Science-based approach to using growth rate to assess coral performance and restoration outcomes

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Electronic Supplementary Material

1. Area-size relationship from Porites spp. sampled from Mo'orea in 2008 and 2009

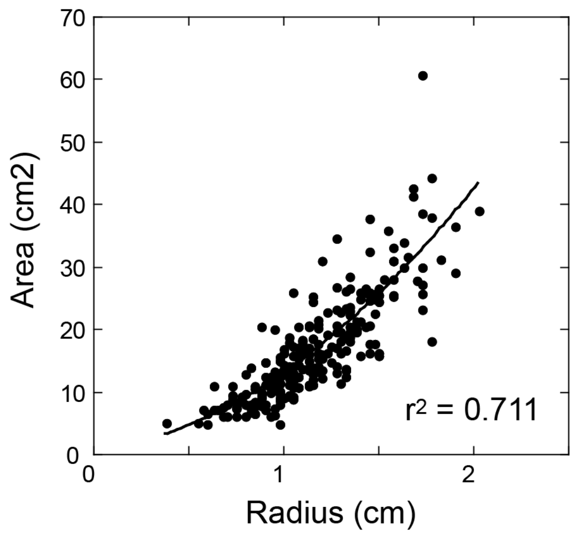


Figure S1. Relationship between the size (planar radius, cm) and tissue area of small colonies of *Porites* spp. sampled from 2–3 m depth on the back reef of the north shore of Mo'orea in 2008 and 2009. These corals represent the same taxon, and come from the same sampling location, as the corals used in the present study, but they were used in previous experiments. Their tissue area was determined using the aluminium foil (Marsh 1970), and a second order polynomial relationship was fitted by least squares linear regression: area = 0.34821 + 4.037x + 8.4296x^2, where x = radius (cm). This relationship was used to estimate the tissue area of corals in the present study.

2. Depth effects on the common garden

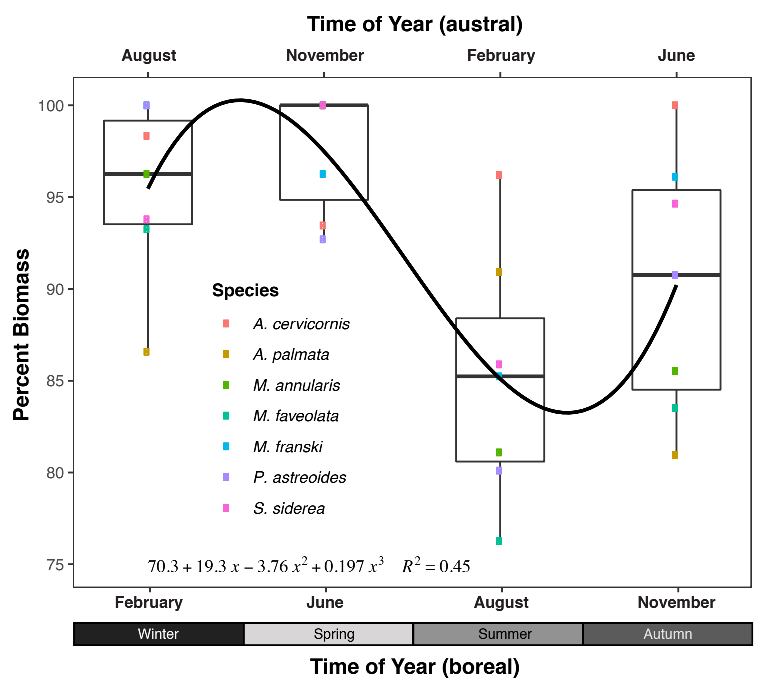
The experiment was initially designed to manipulate coral growth through transplantation between depths (5 and 8 m), with this approach rationalized by the trend for coral growth to decline with depth, particularly below 5 m and for corals with a massive morphology [11]. Two way RM ANOVA was used to compare growth between depths and times (both fixed effects) using corals as the RM factor, and either area-normalized or biomass normalized growth rates as dependent variables. For area-normalized growth, the main effect of depth was not significant ($F_{1,58}$ = 0.099, p = 0.754), although there was an interaction between time and depth ($F_{3,174}$ = 3.247, p = 0.023). For biomass-normalized growth, the main effect of depth also was not significant ($F_{1,58}$ = 0.334, p = 0.566), and again there was an interaction between time and depth ($F_{3,174}$ = 4.463, p = 0.005). As post-hoc analyses could not resolve among times within which depth differed (p ≥ 0.072), results were pooled by depth for further analysis.

3. Estimation of coral biomass in multiple seasons

As corals had to be killed to measure their biomass, it was not possible to measure biomass throughout the present study. To estimate biomass at multiple times based on empirical measurements at the completion of the study in November 2018, an empirical relationship between biomass and time of year was established using published data [38,39]. These studies report ash free dry weight (AFDW) of corals collected quarterly from 1994 to 2007 in the Bahamas, Florida, and Mexico, based on colonies sampled from 1–15 m depth. Equivalent data were not available for Indo-Pacific corals, or from corals sampled in the southern hemisphere. The results from the west Atlantic were assumed to have general application to tropical reef corals, with the timing transposed relative to season between hemispheres.

To normalize growth to biomass on the five occasions that growth was measured (figure 1), biomass was measured when the corals were collected on 1 November, and biomass at the other 4 sampling times was estimated using an empirical relationship describing variation in coral biomass among seasons. This relationship was based on measurements of AFDW in *Acropora cervicornis, A. palmata, Orbicella annularis, O. faveolata, O. franksi, Porites astreoides*, and *Siderastrea siderea*, and were extracted from the raw data table in Thornhill et al. (2011) Dryad repository (https://doi.org/10.5061/dryad.gm005fg8; "Thornhill_etal_DRYAD_datafile_revised.txt"), corresponding to Winter (defined as our boreal February), Spring (defined as our boreal May), Summer (defined as our boreal August), and Fall (defined as our boreal November). AFDW was scaled to a percentage of the annual maximum AFDW, and displayed as a scatterplot (figure S2). Values were summarized by quarter using box plots, and an empirical relationship between AFDW and month determined by least squares regression for a third order polynomial (figure S2). This polynomial was used to estimate scaling factor for the biomass of each massive *Porites* spp. at the four samplings preceding the measurement of biomass in November 2018. Growth rates by coral colony over each period in our study (figure 1) were normalized to the mean of the initial and final biomass over the respective periods. Sampling in Thornhill et al. (2011) was unbalanced among species, depths, sites, and years. Although AFDW varied among species and years (reported in the original study), mean AFDW by species and study varied systematically among quarters, with highest values (approaching 100%) in the boreal second quarter (May) (austral fourth quarter, October) and lowest values in the boreal third quarter (September) (austral first quarter, March).

Figure S2. Annual variation in coral biomass based on ash-free dry weight (AFDW) recorded for seven species sampled over four quarters in the Bahamas, Florida, and Mexico from 1994 to 2007. Values display means, with box plots summarizing values by quarter (boxes enclose upper and lower quartile with the median shown inside the box; whiskers show ± 1.5 × interquartile distance); curve show the best fit third order polynomial using boreal months numbered 1–12 from January (r^2 = 0.45, n = 28). Upper abscissa shows time translated to the austral hemisphere relative to seasonal variation in climate; shaded horizontal bar shows seasons.



References

Marsh JA 1970 Primary productivity of reef-building calcareous red algae. Ecology 51: 255-263