Shennan and Milne (2003) contest the observational interpretation published by Yokoyama et al. (2000, 2001) on sea-level reconstruction around the Last Glacial Maximum (LGM) from cores taken in Bonaparte Gulf of northern Australia. They claim that our relative sea-level reconstructions for the LGM and the period at the rise of sea-level at \( B \) 19 ka are incorrect. Their argument is based on the assumption that there were no hiatuses in cores obtained from Bonaparte Gulf. Although our original paper (Yokoyama et al., 2000) stated that no hiatus was found, this was the result of a communication error between authors when the first author moved to a new institution. This was explained at the EPILOG workshop and in subsequent paper (Yokoyama et al., 2001) which had been prepared before the Yokoyama et al. (2000) paper. Yokoyama et al. (2001) also clearly stated the findings from more complex sedimentation in cores recovered at depths shallower than GC5. This was also consistent with data presented and discussion in Yokoyama’s (1999) thesis.

A local lowest sea-level estimation can be inferred only when reliable chronological information is available for the individual sea-level indicators, and conclusions reached without any age determinations are likely to be incorrect. The constant sedimentation rate assumption would be appropriate if the core is free from reworking and the site is sufficiently deep. Such assumptions cannot be made for the cores from the shallowest sites targeted by our studies. Local environmental changes on short time scales could affect the physical environment of the region with consequent modification of the sedimentation rate at any one site. Therefore, the horizontal lines drawn as indicating the minimum sea-level point in the core in the Fig. 2a by Shennan and Milne is not reliable because the facies age have not been determined as representing the LGM.

In our “master” core GC5, the hiatus was evident at the depth between 353 and 340 cm (cf. Fig. 4, Yokoyama et al., 2001). The conclusion to be drawn from the detailed investigation on GC5 is two-fold. First, from the existence of the hiatus, local sea-level during the earliest part of the LGM must have been lower than the altitude of this site. However, no facies boundary was observed in the deeper cores such as GC4 and GC3. Therefore, local sea-level was near GC5 but above the site of GC4. This determines the local sea-level during the LGM as \( \sim 120 \) m. Secondly, sea-level during the LGM appears to be relatively stable. This is indicated by extensive brackish facies in GC5.

The topography of, and around, Bonaparte Gulf is such that with the tidal regime and its range, as well as the overall very low altitudinal gradients in the area, a closed lake system may be difficult to sustain during the period of sea-level minimum. (Note that a very-high-resolution regional bathymetry is used by Yokoyama et al., 2000, 2001 and not a global coast compilation.) Hence, we have to rely on transitional facies such as an estuarine/marginal marine one in order to define sea-level height with some accuracy. It is obvious that we cannot rely on a non-aquatic facies, best characterized by pedogenic features, to control a sea-level curve because we would have no indicators of the duration of the period of exposure.

Uncertainties in the facies determination for the deeper sediments such as “open marine” and “shallow marine” are larger than that of the brackish facies. For example, the “open marine” facies is defined as “around 20 m” with respect to the coeval sea-level. This is based on the appearance of pteropods and the low abundance of planktonic foraminifers which require deeper water for reproduction during their life cycle (e.g. Bé, 1977; also see discussion in De Deckker and Yokoyama, submitted). However, this depth could be greater than 20 m.

Reliable sea-level indicators should contain both in situ depositional features and a “correct” depositional
age. The ideal situation is one where sediments have not been disturbed after their original deposition. Nevertheless, sediments do become mixed due to tidal current or storm waves. Hence, it is necessary to check the preservation status of microfossils in the sediments and it is important to use information from fossil shells displaying minimal or no abrasion. Earlier studies have, however, reported the possibility of relict material being preserved even though the fossils may appear intact and undamaged (De Deckker et al., 1988; McCulloch et al., 1989). Therefore, we draw our conclusions not from a single core but from several cores located at different water depths, as well as from different sedimentary environments (i.e. inner gulf, Sahul Rise, middle of the Bonaparte Depression) within the Gulf. The use of deep facies information alone as sea-level indicators, as done by Shennan and Milne (Fig. 2 in Shennan and Milne, 2003), results in erroneous conclusions. Instead, we use this information only when supported by supplemental information from several cores, and through a combination of sedimentary features and microfossils.

The reported age from both GC10 and GC11 (see Yokoyama et al., 2000, 2001) are considered reliable for the deglaciation stage in terms of showing the timing of sea-level change. The depositional environment of these two sites is different from that of the others because they are located on the Sahul Rise where locally exposed areas existed during the LGM. No significant sedimentological disruption is observed in these cores and the two basal ages strongly suggest that the main phase of sedimentation started when the sites became inundated during the rise of sea-level (see Fig. 1 in Yokoyama et al., 2000) well after the LGM.

Investigations for shallower sediment cores obtained from this region will provide a firm evidence of the sea-level history for the period leading to the LGM. The absence of any coral terraces younger than ~30 ka at Huon Peninsula, Papua New Guinea, indicates that sea-level fell rapidly immediately before the LGM from below ca ~70 m (Yokoyama, 1999; Lambeck and Chappell, 2001; Lambeck et al., 2002). Additional AMS 14C measurements as well as chemical analyses (i.e. δ18O, δ13C, Mg/Ca, etc.) or microfossils will be conducted by us in the future and will certainly lead to a more complete record of the LGM and its period of still-stand.

To conclude, although we agree with Shennan and Milne that further analyses of cores from the Bonaparte Gulf are desirable (this forms our longer-term goal), we do not agree with their re-interpretation of our data, using as starting point the absence of a hiatus in the cores. We believe that our original interpretation as it is based on the totality of the evidence from several cores remains reliable. Local sea-level was about 120 m during the LGM and a rise of sea-level, of about 10 m, commenced at ~19,000 yr BP. Further, a more detailed microfossil analysis of GC5 and interpretation has been undertaken and supports our original sea-level interpretation (De Deckker and Yokoyama, submitted).

In addition to the comments about the interpretation of the cores, some comments about the isostatic modelling are also made by Shennan and Milne (2002). The discussion is incomplete but does point to some problems that render their conclusions doubtful. Tuning their model to the Barbados sea-level and a particular ice model that has already been tuned to a particular earth model is unwise, particularly as Barbados lies relatively close to the North American ice sheet whose ice-distribution and ice-volume during the LGM remain poorly constrained. One could, in fact, do the opposite and tune the model to the Bonaparte data, on the grounds that it lies far from any ice margin and the isostatic signal is primarily a function of the water loading and insensitive to the details of the ice loading. Better would be to use the information from all far-field locations and estimate the ice and earth model parameters in a consistent manner. When this is done there is in fact little disagreement between the Barbados and Bonaparte results (Lambeck et al., 2002).

References