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Pre- and post-1998 ENSO records of shallow-water octocorals (Alcyonacea) in the Chagos Archipelago

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ABSTRACT

When compared, principal octocorals collected in the Chagos Archipelago before and after the 1998 ENSO shared many common taxa. While a few discontinuities in their biodiversity revealed subtle changes in more persistent genera (*Lobophytum*, *Sarcophyton*), some fast-growing "fugitive" genera (e.g. *Cespitularia*, *Efflatounaria*, *Heteroxenia*) disappeared after the ENSO-related coral bleaching. Such transient fugitives might thus be eliminated from soft coral communities on isolated reef systems, possibly in the long term, by events of this nature. The appearance of *Carijoa riseii*, a species often considered a fouling organism, even an invasive, may well be indicative of reef degradation during the ENSO event. The post-ENSO recovery manifested by this fauna nevertheless gives cause for hope for their survival in the face of climate change.

1. Introduction

The Chagos Archipelago is the largest and most isolated atoll complex in the world and lies in the middle of the Indian Ocean at 6°S (Sheppard and Seaward, 1999). Coral reefs in this archipelago were among the most severely affected by bleaching caused by high SSTs during the 1998 El Nino Southern Oscillation (ENSO), resulting in very high mortalities (Goreau et al., 2000; Sheppard et al., 2002). Immediately after the 1998 ENSO only traces of octocorals could be found and the cover of this fauna was <5% three years thereafter (Sheppard et al., 2002). A further survey in 2006 revealed that coral cover had returned to pre-1998 levels but with changes in coral community structure (Harris and Sheppard, 2008; Sheppard et al., 2008) anticipated earlier (Sheppard et al., 2002). Collections made in 1996 effectively yielded a pre-1998 ENSO record of the octocorals in the Archipelago (Reinicke and van Ofwegen, 1999) and follow-up collections were made in 2006 (this study). In both instances, some undescribed species are still under examination. The present paper provides a comparison of the principal, readily identifiable octocorals of the order Alcyonacea found on the reefs prior to and seven years after the major coral bleaching event.

2. Materials and methods

A species list of the principal octocoral families collected in 1996 was extracted from the list published for the Chagos Archipelago by Reinicke and van Ofwegen (1999). This was derived from samples collected on reefs off the Great Chagos Bank and the Peros Banhos, Salomon and Diego Garcia Atolls to a depth of 50 m. The full range of reef habitats was sampled, ranging from lagoons to seaward reef slopes under different current regimes. Taxonomic changes were made to the earlier records to comply with more recent revisions of octocoral systematics outlined by Alderslade (2000) and Fabricius and Alderslade (2001) for comparison in the present study.

Representative octocorals were collected during 44 dives undertaken between 5 February and 15 March 2006 in a follow-up expedition to the Chagos Archipelago. The sites visited were comparable with the 1996 survey (Fig. 1, Table 1, *cf.* Reinicke and van Ofwegen, 1999, Fig. 1, Table 1) but more sites were visited around Diego Garcia than in 1996. All reef habitats were again sampled as per the earlier survey, a difference being the depth of the dives. For safety reasons, these were limited to 25 m due to the remoteness of the archipelago, with only momentary excursions to 30 m. On fringing reefs, dives thus progressed from 30 m or the deepest reaches of a reef up the reef wall, onto the reef slope, the fore-reef and into the reef shallows. Lagoonal reefs were similarly dived to all their depths within Three Brothers and the Peros Banhos and Salomon Atolls (Fig. 1). The collection of duplicates was avoided to minimise the size of the collection, i.e. when a clearly recognisable species was found at a locality, its re-collection was avoided at further localities to avoid unnecessary duplication. The focus of the study was thus aimed at establishing the octocoral biodiversity, as was the case in the survey reported by Reinicke and van Ofwegen (1999). After collection, samples were fixed overnight in 4%

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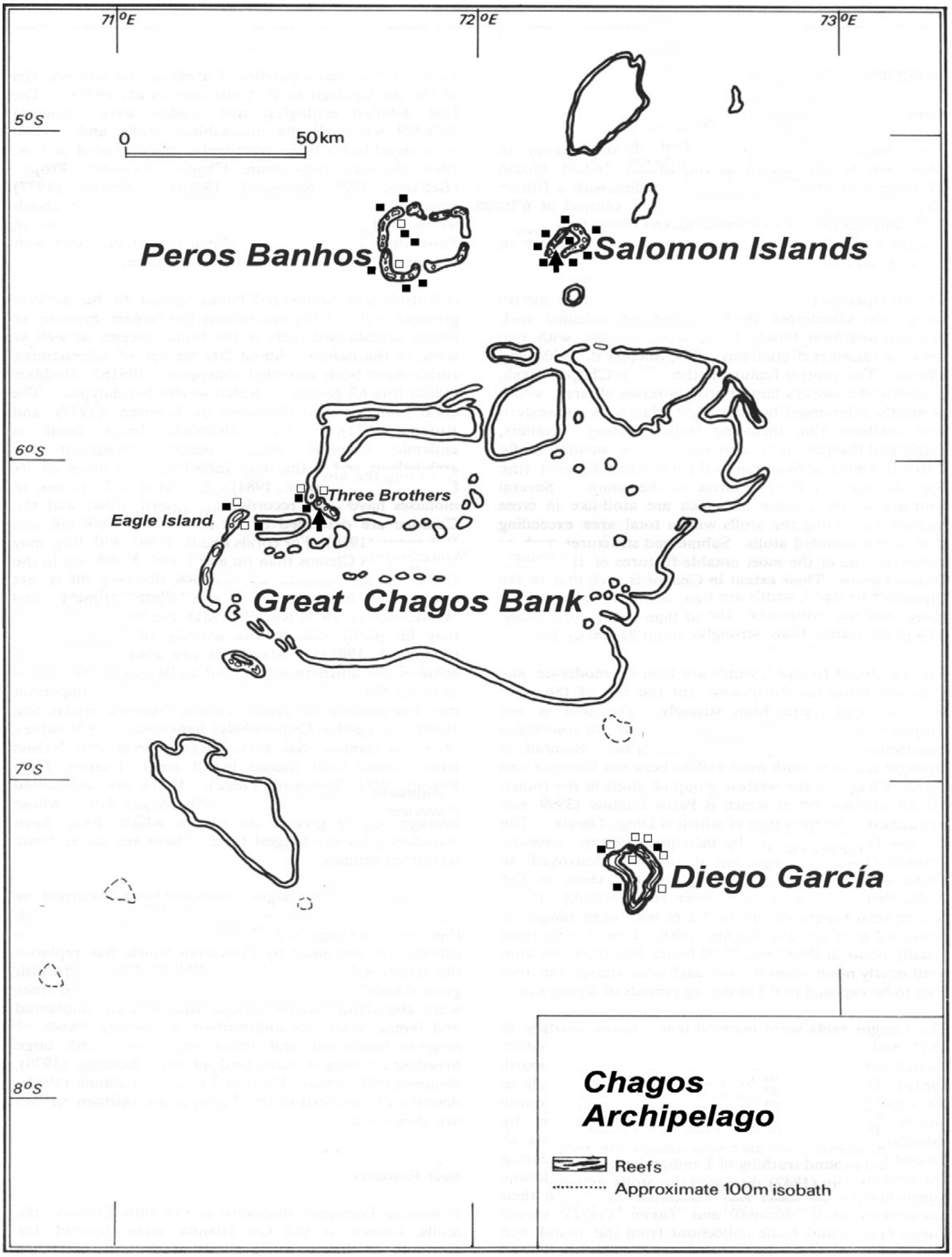

Fig. 1. Map of the Chagos Archipelago showing island complexes where octocoral samples were collected (■) or reefs were only visited (□, ↑) during the 2006 Chagos expedition.

formalin in seawater and subsequently stored in 70% EtOH for identification in the laboratory. Sclerites were extracted from the samples for microscopic comparison with permanent sclerite preparations of type material kept in the Zoological Museum, Department of Zoology, Tel Aviv University, Israel (ZMTAU) and the Nationaal Natuurhistorisch Museum, Leiden, The Netherlands (RMNH). The specimens have been accessioned in the Zoological Museum of Tel Aviv University and duplicates have been lodged at the Oceanographic Research Institute in Durban.

3. Results and discussion

Principal octocorals identified in the 2006 collection are listed in Table 2 together with those derived from Reinicke and van Ofwegen (1999) from the 1996 collection. A total of 168 specimens were identified in the present collection, this being comparable to the figure given by the preceding authors for their collection (*c.* 170). Some samples are still under examination in both cases and are expected to give rise to new genera and species.

Table 1
Localities at which octocoral samples were collected during the 2006 Chagos expedition.

Locality	Latitude S	Longitude E
Peros Banhos		
Ile Diamant	5° 14.77′	71° 46.13′
Ile Poulet	5° 23.89′	71° 44.96′
Bank in Peros Banhos lagoon	5° 24.91′	71° 46.40′
Small bank in Peros Banhos lagoon	5° 26.32′	71° 46.74′
Ile Fouquet	5° 28.87′	71° 48.76′
Salomon Islands		
Ile de la Passe	5° 17.94′	72° 15.45′
Ile Taka Maka	5° 20.15′	72° 16.78′
Ile Anglaise	5° 20.44′	72° 12.81′
Central Ile Anglaise	5° 19.90′	72° 13.12′
Ile Anglaise passage	5° 20.46′	72° 12.80′
Ile Mapou	5° 18.53′	72° 16.06′
Ile du Sel	5° 21.55′	72° 13.79′
Great Chagos Bank		
North Brother	6° 7.90′	71° 29.93′
Middle Brother	6° 8.93′	71° 31.63′
West of Eagle Island	6° 11.06′	71° 19.49′
Eagle Island bank	6° 11.75′	71° 22.15′
Diego Garcia		
NE tip of Diego Garcia	7° 13.46′	72° 25.22′
West of Diego Garcia	7° 15.97′	72° 21.37′
East of Diego Garcia	7° 22.20′	72° 28.97′

Table 2
Principal octocorals collected in the Chagos Archipelago in 1996 (Reinicke and van Ofwegen, 1999) and 2006, being representative of the pre- and post-1998 ENSO soft coral fauna on the reefs to a depth of 30 m. Instances where genera are marked (**?**) denote as yet unidentified, indeterminate or new species. Notable differences discussed in the text are shaded in gray.

	1996	2006
Family Helioporidae		
Genus *Heliopora* de Blainville, 1830		
Heliopora coerulea (Pallas, 1766)	●	●
Family Clavulariidae		
Genus *Carijoa* F. Muller, 1867		
Carijoa riisei (Duchassaing & Michelotti, 1860)		●
Genus *Clavularia* Blainville, 1830	●	●
Family Tubiporidae		
Genus *Tubipora* Linnaeus, 1758		
Tubipora musica Linnaeus, 1758	●	●
Family Alcyoniidae		
Genus *Capnella* Gray, 1869		?
Capnella boullioni Verseveldt, 1976	●	
Genus *Cladiella* Gray, 1869	●	
Cladiella pachyclados (Klunzinger, 1877)		●
Cladiella krempfi (Hickson, 1919)		●
Genus *Klyxum* Alderslade (2000)		
Klyxum flaccidum (Tixier-Durivault, 1966)		●
Klyxum simplex (Thomson & Dean, 1931)	●	
Klyxum utinomii (Verseveldt, 1971)	●	
Genus *Lobophytum* Marenzeller, 1886		
Lobophytum crassum Von Marenzeller, 1886	●	●
Lobophytum depressum Tixier-Durivault, 1966	●	
Lobophytum variatum Tixier-Durivault, 1957	●	
Lobophytum venustum Tixier-Durivault, 1957	●	●
Genus *Sarcophyton* Lesson, 1834		
Sarcophyton crassocaule Moser, 1919		●
Sarcophyton crassum Tixier-Durivault, 1946		●
Sarcophyton flexuosum Tixier-Durivault, 1966		●
Sarcophyton glaucum (Quoy & Gaymard, 1883)	●	●
Sarcophyton trocheliophorum Von Marenzeller, 1886	●	●
Genus *Sinularia* May, 1898	●	●
Sinularia abrupta Tixier-Durivault, 1970	●	●
Sinularia brassica May, 1898	●	●
Sinularia "conferta" (Dana, 1846)		●
Sinularia densa (Whitelegge, 1897)	●	
Sinularia depressa Tixier-Durivault, 1970	●	
Sinularia erecta Tixier-Durivault, 1945	●	●
Sinularia firma Tixier-Durivault, 1970		●
Sinularia gibberosa Tixier-Durivault, 1970	●	●
Sinularia gravis Tixier-Durivault, 1970		●
Sinularia heterospiculata Verseveldt, 1970	●	●
Sinularia hirta (Pratt, 1903)	●	●
Sinularia humesi Verseveldt, 1968	●	●
Sinularia leptoclados (Ehrenberg, 1834)	●	●
Sinularia molesta Tixier-Durivault, 1970	●	
Sinularia muralis May, 1899	●	●
Sinularia nannolobata Verseveldt, 1977		●
Sinularia notanda Tixier-Durivault, 1966		●
Sinularia numerosa Tixier-Durivault, 1970	●	●
Sinularia cf. *parva* Tixier-Durivault, 1970		●
Sinularia aff. *peculiaris* Tixier-Durivault, 1970	●	
Sinularia polydactyla (Ehrenberg, 1834)		●
Sinularia querciformis Pratt, 1903	●	●
Sinularia aff. *rigida* Dana, 1846	●	●
Sinularia variabilis Tixier-Durivault, 1945		●
Sinularia whiteleggii Lüttschwager, 1914	●	
Family Nephtheidae		
Genus *Dendronephthya* Kükenthal, 1905	●	●
Dendronephthya gracillima Kükenthal, 1905	●	
Genus *Scleronephthya* Studer, 1887		●
Genus *Nephthea* Audouin, 1826	●	?
Genus *Stereonephthya* Kükenthal, 1905	●	?
Stereonephthya cordylophora Verseveldt, 1973	●	
Stereonephthya unicolor (Gray, 1862)	●	
Family Nidaliidae		
Genus *Chironephthya* Wright & Studer, 1889	●	●
Family Xeniidae		
Genus *Anthelia* Lamarck, 1816	●	
Anthelia glauca Lamarck, 1816		●
Genus *Cespitularia* Milne-Edwards & Haime, 1850	●	
Genus *Efflatounaria* Gohar, 1934	●	
Genus *Heteroxenia* Roxas, 1933		
Heteroxenia pinnata Roxas, 1933	●	
Genus *Lemnalia* Gray, 1868	●	●
Lemnalia bantayensis Roxas, 1933	●	
Lemnalia flava (May, 1898)		●
Genus *Ovabunda* Alderslade (2001)		?
Genus *Sansibia* Alderslade (2000)		
Sansibia flava (May, 1899)		●
Genus *Xenia* Lamarck, 1816	●	●
Xenia crassa Schenk, 1896		●
Xenia garciae Bourne, 1895	●	
Xenia lillieae Roxas, 1933		●
Xenia novaebrittianiae Ashworth, 1899	●	

The first gratifying conclusion from these results is that, in the case of the principal octocorals, the massive coral mortalities recorded in the Chagos Archipelago (Goreau et al., 2000; Sheppard et al., 2002) have not had an enduring effect on soft coral biodiversity. Furthermore, Sheppard et al. (2008) noted that the octocoral cover, which was negligible immediately after the 1998 ENSO, had increased overall to 13.6% in 2006, a figure probably similar to pre-bleaching values (Reinicke and van Ofwegen, 1999). A return to the previous scleractinian cover on the reefs appeared to be largely attributable to relatively few, fast-growing *Acropora* spp. (Sheppard et al., 2008).

This recovery in soft coral cover contrasts with that encountered up to 6 years after the 1998 ENSO in the isolated Scott Reef system off North Western Australia (Smith et al., 2008). Here, the pre-ENSO octocoral cover of 9.8% was reduced >80% by bleaching and the post-ENSO recovery of this group was negligible, unlike that of the hard corals (~40%). Smith et al. (2008) concluded that the recovery which occurred in the coral community was attributable to regrowth of survivors, rather than from recruitment, as the larval supply advected into the system by currents was deemed inadequate. Since the Scott Reef system is free of anthropogenic stress which would militate against recovery in the coral community, poor octocoral recovery was attributed to their biology (Smith et al., 2008). Most were members of the Alcyonidae, noted for their proliferation by vegetative propagation (McFadden, 1991) and persistence but low growth and reproductive recruitment (Fabricius, 1995).

The Chagos Archipelago is possibly more isolated than the Scott Reef system and as free of anthropogenic perturbation, yet the octocorals in the former have undergone better recovery (Sheppard et al., 2008). In this instance, the archipelago is much larger and, since ENSO-related coral bleaching is notably variable (Sheppard et al., 2002; Smith et al., 2008), some of its reefs probably retained an adequate octocoral population both for re-vegetation and reseeding. Patchy recovery on the coral reefs of Palau, which are similarly isolated and pollution-free, has been attributed to all these factors (Golbuu et al., 2007).

Apart from the aforementioned generalisations, there were nevertheless some changes of note in the octocoral community in the Chagos. The genus *Lobophytum* was better represented prior to the 1998 ENSO than afterwards, the previous species count of four being subsequently halved. The opposite was true of the genus *Sarcophyton* and the earlier record of two species increased to five. While *Lobophytum* colonies were also noticeably scarce in terms of abundance in 2006, *Sarcophyton* colonies were slightly more abundant and larger specimens were observed (Schleyer pers. obs.). Members of these genera would constitute slow-growing, more persistent soft corals with a low turnover as described by Fabricius (1995).

Octocorals of the families Nephtheidae and Xeniidae, conversely, are considered fugitive species that have high growth and turnover rates and may be transient within a soft coral community (Fabricius, 1995). The xeniids *Cespitularia*, *Efflatounaria* and *Heteroxenia* would fall into this category. All were found in the Chagos Archipelago in 1996, but none in 2006, despite the extensive nature of the survey. At this stage, it can thus be assumed that the species collected in the earlier survey did not survive the 1998 ENSO; subsequent conditions have probably not been conducive for their resettlement and the upstream larval supply in the South Equatorial Current has been inadequate. Such transient fugitives might thus be eliminated from soft coral communities on isolated reef systems, possibly in the long term, by events of this nature. *Cespitularia* and *Heteroxenia* have, however, persisted downstream in this current and its offshoots on East African reefs; here colonies of *Cespitularia* have been noted for their opportunistic overgrowth of bleached reefs (Schleyer et al., 2009).

The appearance of *Carijoa riseii* in the post-1998 ENSO collection is of special interest. The genus *Carijoa* is frequently considered a fouling organism in turbid coastal waters, particularly on jetties and wrecks (Fabricius and Alderslade, 2001), and it has been recorded as an invasive species in Hawaii where it successfully inhabits large reef areas (Kahng et al., 2008). Its appearance in the Chagos Archipelago may well be indicative of the degradation that the reefs underwent during this bleaching episode, providing space for their colonisation by this fugitive species.

In conclusion, while both the pre- and post-1998 ENSO collections in the Chagos Archipelago will yet yield new octocoral taxa, the results of known taxa compared in this paper provide evidence of a long term retention of soft coral biodiversity, despite severe environmental adversity. Transient fugitive species have, however, been lost from the system. Additional taxa were collected that were common to both surveys, e.g. deeper forms such as *Annella* and *Siphonogorgia* spp. (Schleyer unpub. data); these were not included in the comparative study due to differences in sampling depth that may have excluded the latter in the 2006 survey. Nevertheless, the recovery manifested by these fauna in the Chagos Archipelago is probably attributable to the survival of resilient pockets of sheltered octocoral communities on the reefs, particularly in sheltered and deeper communities. In view of the severity of the 1998 ENSO bleaching event at equatorial latitudes in the Indian Ocean, this gives cause for hope for their survival in such large systems when faced with climate change.

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