CARBON TURNOVER AND ACCUMULATION

BY CORAL REEFS

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By

Donald William Kinsey

Dissertation Committee:

Stephen V. Smith, Chairman
Robert W. Buddemeier
Keith E. Chave
Jed Hirota
Robert A. Kinzie III
E. Dixon Stroup

ABSTRACT

Previously developed methodology involving the high-precision measurement of changes in oxygen and various parameters of the CO_2 system in sea water has been used to monitor community metabolism in four Pacific coral reef systems. One Tree Is. and Lizard Is. in the Australian Great Barrier Reef, and Kaneohe Bay in Oahu, Hawaii, were each studied intensively over periods exceeding one year. Johnston Is. in the Central Pacific was studied briefly, because of its potential nonconformity to some of the findings from the other sites. There is great operational uniformity in coral reef metabolism apparently regardless of considerable variability in small-scale morphology and community structure. Seasonal variation of metabolism is great, probably at all latitudes at which coral reefs are found. Unperturbed systems are in autotrophic balance (zero gain, i.e. virtually all organic material produced is consumed) over a full year although there may be substantial organic gains or losses within the year. In this balanced system there is a predictable zonation of activity associated with biomass zonation. Much of the carbon fixed is redistributed downwind, mostly as detritus, but nearly all such material remains within the system (i.e., there are internal source areas and sink areas). The inorganic carbon cycle is at least 75% gain (i.e., 25% or less of the carbonate formed is likely to redissolve) in contrast to the balanced organic cycle. As with organic production, there is significant redistribution of inorganic carbonates (sediments) away from, and mostly downwind from, the site of fixation. High metabolic activity is entirely related to perimeters, from the main seaward perimeter to the narrow perimeters of lagoon patch reefs. This high activity is very uniform in rate, but its lateral extent appears related to upwind open water fetch. There is a pronounced relationship between gross photosynthesis and calcification in all functional reef areas. Standards are proposed for coral reef performance. A present-day reef-flat is likely to exhibit the characteristics: gross diel photosynthesis (P) of 7 gC $m^{-2}d^{-1}$, an autotrophic self-sufficiency (P/R) of unity, and a net gain in carbonates (G) equivalent to 4 $kgCaCO_3$ $m^{-2}y^{-1}$. However, this operational status is found to be only a compromise between an "ultimate" mode of approximately P = 20, G = 10 and attenuation by a low activity sand/rubble mode of P = 1, G = 0.5. It is suggested that the "ultimate" mode, still found in small or specialized areas today, may have been of more general importance during a rising sea level. It is stressed that algal pavements (P = 5, G = 4) are a specialized feature of a standing sea level. By deduction only, the physical energy regime (waves, turbulence, etc.) is invoked as the factor controlling most operational parameters of coral reef metabolism. Several perturbations influencing standard performance are discussed. High nutrient levels in the absence of plankton response will elevate primary production and directly suppress calcification even without marked changes in community structure. Nutrient input resulting in a marked plankton response (Kaneohe Bay sewage impact) will result in a decline in photosynthesis, a massive increase in heterotrophic feeding (indicated by increasing R and a P/R as low as 0.4) and an eventual total degradation of the community. This latter shift involves a loss of structural maintenance (reduced

calcification), and eventually active erosion (pronounced carbonate dissolution by boring infauna). The final perturbation considered is terrigenous sedimentation, which is found to cause a simple loss of calcifying reef status. Photosynthesis declines but P/R increases. Calcification falls to zero but active dissolution does not occur. This response is analogous to the normal response in any reef system in the downstream sediment sink zones (algal and sea grass flats).