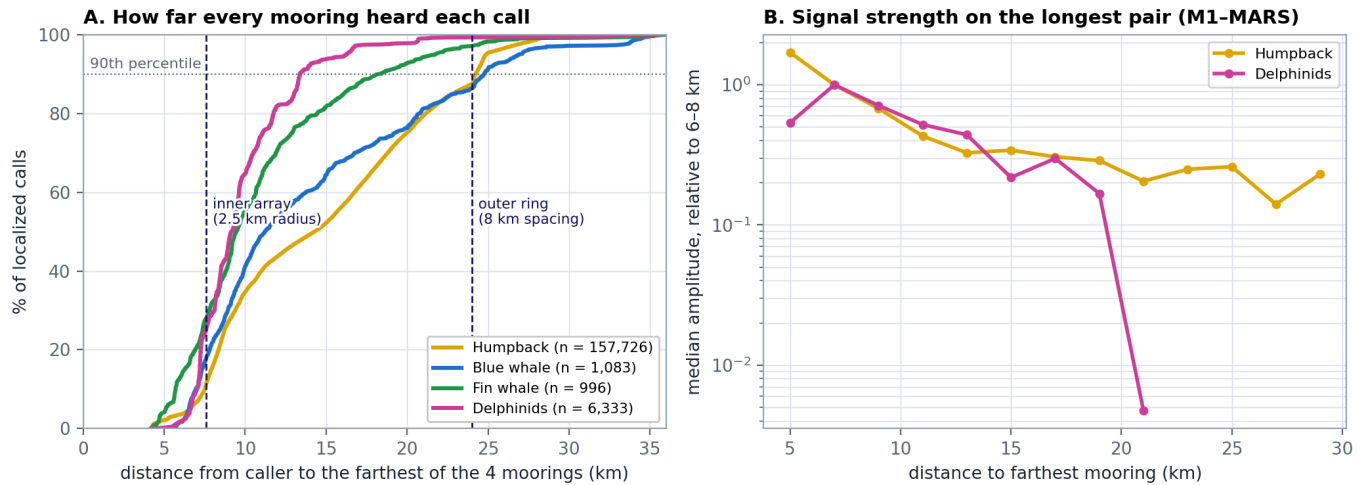


Figure 1. (A) Share of localized calls versus distance to the farthest mooring. Dashed lines: the farthest-mooring distance at the edge of the well-mapped area for a 2.5 km inner array and for an 8 km outer ring (section 4). (B) Median cross-correlation amplitude on the longest mooring pair, M1-MARS, versus distance, scaled to 1 at 6-8 km. Bins with fewer than 20 calls are omitted.

Why dolphins drop out first. Seawater absorbs high frequencies much more strongly: about 1 dB per km at 10 kHz, a few hundredths of a dB per km at 1 kHz, and essentially nothing at the 15-45 Hz of blue and fin whales. Dolphin sounds are also beamed forward, so a mooring behind or beside the animal hears a weaker signal. Figure 1B shows the result: dolphin signal strength keeps pace with humpback song out to about 13 km, then falls faster and collapses beyond about 19 km. Only 2% of dolphin positions came from beyond 19 km, compared with 29% for humpbacks.

Why fin whales sit in between. Their 20 Hz pulses travel far, but in LMR 1.3 they were detected less often at long range than blue whales or humpbacks. We do not know whether this reflects the animals' positions, calling levels or the detector, and we treat 18 km as the fin whale design value until more data are available.

3 Hydrophone height and terrain shielding

Each LMR 1.3 hydrophone sat only 7.3 m (24 ft) above the seafloor, on the walls and floor of Monterey Canyon. A low hydrophone in a canyon can be hidden from parts of the bay by the surrounding terrain. To test whether this mattered, we traced straight lines from a whale calling at 50 m depth to each hydrophone across the GMRT bathymetry grid (Figure 2A). This is a simple geometric check; real sound bends (refracts) and spreads around obstacles (diffracts), especially at low frequency.

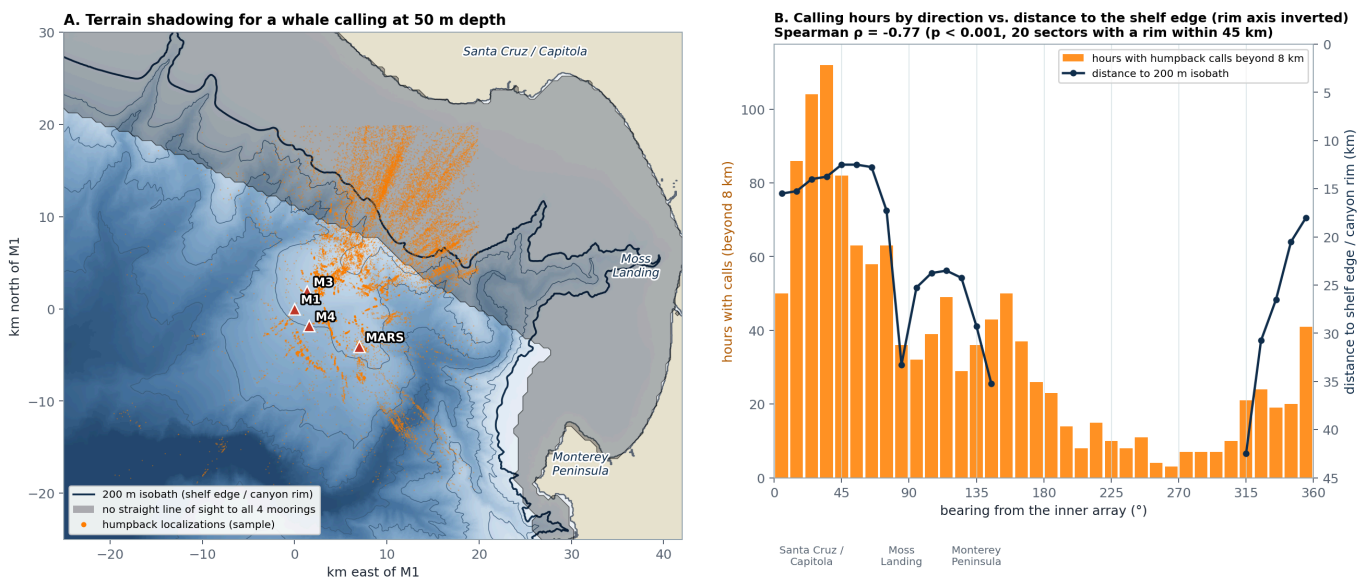


Figure 2. (A) Gray: areas from which a whale calling at 50 m depth has no straight line of sight to all four hydrophones (7.3 m above the seafloor). Orange: humpback positions. Dark line: 200 m isobath (shelf edge and canyon rim). (B) Hours with humpback calls beyond 8 km in each 10° direction (bars) against the distance from the array to the shelf edge in that direction (line, axis inverted).

Three observations stand out:

- **Lines of sight end at the canyon rim.** Toward the north-northeast they are lost about 10–12 km out, toward Moss Landing at 15–19 km, and to the southeast at 26–31 km. M4, deepest in the canyon and shielded by Smooth Ridge, loses sight first.
- **Humpbacks were found where the rim is close.** Calling hours by direction track the distance to the shelf edge closely (Spearman $\rho = -0.77$, $p < 0.001$, 20 directions). The bright streaks to the north-northeast point straight at the nearest stretch of rim.
- **The shelf was not completely silent.** Some humpbacks were still localized over the shelf, beyond the line-of-sight limit, so terrain weakens rather than blocks low-frequency sound. High-frequency dolphin signals, which bend around obstacles less, should be affected more.

We cannot separate cleanly how much of the pattern reflects where the whales actually were (they may favor the rim) and how much reflects what the array could hear. Both point to the same design advice. Our redundancy work found the same effect for the array's own timing pings: they fade beyond about 100 times the pinger's height above the seafloor.

IN THE FIELD

- Before choosing sites, run a line-of-sight check on the best available bathymetry toward each area you want to cover.
- Prefer high ground (ridges, canyon shoulders) over channel floors for outer moorings. A few meters of extra height matter most at the edge of a slope.
- Where the target area lies beyond a rim, consider a taller mooring that lifts the hydrophone higher, within the float rating.

4 Spacing, mapped area and accuracy

To compare designs, we use the same geometry model as our accuracy note, with timing noise calibrated to the LMR 1.3 playback test. The model predicts the typical (1σ) position error at any point. Inside the LMR 1.3 array it gives about 41 m, in line with the 62–75 m measured from GPS-referenced playback once a small fixed offset is included.

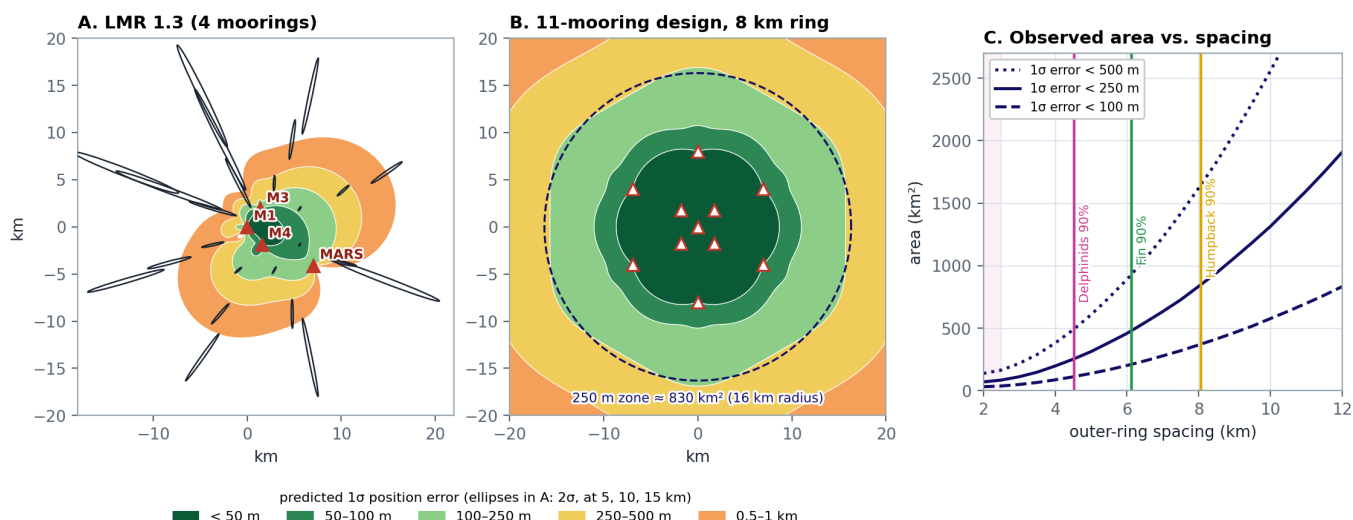


Figure 3. Predicted 1σ horizontal error. (A) LMR 1.3. Ellipses show the 2σ uncertainty at 5, 10 and 15 km from the array: long along the line of sight, narrow across it (capped at 12 km for display). (B) The planned 11-mooring design: 5 moorings within 2.5 km of the center and 6 on an 8 km hexagonal ring. Dashed circle: the 250 m contour. (C) Area mapped to better than 100, 250 and 500 m as the ring spacing changes. Vertical lines: ring spacing at which the farthest-mooring distance at the edge of the 250 m zone equals each species' 90th-percentile detection distance from the table in section 2.

Area grows with the square of spacing. Doubling the ring spacing roughly quadruples the area at any accuracy level. For the 11-mooring layout:

Ring spacing	Area < 50 m	< 100 m	< 250 m	< 500 m	Farthest mooring at edge of 250 m zone
4 km	54 km ²	87 km ²	197 km ²	381 km ²	12 km
6 km	125 km ²	201 km ²	460 km ²	889 km ²	18 km
8 km	224 km ²	365 km ²	832 km ²	1,617 km ²	24 km
10 km	352 km ²	575 km ²	1,316 km ²	2,558 km ²	30 km
LMR 1.3, for reference	10 km ²	31 km ²	83 km ²	165 km ²	—

The detection limit sets the useful spacing. The 250 m zone of a hexagonal array extends about twice the ring spacing from the center, and a caller at its edge is about three ring spacings from the farthest mooring. For an 8 km ring that is 24 km, which matches the 90th-percentile

detection distance of humpback and blue whales in LMR 1.3. A wider ring would add area on paper that the far moorings could not reliably hear. For fin whales the same reasoning gives about 6 km and for dolphins about 4.5 km (Figure 3C).

More moorings relax the "all must hear" rule. With 11 moorings a call only needs to reach the nearest four or five. On the 8 km design, a dolphin within about 13 km of at least five moorings can be anywhere in roughly 580 km². These dolphin fixes rest on the nearest few moorings, though, so their accuracy resembles that of a small array, and the inner cluster remains where dolphins are both heard by many moorings and positioned accurately.

5 Inside versus outside the array

Position quality changes character at the edge of the array, and users should read maps with this in mind.

Inside the array, errors are small and roughly round. Playback fixes landed 62–75 m from GPS, about 1% of the 8.1 km baseline. Errors grow only slowly across the interior, and a mooring placed off the main axis improves them further.

Outside the array, the distance to the caller becomes uncertain much faster than its direction. Range error grows with the square of distance. In the playback test, fixes 0.7–2 km outside the array were 360–790 m off. For LMR 1.3 the model predicts a typical range error of about 160 m at 3 km from the array center, 0.9 km at 10 km and 2.2 km at 15 km.

Direction stays reliable. The across-range error at 15 km is only about 110 m, so uncertainty ellipses become long and thin, roughly 1.4 times longer than wide for every kilometer of distance. On maps this produces the radial "flashlight beam" streaks seen in LMR 1.3 (Figure 2A). Re-solving distant calls that had been pinned to the edge of the search grid moved them outward along these beams, to a median of about 30 km, while their direction changed by only 1–2°.

Practical reading: treat positions well outside the array as reliable bearings with an approximate range. Use the per-fix residual check to screen out bad fixes in both regions.

6 Recommendations

Target	Spacing	Why
Dolphins and other high-frequency callers	Compact cluster of at least 4–5 moorings within 2.5 km of a center	Keeps every mooring well within the 9–13 km over which dolphins were reliably heard, with margin for directional sounds and shielding. 93% of LMR 1.3 dolphin fixes lay within 9 km of all four moorings.
Fin whales	Outer ring up to about 6 km	90th-percentile detection distance about 18 km. Treat as provisional: fin whale sample (996 calls) is small.
Humpback and blue whales	Outer ring up to about 8 km (8.5 km in our July note)	Edge of the 250 m zone is 24 km from the farthest mooring, the 90th-percentile detection distance. Gives about 830 km ² at better than 250 m.
Mixed communities	Dense inner cluster plus an 8 km outer ring (the 11-mooring design)	The cluster serves dolphins and gives the best accuracy at the center; the ring extends baleen coverage.

These values are deliberately conservative: they are based on what one deployment, in one season and one canyon, achieved. Ambient noise, season, depth and the calling behavior of the animals will shift them. We encourage users to start at or inside these spacings and widen them as their own data justify it.

IN THE FIELD

- Decide which species matter most, then set the spacing from the most demanding one in the table above.
- Add at least one mooring off the main axis. A near-linear array, like LMR 1.3, is accurate along its axis but weak across it.
- Check lines of sight from each candidate site to the target area before deployment (section 3).
- Plan for one more mooring than strictly needed: a single silent or shielded mooring removes many fixes from a four-mooring array.

7 Limitations

- One deployment.** All detection distances come from 12 days in autumn 2025 in Monterey Canyon. Other sites, seasons and noise conditions will differ.
- Where animals were versus what was heard.** Detection distances mix animal distribution with array sensitivity. A species that simply stayed close to the array will appear to have a short detection range.
- Model, not measurement, for new layouts.** The area figures for larger arrays come from a geometry model calibrated to LMR 1.3 playback. They assume every mooring hears the call and clocks are synchronized. The model's area below 250 m (about 830 km²) agrees with the

"about 800 km²" in our accuracy note; its inner-area error is somewhat larger than that note's 25 m estimate, which used a lower timing-noise assumption.

- **Simplified terrain analysis.** The line-of-sight check ignores refraction and diffraction, and the bathymetry grid smooths small features near the hydrophones.
- **Dolphins as one group.** Different dolphin species and sound types (whistles, burst pulses, clicks) will have different ranges.

Bottom line

- Baleen whales were reliably localized with the farthest mooring about 24 km away; dolphins about 13 km. These set the useful spacing: about 8 km rings for humpback and blue whales, and a compact 2.5 km cluster for dolphins.
- Mapped area grows with the square of spacing. 11 moorings on an 8 km ring are predicted to map about 830 km² to better than 250 m, and about 220 km² to better than 50 m.
- Inside the array, expect errors around 1% of mooring spacing. Outside, direction stays good but distance becomes uncertain quickly.
- Low hydrophones in a canyon can be shielded by the rim. Check lines of sight and favor high ground for outer moorings.

Related application notes: *How accurate is a sparse SonarPoint array?* · *Built to come back: redundancy in SonarPoint arrays* · *SonarPoint Localization Array: Species-Specific Recommendations for Recorder Spacing* (22 July 2026, superseded by this note). Contact: Marco Flagg, m.flagg@desertstar.com.