**Text S2. Supplemental methods**

*Micro-architecture organization of the skeleton*

Micro-skeletal structures of different sizes vary in micro-density and these variations in density, which as in other structures give rise to light scattering, result in different refractive indices (Kim et al. 2004; Rogers et al. 2009; Rogers et al. 2014). Since optical refractive index is linearly dependent on local mass density, the overall organization of structures with size *r* between ~30–1,000 nm can be characterized by the optical refractive index correlation function C(*r*) (Kim et al. 2004; Rogers et al. 2009; Rogers et al. 2014). LEBS measures fractal-dimension *Df,* which quantifies the shape of C(*r*) (Marcelino et al. 2013). *Df* was measured for all 88 species and determined to be consistent with a “mass-fractal” structure (i.e., *Df*<3) and varied significantly between low- and high-$μ\_{s,m}^{'}$ corals (Marcelino et al. 2013). However, LEBS measures “effective *Df*”, which is an approximation for *Df*. (see Supplementary Information). *Df* depends on the sizes of the nanograins (*r*) and the ratio *R/r*; from our simulations (data not shown), ‘effective *Df*’ measured by LEBS approximates *Df* when the size of the nanograin is much smaller than the wavelength of light (<500nm) and *R* is at least 1,000-fold larger than the size of the nanograin. However, *r* in various skeletons ranges between 30 and 100nm (Stolarski 2003; Cuif and Dauphin 2005a,b; Stolarski and Mazur 2005; Nothdurft and Webb 2007; Benzerara et al. 2011) and *R* in *Porites sp.* is in the micrometer range (Benzerara et al. 2011), so the ratio between *R/r* is smaller than 1,000-fold. Under these parameters, our simulations show that *Df* is about 0.5 smaller than the ‘effective *Df*’ measured by LEBS (the D*f* values reported in here are the ‘effective *Df*’ and thus uncorrected).

*Surface area to volume ratio (SA:V) estimated from growth form*

As empirical surface area to volume ratio (SA:V) data are available for a limited number of species, Madin et al. (2016) estimated SA:V ratios for ten growth forms based on arranging 1000 1cm3 cubes into similar forms, and calculating the tissue-covered surface area (SA) for each growth form and dividing by the volume (V) of the cubes (1000 cm3). This provides a SA:V for each growth form, which we used as a parameterization of growth form to assess its relationship with variance in bleaching response and other structural characters.

**References**

Benzerara K, Menguy N, Obst M, Stolarski J, Mazur M, Tylisczak T, Brown GE, Meibom A (2011) Study of the crystallographic architecture of corals at the nanoscale by scanning transmission X-ray microscopy and transmission electron microscopy. Ultramicroscopy 111:1268-1275

Cuif JP, Dauphin Y (2005a) The environment recording unit in coral skeletons - a synthesis of structural and chemical evidences for a biochemically driven, stepping-growth process in fibres. Biogeosciences 2:61-73

Cuif JP, Dauphin Y (2005b) The two-step mode of growth in the Scleractinian coral skeletons from the micrometre to the overall scale. Journal of Structural Biology 150:319-331

Kim YL, Liu Y, Turzhitsky VM, Roy HK, Wali RK, Backman V (2004) Coherent backscattering spectroscopy. Optics Letters 29:1906-1908

Madin JS, Hoogenboom MO, Connolly SR, Darling ES, Falster DS, Huang DW, Keith SA, Mizerek T, Pandolfi JM, Putnam HM, Baird AH (2016) A trait-based approach to advance coral reef science. Trends in Ecology & Evolution 31:419-428

Marcelino LA, Westneat MW, Stoyneva V, Henss J, Rogers JD, Radosevich A, Turzhitsky V, Siple M, Fang A, Swain TD, Fung J, Backman V (2013) Modulation of light-enhancement to symbiotic algae by light-scattering in corals and evolutionary trends in bleaching. PLoS ONE 8:1-9

Nothdurft LD, Webb GE (2007) Microstructure of common reef-building coral genera *Acropora*, *Pocillopora*, *Goniastrea* and *Porites*: constraints on spatial resolution in geochemical sampling. Facies 53:1-26

Rogers JD, Çapoğlu IR, Backman V (2009) Nonscalar elastic light scattering from continuous random media in the Born approximation. Optics Letters 34:1891-1893

Rogers JD, Radosevich AJ, Yi J, Backman V (2014) Modeling light scattering in tissue as continuous random media using a versatile refractive index correlation function IEEE Journal of Selected Topics in Quantum Electronics

Stolarski J (2003) Three-dimensional micro- and nanostructural characteristics of the scleractinian coral skeleton: A biocalcification proxy. Acta Palaeontologica Polonica 48:497-530

Stolarski J, Mazur M (2005) Nanostructure of biogenic versus abiogenic calcium carbonate crystals. Acta Palaeontologica Polonica 50:847-865