

Supplementary Materials

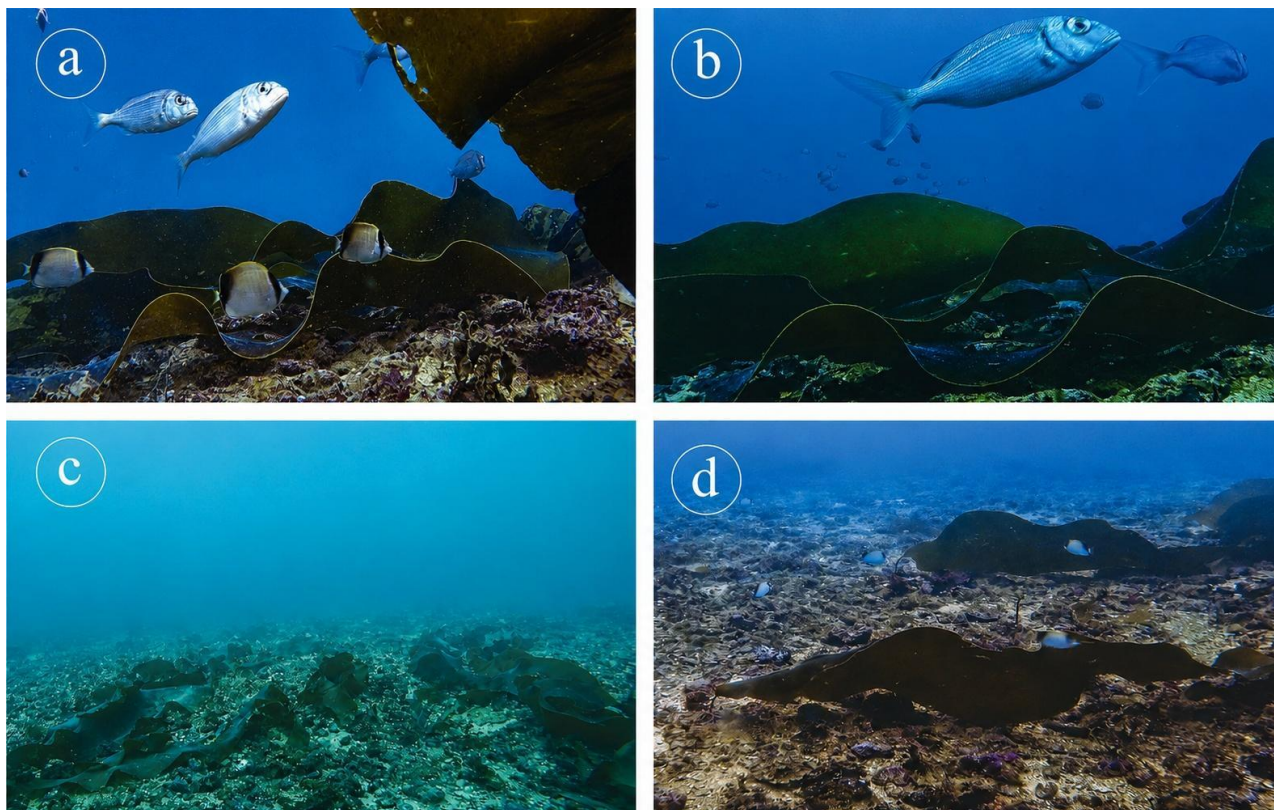


Figure S1. In situ Dropcam imagery of the mesophotic *Laminaria abyssalis* habitat on the central Brazilian shelf. Panels (a) and (b) show reef-associated fishes and mobile fauna among kelp blades; panels (c) and (d) show the broader bed structure and kelp growth over rhodolith and rocky substrates. Images were collected during the austral summer of 2024 at approximately 55 m depth. These photographs are qualitative habitat documentation only. No artificial lighting array was active during image acquisition; no calibrated laser scale, stereoscopic reference, or fixed field-of-view calibration was available, so organism size, canopy cover, and spatial dimensions cannot be quantified from the frames.

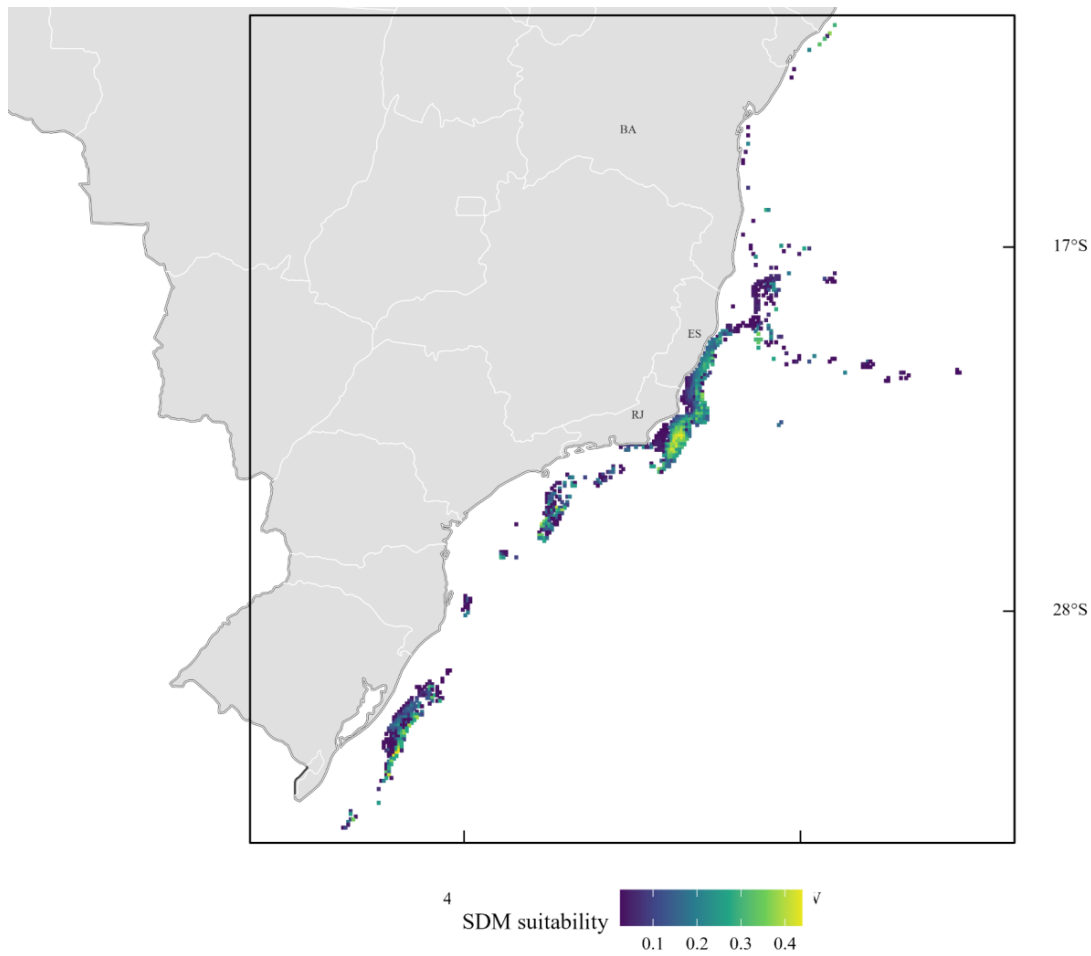


Figure S2. Uncropped present-day ensemble species-distribution-model input for *L. abyssalis*. Viridis colors show relative SDM suitability across the complete raster extent; land and Brazilian state boundaries provide geographic context. The map is shown for model-domain transparency and is not interpreted as abundance, occupied cover, biomass, productivity, export, or retained carbon.

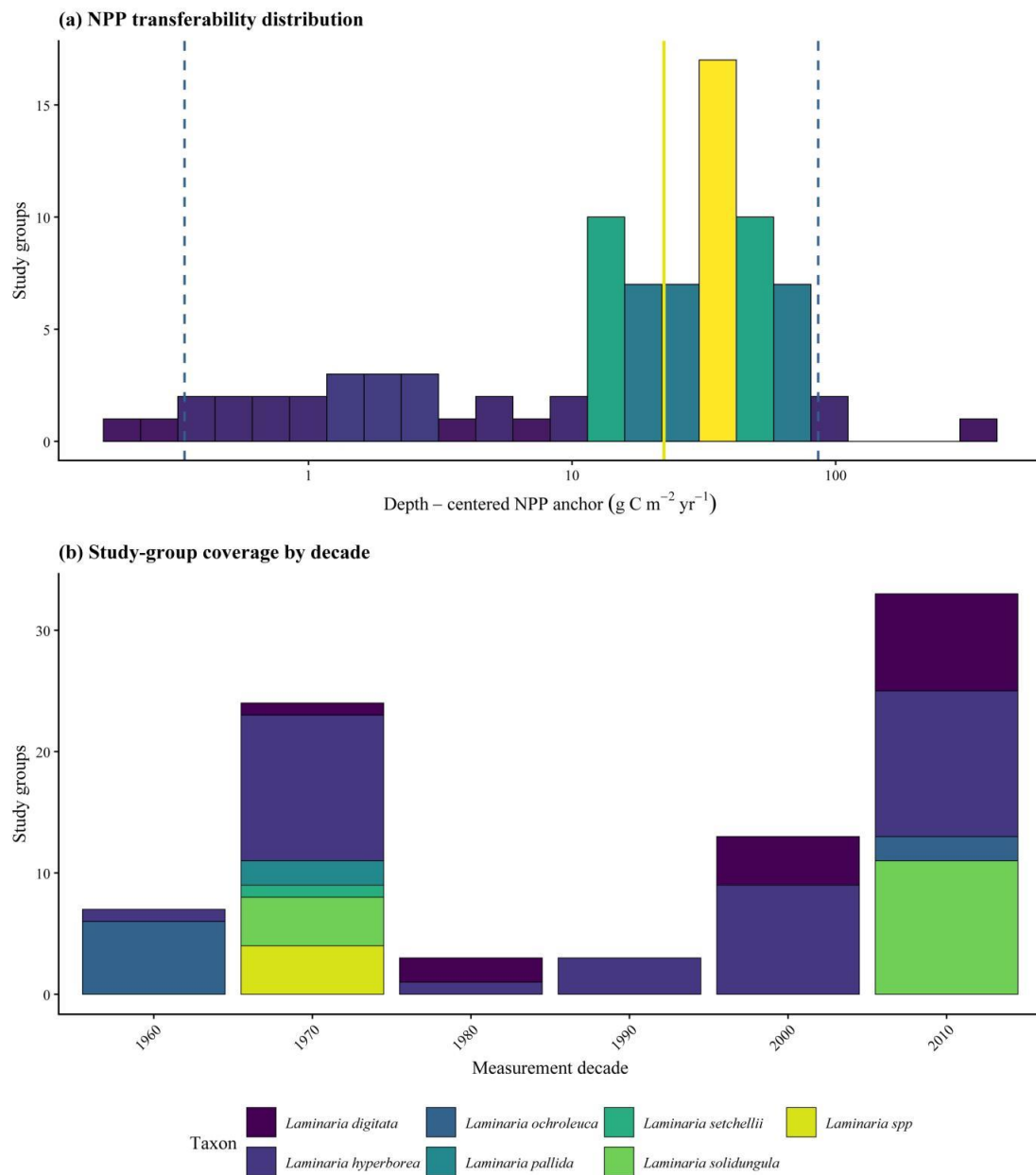


Figure S3. Historical *Laminaria* productivity evidence used to define the empirical transferability envelope. Panel (a) shows the study-group distribution of depth-centered NPP anchors on a logarithmic axis; the solid yellow line marks the $22.32 \text{ g C m}^{-2} \text{ yr}^{-1}$ depth-overlapping analog and the dashed lines mark the empirical 2.5th and 97.5th percentile anchors. Panel (b) summarizes study-group coverage by measurement decade and taxon. The evidence base comprises 133 positive records consolidated into 86 species-reference-site groups from seven taxa and 26 source references. The envelope is a genus-level extrapolation audit, not a confidence interval for *L. abyssalis*.

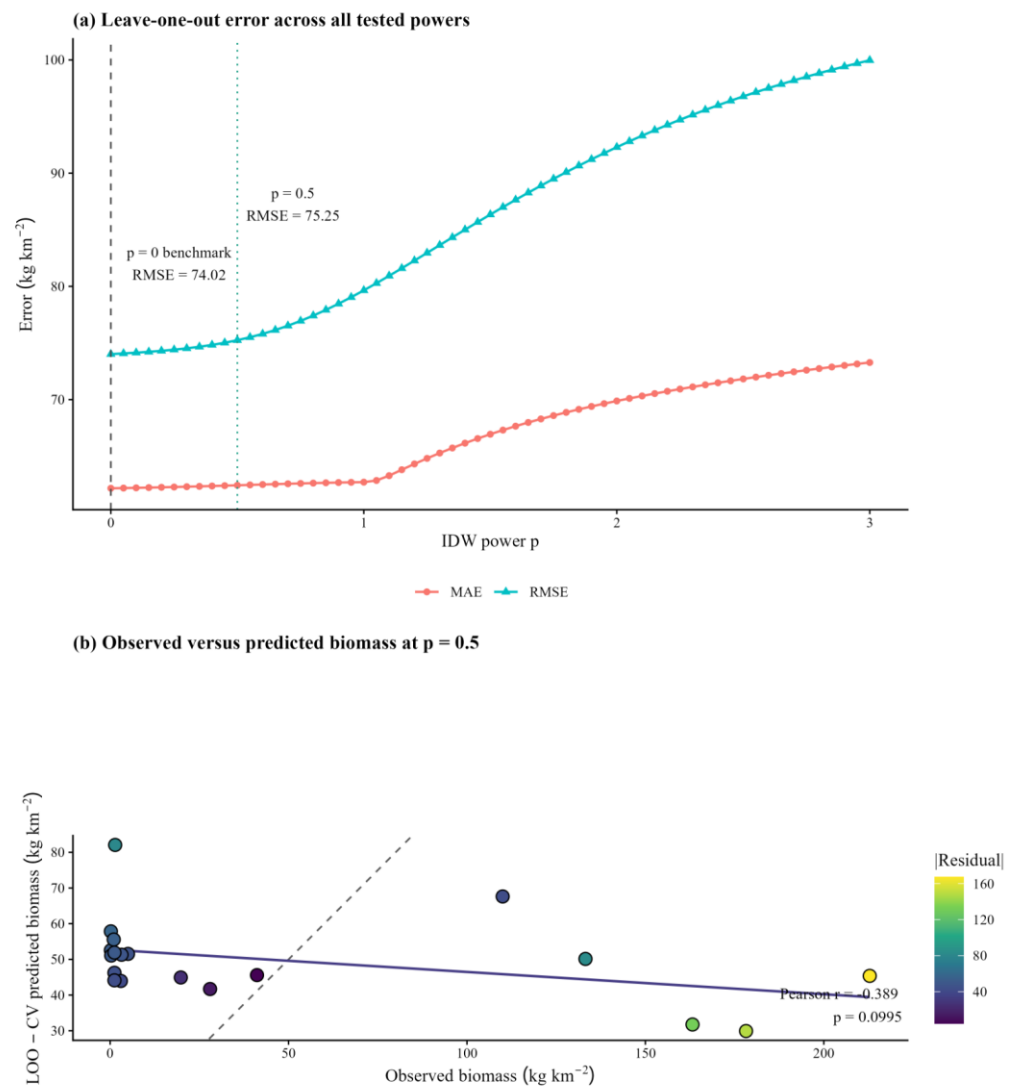


Figure S4. Complete inverse-distance-weighting (IDW) falsification and validation audit. Panel (a) shows leave-one-out root mean square error (RMSE) and mean absolute error (MAE) for $p = 0$ – 3.0 in 0.05 increments. The $p = 0$ non-spatial leave-one-out benchmark had RMSE = 74.02 kg km^{-2} ; at $p = 0.5$, RMSE = 75.25 kg km^{-2} , so no positive power improved prediction. Panel (b) shows observed versus leave-one-out cross-validation predictions at $p = 0.5$ using the primary native-raster-cell-centroid coordinate convention (Pearson $r = -0.389$, $p = 0.0995$). IDW is therefore retained only as a falsification diagnostic and is not used for regional biomass, NPP, or carbon upscaling.

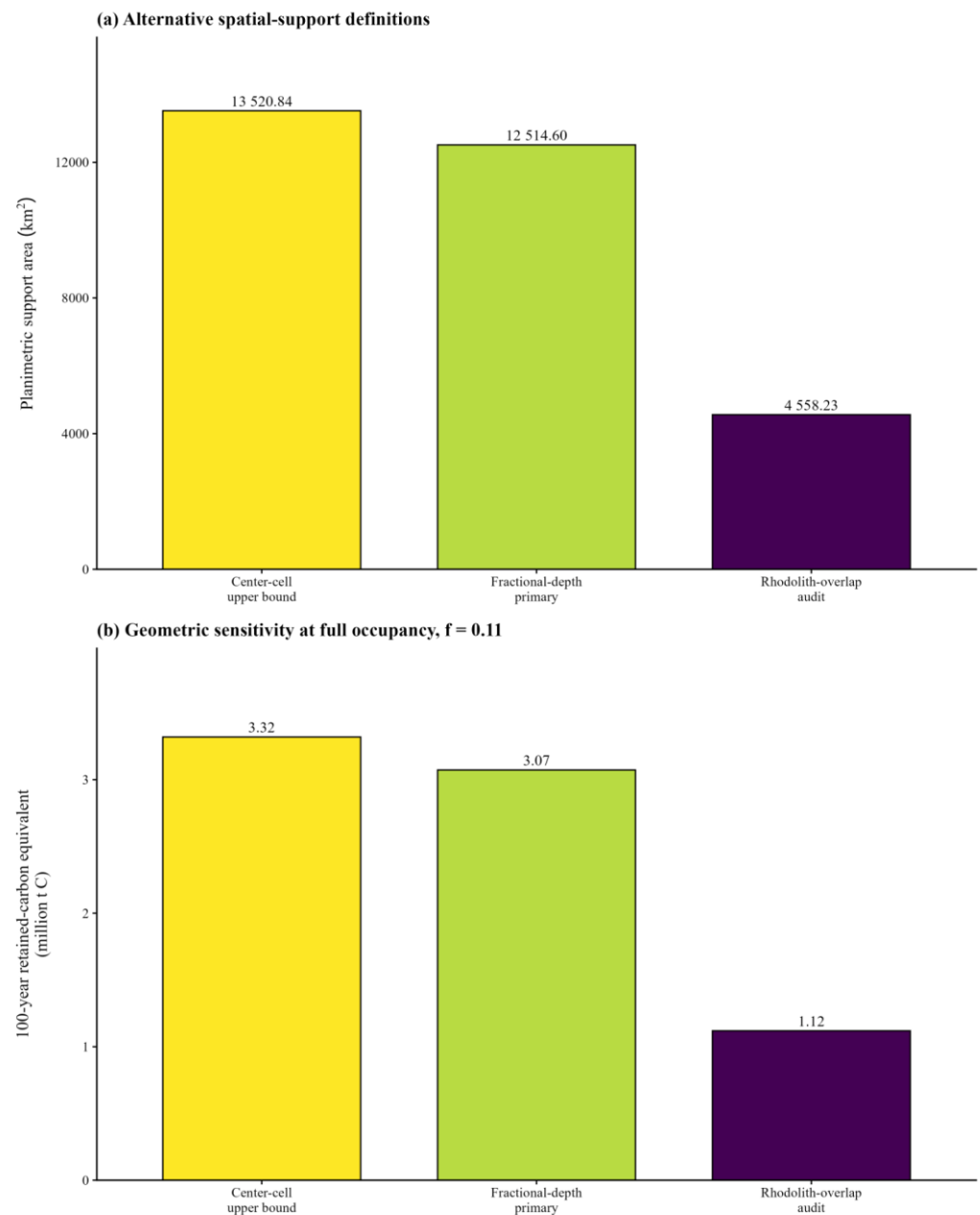


Figure S5. Spatial-support audit. Panel (a) compares the 45–70 m center-cell upper bound (13,520.84 km²), the primary high-resolution GEBCO fractional-depth support (12,514.60 km²), and the incomplete rhodolith-overlap audit (4,558.23 km²). Panel (b) shows the corresponding static 100-year retained-carbon equivalents at full assumed occupancy, the central 22.32 g C m⁻² yr⁻¹ analog, and $f = 0.11$ (3.32, 3.07, and 1.12 million t C, respectively). The rhodolith value is not a validated lower bound because substrate coverage is incomplete. These bars quantify geometric sensitivity, not observed kelp occupancy or verified sequestration.

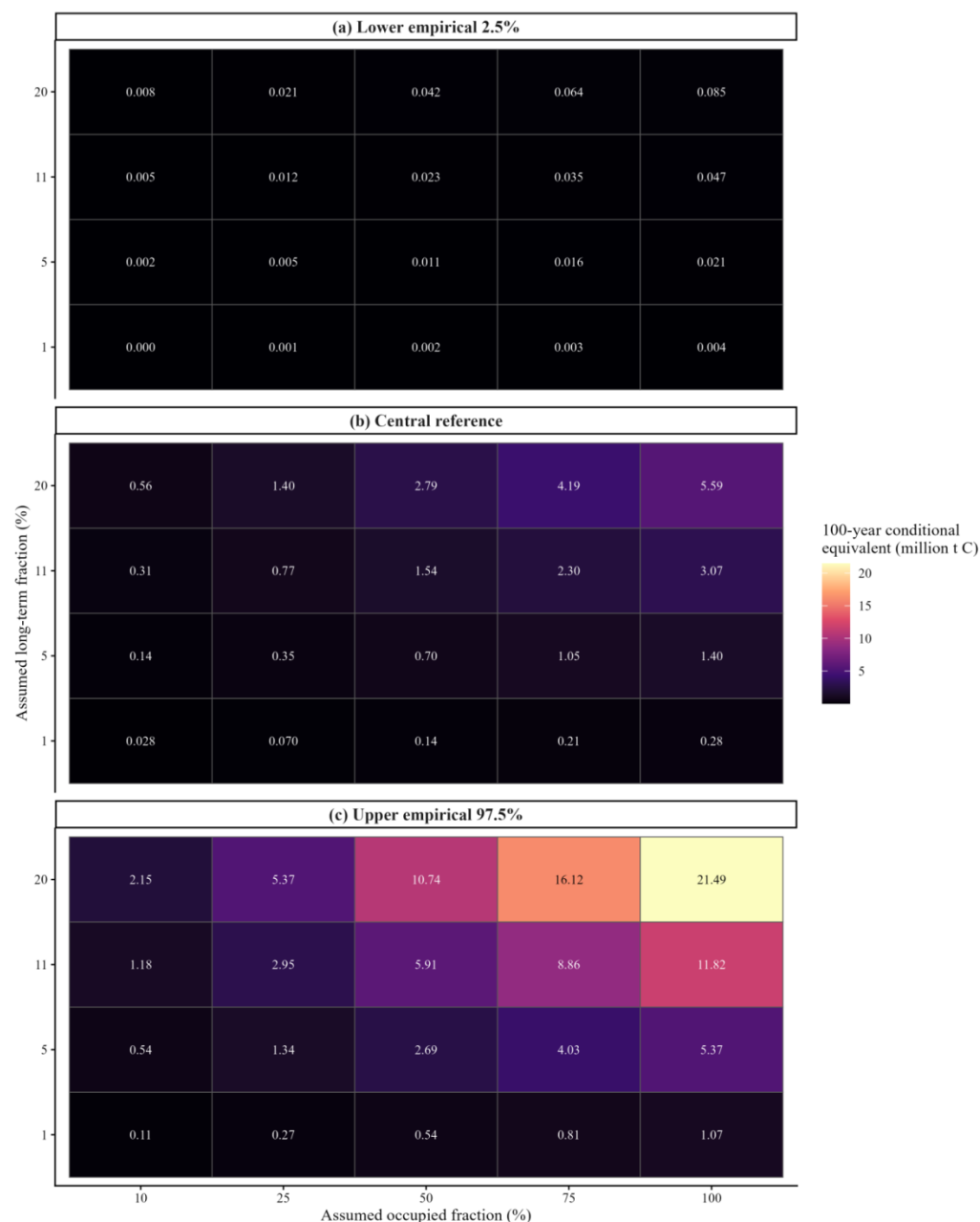


Figure S6. Complete deterministic NPP-transferability scenario envelope for the 100-year conditional retained-carbon equivalent. Panels show all combinations of assumed occupied fraction (10–100%) and long-term fraction (1–20%) under (a) the empirical lower 2.5% depth-centered *Laminaria* anchor, (b) the central 55 m depth-overlapping reference, and (c) the empirical upper 97.5% anchor. Values are million tonnes of carbon. The panels are transferability and sensitivity limits, not probability distributions, local confidence intervals, forecasts, measured export, burial, verified sequestration, or carbon-credit quantities.