matters arising

Holocene reef growth on the edge of the Florida Shelf

LIGHTY *ET AL.*[1] have raised several important lines of speculation concerning the growth of reefs in the Florida and Bahamas areas and elsewhere in the Caribbean. The principal contribution of these authors has been to show an effective growth of a shallow-water coral-frame assemblage dominated by *Acropora palmata* in a period between 9,440±85 and 7,145±80 yr BP. This extends the evidence previously presented by Macintyre and Glynn[2], Adey[3] and Easton and Olson[4] for progressive growth over the past 6,000 yr.

The structures described lie within a depth range (15–30 m) which, only 40 km to the south, is accessible to Recent coral growth. One might speculate that, where conditions of growth are more favourable, reefs of the same age as those described by Lighty *et al.*[1] have been buried beneath growth covering the period from ~7,000 yr BP to the present.

Observations by Goreau and Goreau[5] and Goreau and Land[6] in Jamaica and by Newall and Rigby[7] and Shinn[8] and myself in the Florida–Bahamas province show a remarkable similarity of offshore profiles. The first element is a gentle slope to ~10–15 m depth (visible as a distinctive terrace on Fig. 1 of Lighty *et al.*[1]). It is from this that the major reefs in Florida (for example, Carysfort, Dry Rocks, Alligator Reef, and so on) rise and, at least on Andros and Eleuthera, so do the major reef patches. Seawards, the surface slopes more steeply to about 30 m before plunging almost vertically in "the wall" described by Ginsburg and James[9], Goreau and Land[6] and others. The illustrations of Goreau and Goreau[5] seem to apply throughout the Caribbean area and suggest only two shelf-edge growth sites. Figure 1 of Lighty *et al.*[1] suggests a third, from 15 m.

We need to exercise some care in interpreting terrace levels as much of the mobile sand is derived from the excess production of the shallow-water zone (see Neumann and Land[10] and Moore *et al.*[11]). However, the widespread occurrence within these offshore platforms of exposed Pleistocene limestones indicates that we are not dealing with accretion levels but with surfaces prepared by erosion during glacial periods (compare Purdy[12]).

Now, although there are no readily available figures for growth rates at 30 m depth there is certainly subjective evidence that they are slow. There are commonly <2 m of 'frame' projecting above the sand surface. In effect, relief from present-day surfaces in these depths is no greater, and may perhaps be less, than on the 'inactive' structures to the north.

Thus, it seems reasonable to assume first that surfaces which could have supported active coral growth at a time of rising sea level did not and, second, that the structures which we now see at 30 m are in effect the surfaces of frames which were first formed 7,000–10,000 yr ago. There is an obvious incentive to test them, using the methods described by Macintyre[13], bearing in mind the suggestion of Macintyre[14] that structures on terraces at 30–80 m depth in the eastern Caribbean do indeed represent an older phase of accretion.

We may now rephrase the question posed by Lighty *et al.*[1] What event, taking place ~7,000 yr ago, inhibited all shallow-water reef growth in the Caribbean? This growth was never able to resume in their northern area, presumably for the reasons which they accept pertaining to cold surface waters. In southern areas, however, growth began on new sites along the edge of the inner break in slope, forming the present shelf edge patches.

Lighty *et al.*[1] provide figures to show that an *Acropora palmata* reef is capable of keeping pace with rising sea level. There seems little reason to doubt this capability, but did it in fact do so? I believe that it did not and that, far from creeping upwards along the surface of a submerging slope, the principal locus of growth was established on a new and much shallower site. We are left with the conclusion that although sea level rose throughout the Caribbean there was a relatively abrupt change at ~7,000 yr BP. The broad outlines of reef morphology may have been defined at some earlier date but it was this event which determined the areas in which corals would grow. Sadly, in the area described by Lighty *et al.*[1] growth was no longer possible.

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LIGHTY *ET AL.* REPLY—The points raised by Braithwaite have been discussed in several studies of Caribbean Holocene reefs. As mentioned in our letter[1], for example, core data from a relict reef (depth 18 m) off southeastern St Croix indicated that a flourishing, shallow-water *Acropora palmata* (Lamarck) barrier reef was killed about 8,000 to 9,000 yr BP, when the shelf was flooded[2]. Increased water turbidity related to the erosion of soil cover was thought to be responsible for the demise of this early Holocene reef. By the time water conditions returned to normal, the depth of water was too great for an *A. palmata* reef to be re-established. Subsequently, the substrate was colonised by a slowly accreting, deeper water community consisting of coral heads and octocorals.

That study[2] and others[3,4] have proposed that turbidity, related to shelf erosion accompanying rising sea level, has generally prevented the continuous accumulation of Holocene reefs on wide shelf platforms of the Caribbean that are deeper than 10 m below present sea level. Although impressive reef structures are present on platforms <10 m below present sea level, these structures cannot be older than 4,000–7,000 yr BP, which is the period of initial flooding of these platforms. In south Florida, for example, the present reef tract has developed over the past 7,000 yr (ref. 5) on shallow areas of the shelf, behind the relict, shelf-edge reef of early Holocene age[6].

Some deeper shelf areas isolated from the effects of shelf erosion might have continuous Holocene reef sections dating back to 10,000 yr BP, but no such section has yet been found.

Note, however, that in protected areas,