Rebuilding Coral Reef Structure And Complexity Following Anthropogenic Disturbance

William F. Precht

DIAL CORDY AND ASSOCIATES INC
Environmental Consultants

A Scientific Basis for Reef Restoration

Loss of Ecosystem Function and Values

The Most Important Questions that Need to be Answered in All Reef Restoration Programs

1. How long will it take for natural recovery to occur at any given site without manipulation?
2. Will natural recovery converge on a community state that is different from its pre-disturbance state?
3. Will reefs disturbed by humans respond differently than those injured by natural processes?

Hypothesis-Driven, Ecological Studies are the Only Means of Answering these Critical Questions.

Natural Recovery Functions Are Scaled in Centuries – Not Years or Decades.

Structural Complexity

Structure refers to the spatial arrangement of the various components of the ecosystem, such as the height and the spacing of corals, sponges and octocorals.

Rugosity

- Rugosity as defined here is an index of substrate complexity. The term rugose is derived from a Latin term meaning wrinkled. The index of rugosity describes the amount of "wrinkling" of the substrate.

- Areas of high complexity are likely to provide more cover for reef fish and more places of attachment for algae, corals and various sessile invertebrates.

Why is “rugosity” so important?

- Increased substrate provides habitat for benthic invertebrates, which serve as the main diet of many species of fishes, which in turn are utilized at other trophic levels.

- Spatial complexity increases habitat heterogeneity, providing increased areas of refuge for fish populations from predation and competition.

- Topographical relief can expand the availability of resources and their production rate.

- Increased rugosity results in higher heterogeneity, creating habitat complexity that increases fish diversity. Coral diversity, correlated with fish populations, is also probably a direct result of habitat complexity.

Current Biology 19, 1–6, April 14, 2009 DOI 10.1016/j.cub.2009.02.041

Report

Recent Region-wide Declines in Caribbean Reef Fish Abundance

"… structural complexity is important for Caribbean fishes and it is likely that the three-dimensional relief of Caribbean reefs has been gradually deteriorating, particularly in recent years as corals—the building blocks of reef platforms—have been reduced to very low abundance."

Paddock et al. (2009)

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Flattening of Caribbean coral reefs: region-wide declines in architectural complexity

Lorenzo Alvarez-Filip[1,*], Nicholas K. Dulvy[3], Jennifer A. Gill[1,4], Isabelle M. Côté[3] and Andrew R. Watkinson[2]

[1]*Centre for Ecology, Evolution and Conservation, School of Biological Sciences, and*
[2]*School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK*
[3]*Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada*
[4]*Tyndall Centre for Climate Change Research, Norwich NR4 7TJ, UK*

Ecology, 86(10), 2005, pp. 2578–2585

STABILITY OF CORAL REEF FISH ASSEMBLAGES IMPACTED BY NUCLEAR TESTS

S. Planes,[1,2,5] R. Galzin,[1,2] J.-P. Bablet,[3,6] and P. F. Sale[4]

"Reef fishery conservation efforts must emphasize protection of habitat, because reef fish assemblages are resilient even to intensive, localized harvesting so long as the structural and biotic integrity of their habitat is maintained…"

ATOLL RESEARCH BULLETIN

NO. 421

Topographic complexity is measured by carefully conforming a 5-m length of fine brass chain to the substratum adjacent to the central part of each transect tape. The chain is conformed to the finest topographic features that the 17-mm links permit; it is carefully inserted into small cavities and into the spaces within thickets of foliose and branching corals. The 5-m chain length was chosen so that the procedure could be completed in a reasonable length of time (10-15 min); the chain must be carefully straightened before it is conformed to the substratum. A complexity index, C, is calculated as $C=1-d/l$, where d is the horizontal distance covered by the conformed chain (measured against the transect tape) and l is its length when fully extended (e.g., Risk 1972; Rogers et al. 1982; Aronson and Harms 1985; Hubbard et al. 1990; Connell and Jones 1991).

LARGE-SCALE, LONG-TERM MONITORING OF CARIBBEAN CORAL REEFS: SIMPLE, QUICK, INEXPENSIVE TECHNIQUES

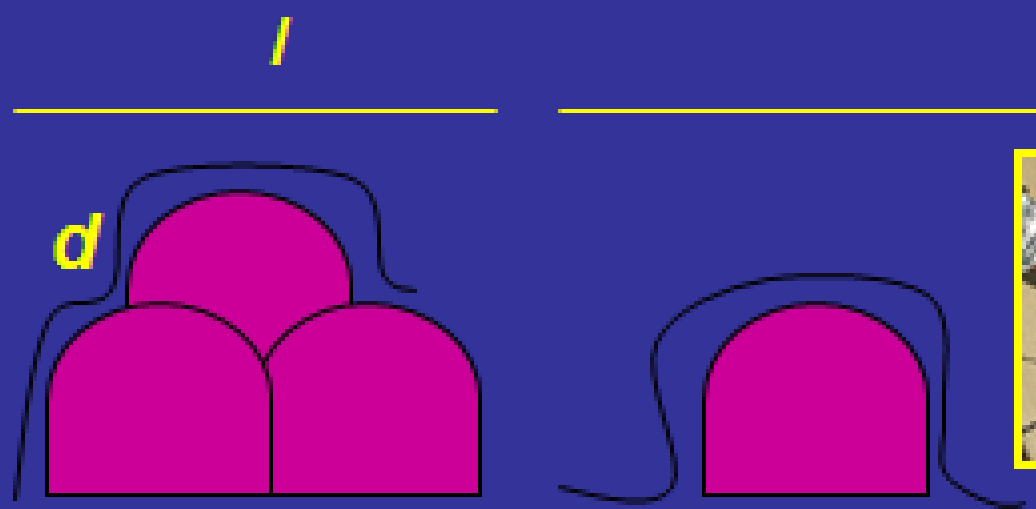
BY

RICHARD B. ARONSON, PETER J. EDMUNDS, WILLIAM F. PRECHT, DIONE W. SWANSON, AND DON R. LEVITAN

Measuring Rugosity

Chain and tape method, which assigns a numerical value to rugosity by measuring the length of chain draped over the reef surface that is needed to cover a given straight-line distance between two points. Surveyors tape is used to measure the straight-line distance between the two marker pins on a transect.

$$C = 1-(d/l)$$



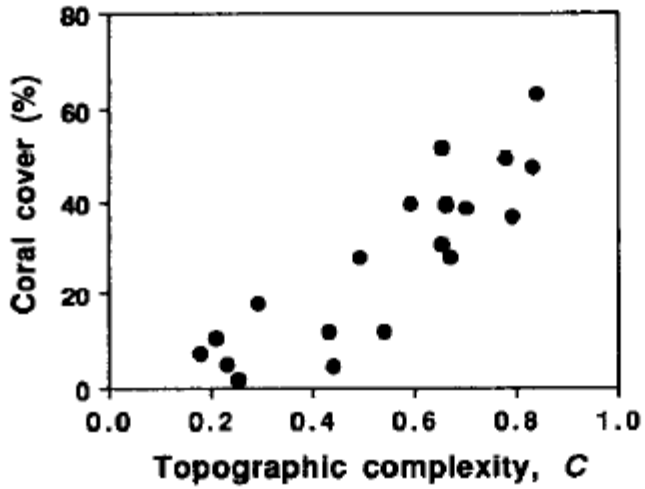
ELSEVIER

Journal of Experimental Marine Biology and Ecology
192 (1995) 1–14

JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY

Landscape patterns of reef coral diversity: A test of the intermediate disturbance hypothesis

Richard B. Aronson[a,*], William F. Precht[b]



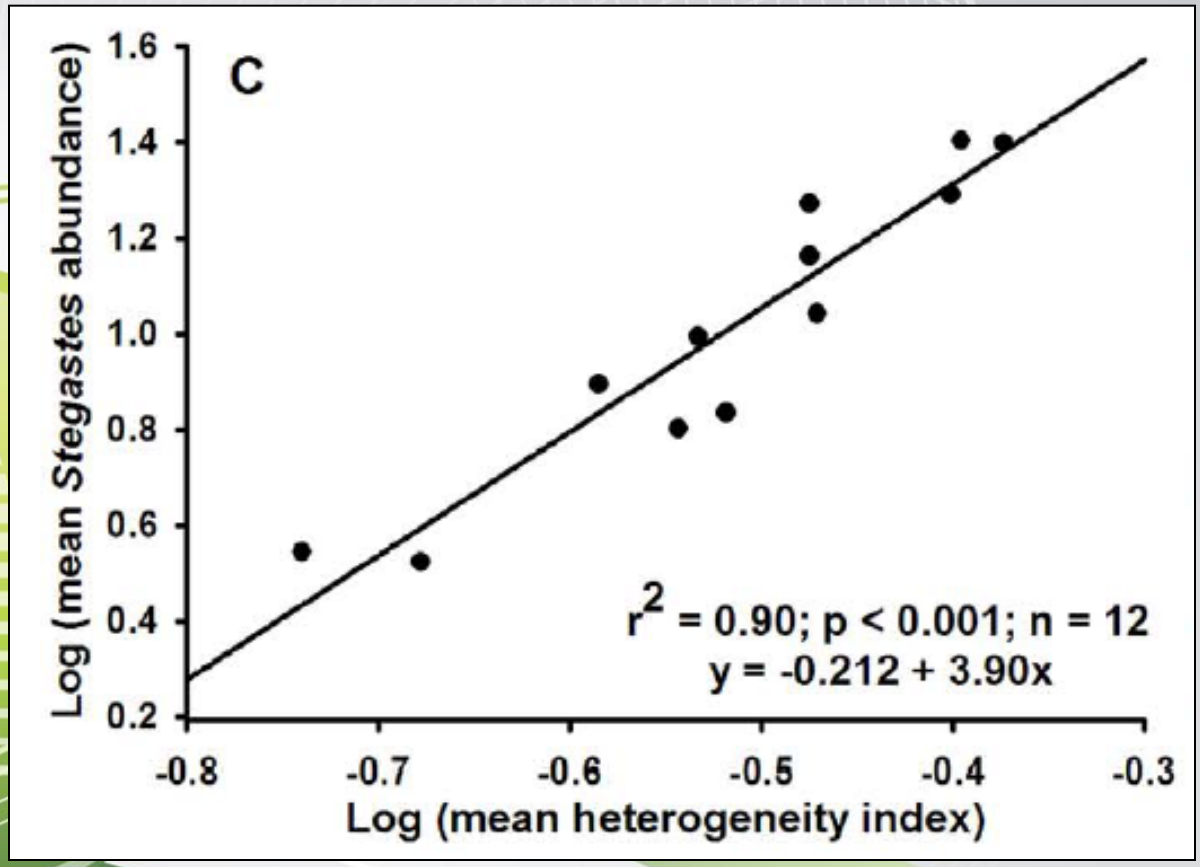
Relationship between percent coral cover and topographic complexity, *C*.

OPEN ACCESS Freely available online

PLoS one

Changing Patterns of Microhabitat Utilization by the Threespot Damselfish, *Stegastes planifrons*, on Caribbean Reefs

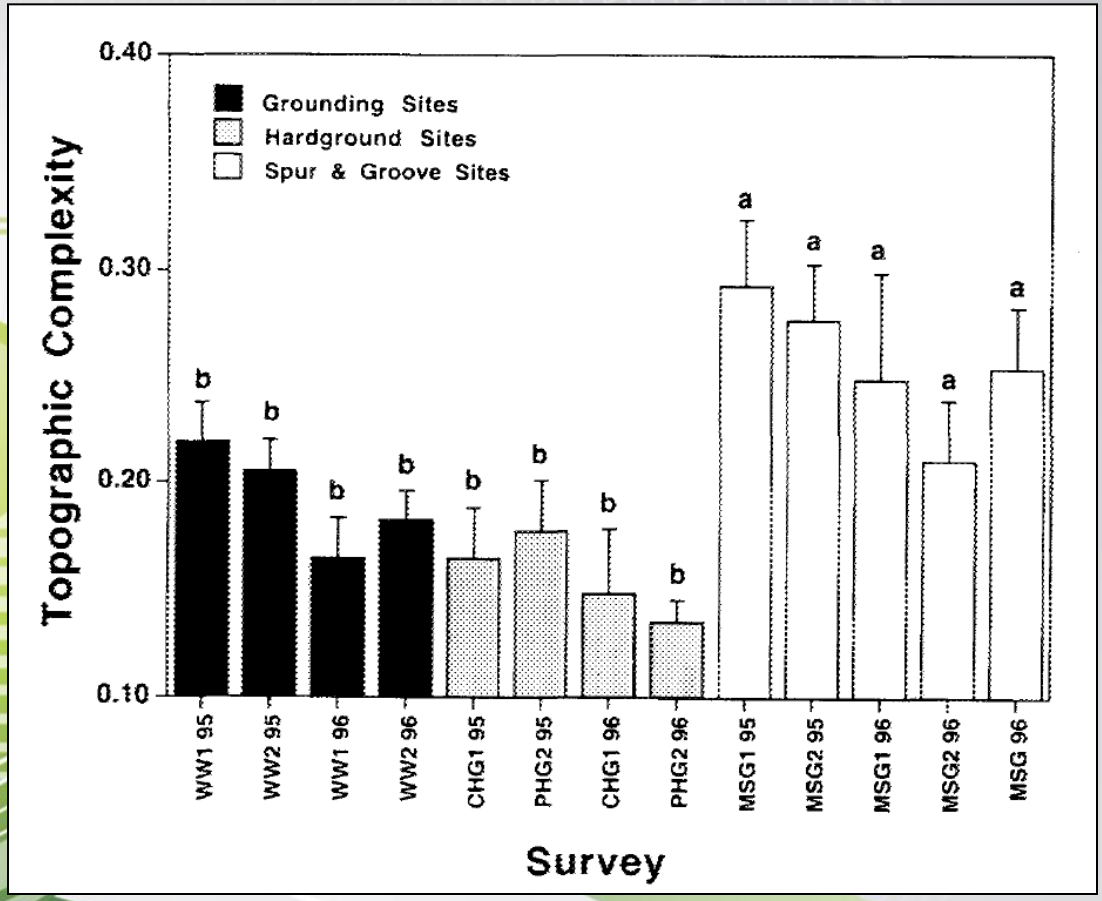
William F. Precht[1], Richard B. Aronson[2]*, Ryan M. Moody[3], Les Kaufman[4]



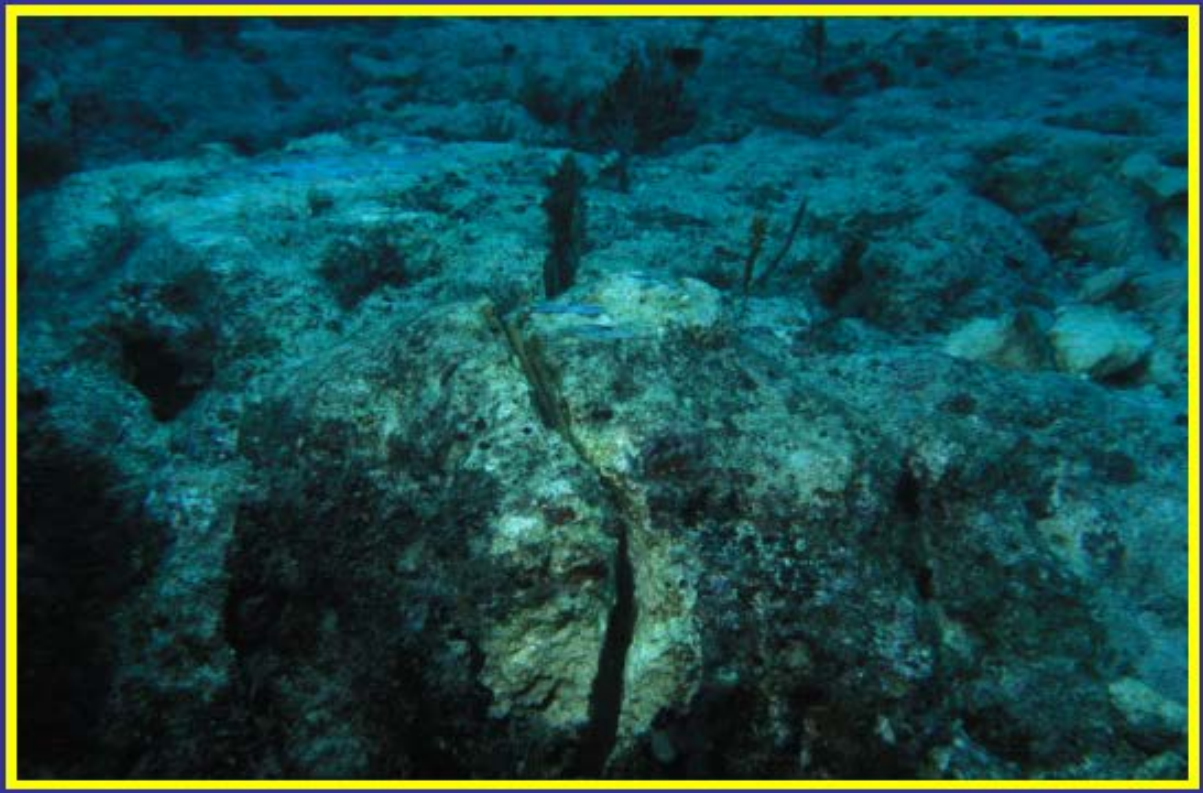
BULLETIN OF MARINE SCIENCE, 69(2): 1001–1012, 2001

IMPROVING SCIENTIFIC DECISION-MAKING IN THE RESTORATION OF SHIP-GROUNDING SITES ON CORAL REEFS

William F. Precht, Richard B. Aronson and Dione W. Swanson



High-Relief, Spur-and-Groove Areas Injured by Vessel Groundings Converge on an Alternate Community State More Similar to Low-Relief, Hardgrounds.

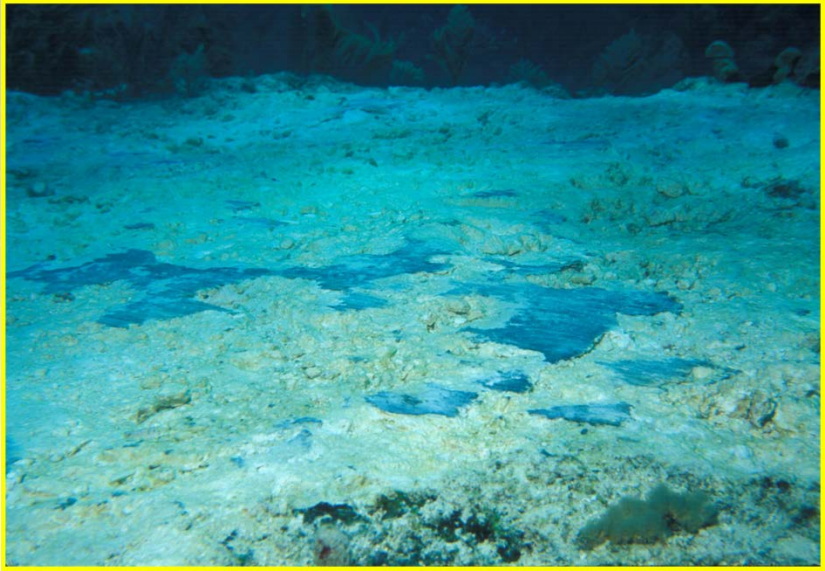


Habitat Issue Limiting Recovery

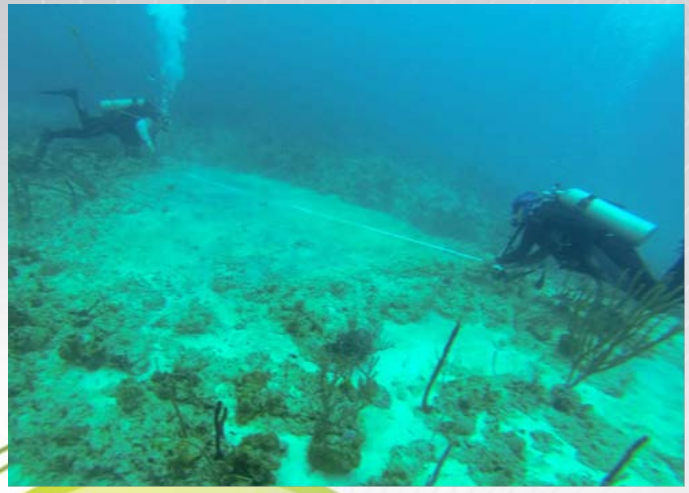
Lessons Learned: Oyster Reef Restoration

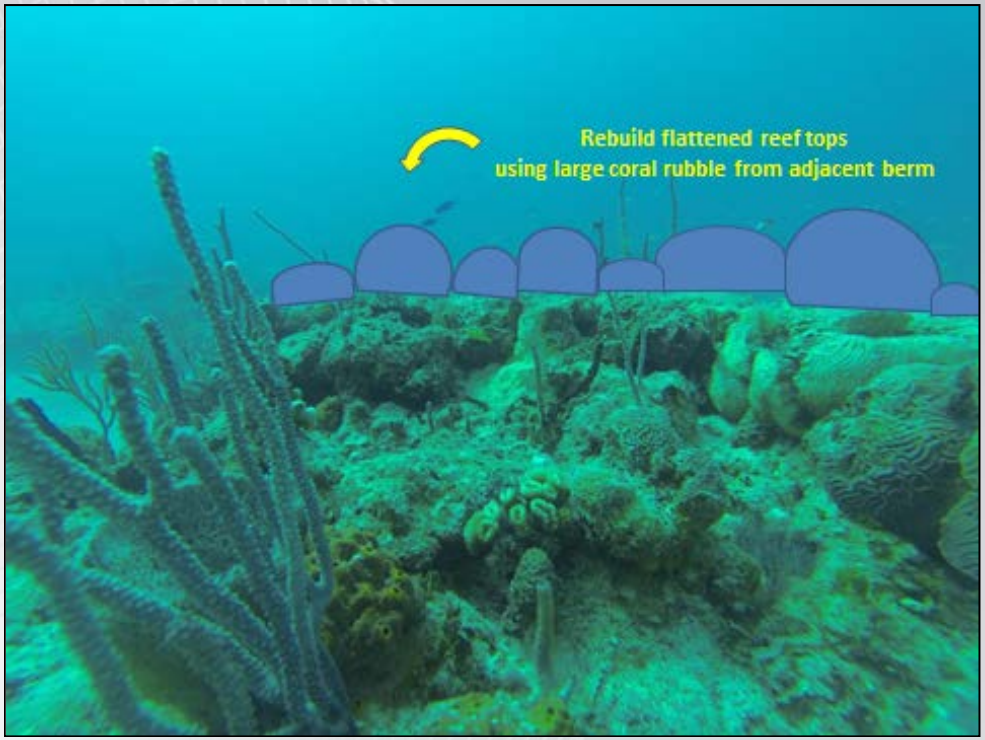
- Sweat the small stuff!!! (Lisa Kellogg)
- Returning complexity vital to oyster recruitment and returning ecological function.
- Fractally-scaled from landscape down to individual shells.

Rebuilding Complexity



Rebuilding Complexity





Rebuilding Complexity

Summary

- Restoring severely degraded coral reef ecosystems requires an understanding of the factors that have caused their degradation.
- Reefs are disturbance-structured systems that often exhibit catastrophic phase shifts in community structure. For instance, the loss of reef structure following the injuries caused by vessel groundings can lead to long-term shifts in community structure that often recover to an alternate community state.
- Many restoration efforts fail to recognize the importance of structural complexity, instead focusing only on coral propagation and transplantation.

Conclusions

- For coral reef communities to recover back to their original baseline state, restoration ecologists need to rebuild this lost structure and biological complexity to jump-start the natural recovery process.

- The science of “complexity” is the cornerstone of the coral reef restoration process.

Take Home Message

- Management interventions to “rebuild” natural communities are also most likely to succeed if they are able to mimic natural processes of community assembly and organization. Thus, if properly designed and executed, structural restoration will significantly reduce the recovery period of severely disturbed reefs and provide the foundation upon which successful reef restoration projects are based.