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# Late Quaternary sea-level highstands in the central and eastern Indian Ocean: A review

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**Abstract**

The relative sea-level history of several atolls in the central and eastern Indian Ocean, including the Cocos (Keeling) Islands, Chagos Archipelago, and the Maldives–Laccadive Archipelagoes, has been debated for over a century but takes on a particular significance in the face of anticipated climate change. For each of these central and eastern Indian Ocean atolls Pleistocene limestone is encountered at depths of 6–20 m below sea level. On the Cocos (Keeling) Islands this has been dated to Last Interglacial age. Conglomerate platform underlies the reef islands on Cocos within which a sequence of fossil microatolls of massive and branching *Porites* records a gradual fall of sea level relative to the atoll. In the Maldives, the significance of outcrops of 'reef rock' has been vigorously debated without resolving sea-level history. Although in situ *Heliopora* occurs on the reef flat of Addu Atoll, dated at around 2700 radiocarbon yrs BP, other evidence for higher sea level remains poorly constrained. Conglomerates of a similar age have been described from the Chagos Archipelago, but it has not been unequivocally demonstrated that they formed under conditions of relatively higher sea level. In contrast to reefs further west in the Indian Ocean, each of these atolls has living microatolls of massive *Porites* that have been constrained in their upward growth by sea level. Interpretation of the upper surface of two such specimens from the Cocos (Keeling) Islands indicates broad fluctuations in the sea surface over the past century; similar microatolls are described from the Maldives implying little change in sea level over recent years. Regardless of minor past fluctuations, most reef islands in the Maldives are particularly low-lying and appear vulnerable to inundation, and extracting a more detailed sea-level history remains an important challenge.


*Keywords:* sea-level changes; Holocene; Maldives; Chagos; Cocos (Keeling) Islands; Indian Ocean

## 1. Introduction

Reef islands, the unconsolidated or poorly consolidated accumulations of sand and shingle that form on the tops of coral reefs, appear some of the most precarious landforms in the face of the sea-level rise anticipated as a consequence of global warming. In order to better understand the future changes that will occur on these reefs, studies of the variations of sea level that they have experienced in the past, and the

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subsequent response of the islands to those variations, are important and urgent research priorities. In global assessments, the reef islands on the margins of atolls are viewed as especially vulnerable (McLean and Tsyban, 2001), and concern has been expressed about their persistence under conditions of higher sea level (Roy and Connell, 1991). The history of past sea level is of interest, first in its own right, but also because it may give insights into how the low-lying reef islands that have formed on the reefs have responded under different, and changing, sea-level conditions, such as seem likely in the future.

There are many parts of the world, in far-field areas distant from ice-sheet formation during glaciations, where it has been shown that relative sea levels have been higher in the Holocene, as a result of hydro-isostatic adjustments to ice- and water-loads and their reorganisation (Pirazzoli, 1991, 1996). Evidence for past periods of higher sea level has been recognised across the Pacific for a long time (David and Sweet, 1904; Wentworth, 1931; Daly, 1934), although their interpretation has been the subject of robust debate. For example, the CARMARSEL expedition to Micronesia, with the resolution of the sea-level issue as its prime objective, produced polarised views for and against there having been a mid-Holocene highstand (Shepard et al., 1967; Newell and Bloom, 1970). A further example is the case for higher sea level on Oahu, in the Hawaiian Islands; early interpretation of a Holocene highstand by Stearns (1935) was dismissed by Easton and Olson (1976), but has been subsequently reconfirmed (e.g.. Grossman and Fletcher, 1998). It is now widely accepted that Holocene sea level reached a highstand slightly above present across most of the Pacific (Hopley, 1987; Grossman et al., 1998), in agreement with recent geophysical modelling (Nunn and Peltier, 2001). It has been proposed that the reef islands on atolls began to accumulate as a result of a slight fall of sea level (Schofield, 1977) an argument that has recently been re-invigorated (Dickinson, 2004).

By contrast with reefs in the Pacific, interpretation of sea-level changes in the Caribbean indicates that the sea has been gradually rising throughout the Holocene, decelerating up to the present time (Lighty et al., 1982; Toscano and Macintyre, 2003). Whereas

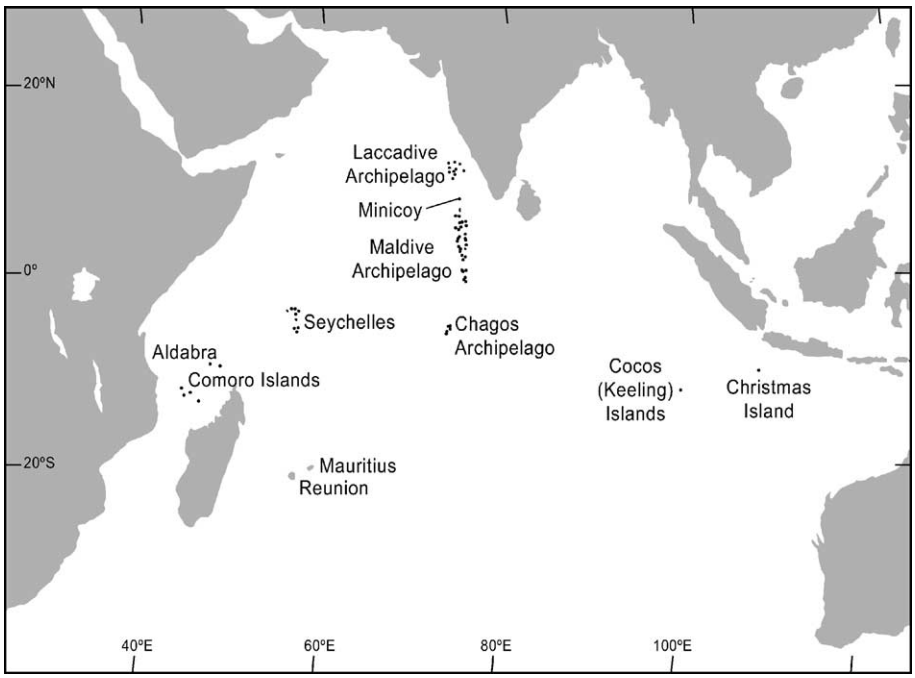


Fig. 1. The Indian Ocean showing the location of the Cocos (Keeling) Islands, and the Maldives and Chagos Archipelagoes, and the other islands from which reefs are described in the text.