Carbonate budgets of structurally distinct mesophotic reefs

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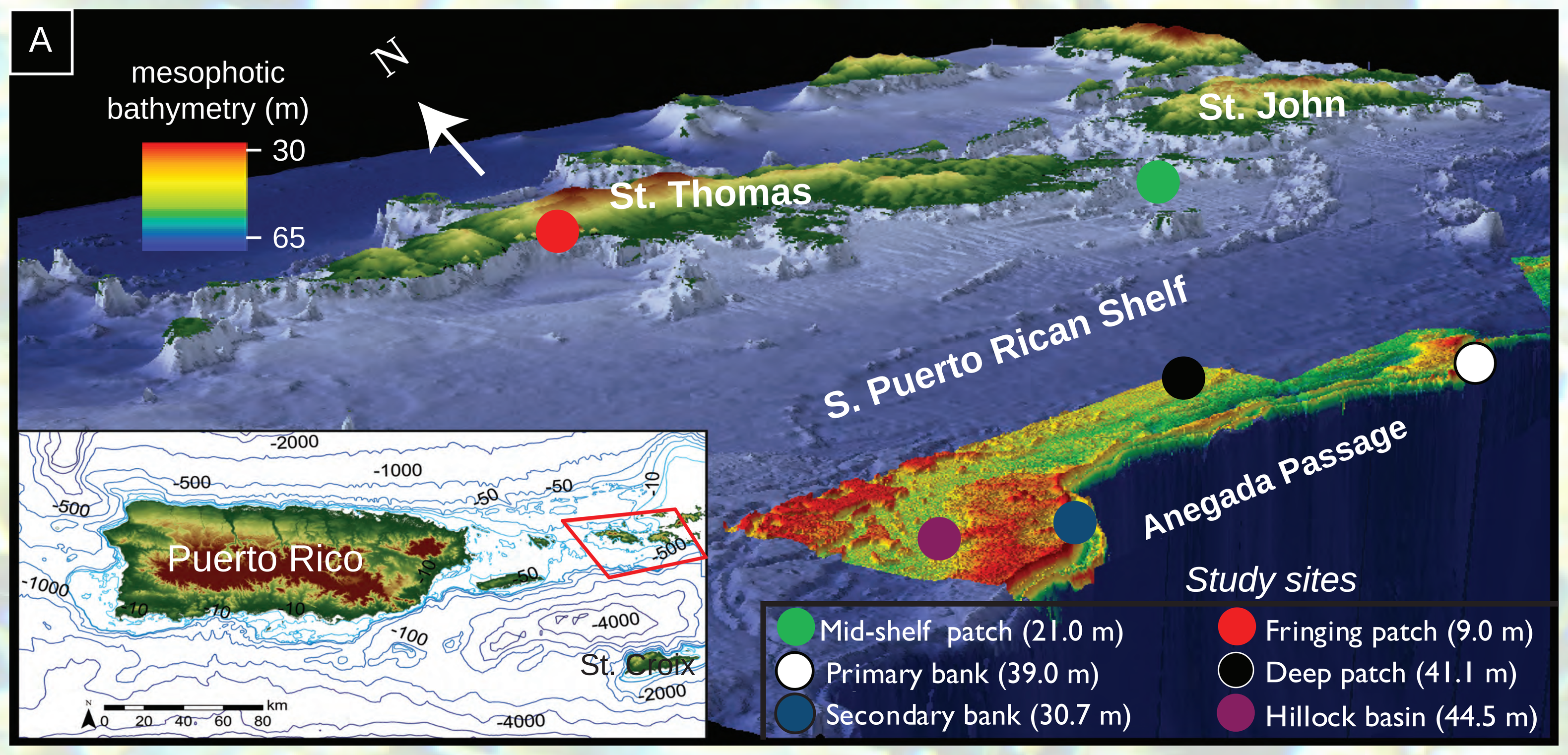
Background

Shallower reef carbonate budgets, summations of carbonate production and sedimentation minus carbonate loss through physical and biological erosion, have shown that reef geomorphology and long-term accretion are highly determined by the balance of localized carbonate constructive and destructive sedimentary processes. Despite the recent influx of insightful publications addressing mesophotic coral reef physiology and ecology, there is still little known regarding the fundamental sedimentary processes that construct, maintain, and alter mesophotic reef framework and how these processes interact to determine the sustainability and structural integrity of mesophotic reefs[a]. To address this lack of knowledge, bioaccretion and bioerosion rates obtained from experimental substrates exposed for 3 years, and growth versus erosion rates of primary coral framework were scaled by benthic composition at 4 structurally unique mesophotic reefs and 2 shallow reef counterparts on a near-horizontal bank south of St. Thomas, U.S. Virgin Islands. These data were used to calculate carbonate budgets at all sites.



B

	Rugosity	% coral cover (relative % MACX)	% exposed substrate
● (Hillock basin)	1.84	12.99 (91.67)*	67.70*
● (Deep patch)	1.13	1.79 (0.0)	82.83
● (Secondary bank)	2.62	32.20 (88.78) 46.30 (85.52)	55.68 52.92
○ (Primary bank)	1.55	33.73 (81.75) 44.85 (90.78)	58.31 41.32
● (Mid-shelf patch)	1.18	17.64 (72.28) 32.38 (68.03)	72.68 60.37
● (Fringing patch)	1.25	3.19 (6.68)	93.66

*Based on available benthic data from 2007

Fig. 1 (A) South Puerto Rican Shelf, with red-boxed area in smaller map inlet indicating study location in 1 m resolution multi-beam bathymetry (with 20x vertical exaggeration). The 4 mesophotic reef sites, with distinctive structural habitats, are greater than 10 km south of St. Thomas. (B) Reef rugosity and video linear transects were conducted in 2012 (and in 2003 for values in purple) by the University of the Virgin Islands, and relative coral cover was obtained for *M. annularis* complex (*M. annularis, M. faveolata, M. franksi*). Benthicdata were used with results from this study to obtain site specific carbonate fluctuation measurements following a modified census-based carbonate budget methodology[b].

Methods

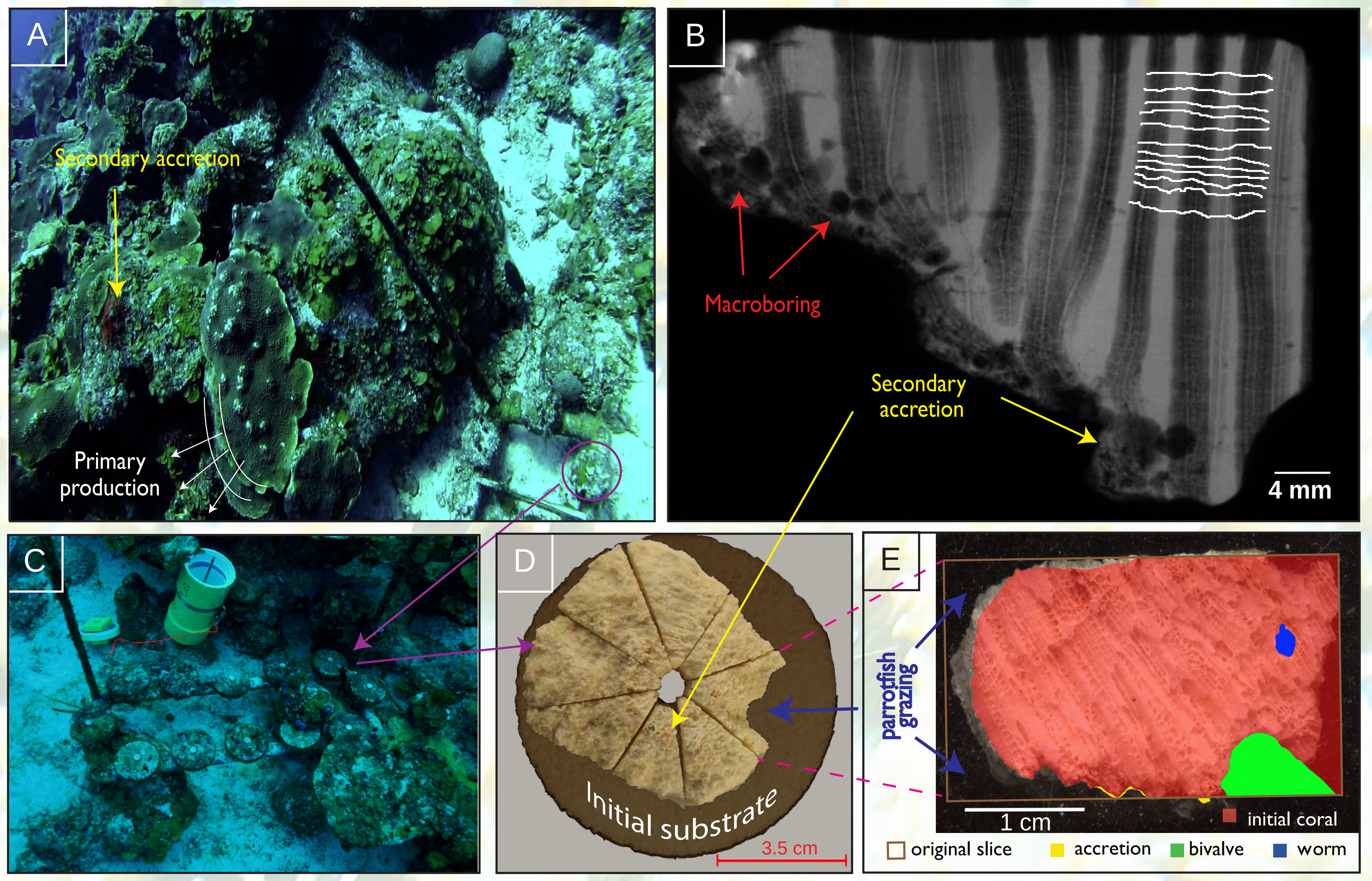


Fig. 2 Mesophotic reef carbonate budget analysis (A) utilized recently dead mesophotic MACX framework and experimental coral substrates deployed in Aug. 2010[a]. The framework was cut parallel to the growth axis and x-rayed (B) to reveal density banding (assumed annual from geochemical testing). Density bands were used to calculate linear extension rates, which were multiplied by coral density (obtained using buoyant weight method[c]) to obtain site specific MACX calcification rates. Point count analysis was usedto calculate living framework macroboring and secondary accretion rates. After 3 years of exposure (C), collected substrates were measured and compared (D) to pre-exposure values. Substrates were then sliced (E) to identifythe cross section area removed by different eroding groups to determine bioerosion rates on dead exposed substrate.

Results

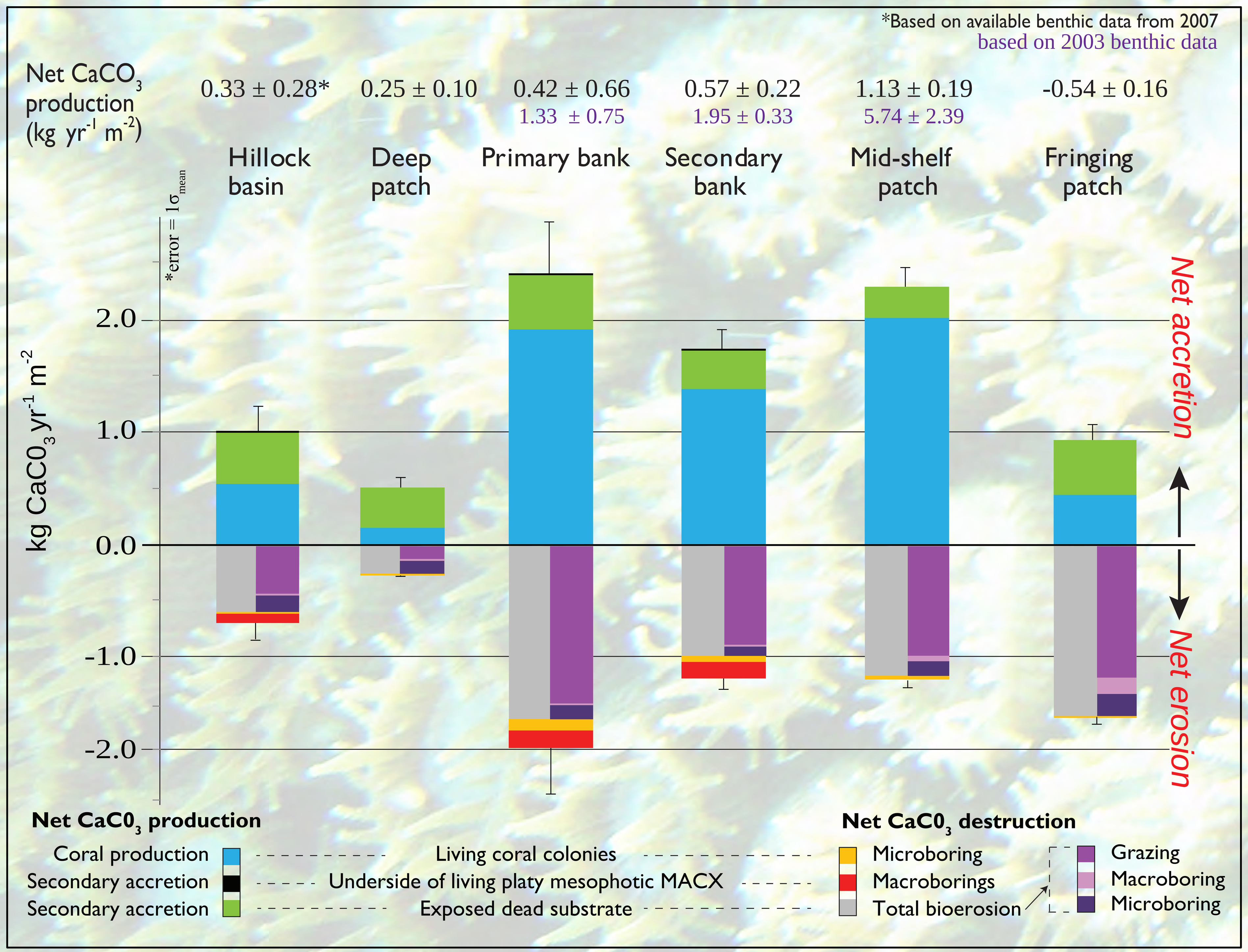


Fig. 3: Total values and major components of the carbonate budgets calculated at each site, primarily utilizing site-specific data obtained Aug. 2010 - May 2013. Mesophotic primary production was mainly based on measured linear growth rates and density of mesophotic MACX and is assumed to have little impact on results as MACX is the dominate coral framework builder at all coral reef mesophotic study sites (Fig. 1B). Depth appropriate growth and density values from Perry et. al. (2012) were used to fill in gaps for other coral found at mesophotic sites. Microbioerosion estimates were obtained by multiplying depth appropriate rates from the Bahamas[d] by benthic coverage (Fig. 1B).

Discussion

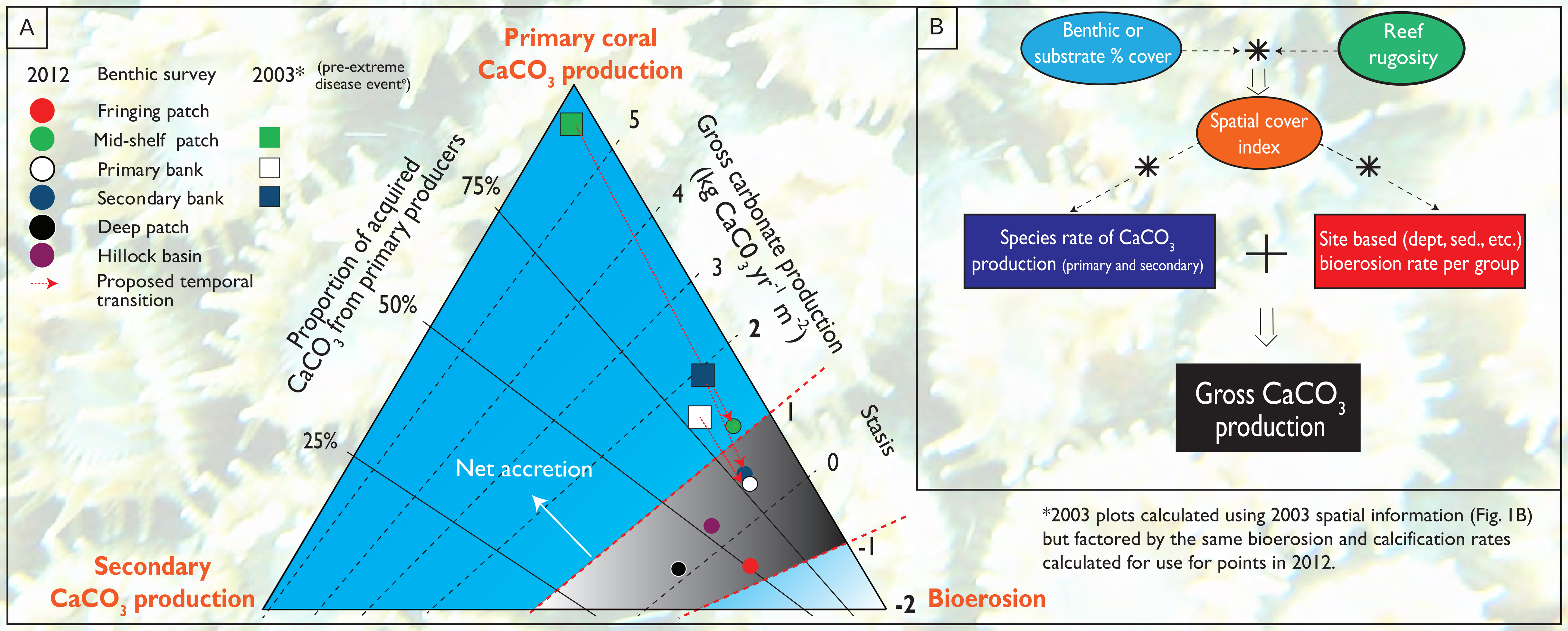


Fig. 4 (A) "Ternary space" approach to evaluate reef framework production states[b] where 'stasis' region represents a budget considered in a static equilibrium. Right axis denotes the gross carbonate budget value; the inner position represents the proportion of acquired carbonate attributed to primary (coral) carbonate producers compared to secondary produces. (B) A visual framework outlining the overall approach taken for the calculation of the carbonate budgets represented in the ternary space diagram.

Conclusions

1. All mesophotic sites have net accretion; precarious 'stasis' equilibrium
   - Larger primary production habitats have higher bioerosion rates,
   - Smaller coral cover habitats have net positive budgets due to lower bioerosion levels, a result of compensation from high secondary production and lower reef structural complexity
2. High heterogeneity in mesophotic sedimentary processes at different structural habitats, but overall processes balance out to similar stable, slow accreting geomorphology state. Shallow sites have more variable carbonate budgets
   - Implies a more generalized approach may be used for long-term mitigation of mesophotic reef structural sustainability.
3. Recorded extreme disease event[e] altered mesophotic reef budget from a "production-dominated" to a stasis state.

RSMAS student travel fund

[a]Weinstein, D.K., Klaus, J.S., Smith, T.B., (in press), Geomorphology: [b]Perry, C. T. et al., (2012), Estimating rates of biologically driven coral reef framework production and erosion: a new census-based carbonate budget methodology and applications to the reefs of Bonaire, Coral Reefs, 31, 853-68: [c]Davies, P. S., (1989), Marine Biology, 101 389-95: [d]Vogel, K. et al., (2000), Experimental studies on microbial bioerosion at Lee Stocking Island, Bahamas and One Tree Island, Great Barrier Reef, Australia: implications for paleoecological reconstructions, Lethaia, 33, 190-204: [e]Smith, T.B. et al., (2009), Benthic structure and cryptic mortality in a Caribbean mesophotic coral reef bank system, the Hind Bank Marine Conservation District, U.S. Virgin Islands, Coral Reefs, 29(2), 289-308.