

# The 1997-1998 Mass Bleaching Event Around The World

Compiled by Clive Wilkinson

## ABSTRACT

There has been significant bleaching of hard and soft corals in widely separate parts of the world from mid-1997 to the last months of 1998. Much of this bleaching coincided with a large El Nino event, immediately switching over to a strong La Nina. Some of the reports by experienced observers are of unprecedented bleaching in places as widespread as (from west to east) the Middle East, East Africa, the Indian Ocean, South, Southeast and East Asia, far West and far East Pacific, the Caribbean and Atlantic Ocean.

There was a wide spectrum of reports on bleaching ranging from:

- catastrophic bleaching with massive mortality, often near 95% of shallow (and sometimes deep water) corals such as in Bahrain, Maldives, Sri Lanka, Singapore, and parts of Tanzania; through
- severe bleaching over large areas with significant mortality (around 50 to 70%) with recovery of larger, more resistant species (Kenya, Seychelles, Thailand, Vietnam, Japan, and Belize); to
- severe bleaching only in some of the reefs, with a mix of recovery and mortality (around 20 to 50% in places) e.g. Oman, Madagascar, parts of the Great Barrier Reef, parts of Indonesia and the Philippines, Taiwan, Palau, French Polynesia, Galapagos, Bahamas, Cayman Islands, Florida, Bermuda, Brazil; and
- finally, on large areas of the worlds reefs, there was insignificant or no bleaching was observed.

Bleaching was most pronounced in shallow water (less than 15 m) and particularly affected staghorn and plate *Acropora* and other fast growing species, with a high proportion of coral death. Slower growing massive species, like *Porites*, also bleached, but many recovered within 1 or 2 months. Some people commented that bleaching like this had not been seen in 40 years of observations.

While this was occurring, there were large areas of the world where bleaching was not observed. Little or insignificant bleaching was seen in the Red Sea, southern Indian Ocean, eastern Andaman Sea, most of Indonesia, large parts of the Great Barrier Reef, most of the central Pacific and many parts of the southern and eastern Caribbean. In some places with no bleaching, severe bleaching similar to that observed above had occurred in past years, with significant recovery since

then.

The consensus is that this is probably the most severe bleaching event ever observed, but there were far more observations and observers this year, and a greater degree of interest in reporting bleaching. Many of the bleaching reports e.g. 80% are estimates and may be exaggerated because bleached corals are particularly dramatic. However, amongst the reports there are actual measures which often are close to the estimates. Much of the interest has arisen because regular, real-time reports are available on sea-surface temperatures over the internet and on e-mail lists through the National Oceanic and Atmospheric Administration of the USA. Now the large questions are whether observed bleaching will result in death or recovery of the corals, and whether there is potential for the damaged reefs to recover from this event. But the most important question is whether this is just a severe, one-off event, as it now appears, or whether events like this will occur more frequently as the world's atmosphere and waters warm up.

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## INTRODUCTION

There has been unprecedented bleaching in coral reefs throughout the Indian Ocean, South East Asia, the Caribbean and parts of the far eastern and western Pacific Ocean. This bleaching has been in parallel with big swings in the global climate with a severe El Nino event during late-1997 and early-1998, which switched over to a strong La Nina in mid-1998.

The coral bleaching of 1997-1998, is the most geographically widespread ever recorded, and probably the most severe in recorded history. Bleaching means that corals (both hard and soft), as well as giant clams and some other animals like sponges, lose their symbiotic algae (zooxanthellae) and/or the pigments of those algae, such that the coral appears pale to stark white. Some bleaching may be a seasonal event in the Pacific, Indian Ocean, and the Caribbean, and full recovery is the norm. Frequently many corals recover from bleaching, but death may result if the stress is extreme or prolonged. Normally fast-growing, branching corals in the Indo-Pacific are more susceptible than slow-growing boulder corals, which if they are bleached, frequently recover in 1 to 2 months. In this year's bleaching event, there has been widespread death of the fast growing corals, and also bleaching of the more resistant forms - the boulder and plate-like corals. For example, some 700-year-old *Porites* corals on inner reefs of the Australian Great Barrier Reef and Vietnam have been extensively bleached, and some have died. Complete recovery of these reefs will be slow.

Mass bleaching can occur when sea-surface temperatures (SST) rise well above

the average for summer and this stresses corals. Frequently the warmer temperatures coincide with more solar radiation, particularly during very calm periods. Bleaching also occurs during extreme low tides or heavy freshwater runoff onto reefs. This time, bleaching has been seen both in shallow water down to very deep water, for example down to 50 m deep.

There are some correlations between the widespread coral bleaching in 1997-1998 and one of the strongest El Nino events of this century, but the patterns are unclear with many exceptions. The correlation exists for the east Pacific, but the bleaching in southeast Asia coincides with a strong La Nina (the complete reverse of El Nino), and the bleaching in the Indian Ocean and parts of the Caribbean do correlate with either El Nino or La Nina.

The 1997-1998 episode of worldwide bleaching is a major cause for concern. Although sea temperatures have returned to normal in many tropical areas, the full extent of bleaching-induced mortality may not be fully apparent for several months yet.

This report was only possible through the cooperation of many, many people throughout the world (whose names are listed after the country reports), and through the power of electronic mail, particularly using a list server run by the National Oceanic and Atmospheric Administration of the USA. Reports received varied from detailed accounts with accurate measures of bleaching and mortality, to brief anecdotal reports obtained during a rapid site visit. While it is being published for the International Tropical Marine Ecosystems Management Symposium in Townsville in November 1998, it is also being lodged on the internet and hopefully upgraded as more reports come in. Many of the reports were very detailed; I edited them to reduce the length of this report, so any errors are probably mine, not the author's. The latest reports were added on 1st November 1998.

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## MIDDLE EAST

The waters of the Arabian/Persian Gulf experience major variations in temperature from lows of around 15°C to highs of mid-30°C. Thus the corals are adapted to wide fluctuations in temperature (as well as salinity). Extensive bleaching was seen in the Gulf in 1996; and now there has been extensive bleaching over the entire Arabian Gulf and parts of the Arabian Sea in 1998. The Gulf of Oman and Arabian Gulf are subject to considerable upwellings, which lower temperatures and stress corals (which in turn favours the growth of macroalgae).

The Red Sea also experiences warm temperatures, but bleaching is an infrequent

event and some localized bleaching was seen over several months of mid-1998. There was considerable bleaching in the Red Sea in 1996.

### **Bahrain**

1998 was a very hot year on land, and coral bleaching was first observed in mid-August when water temperatures went from 34°C to 37°C in a week, and stayed that way for a few weeks (up to 39°C in shallow areas). There was 100% bleaching from Hayr Shutaya (20 miles north of Bahrain) south to Fasht Al Adhom, and Fasht Al Dibal (all less than 10m depth). Coral mortality was 90% to 95% a few weeks later, and surviving corals were still bleached in October. Bleaching was estimated at 50% on Abul Thama (about 50 miles north of Bahrain). There was major bleaching in summer of 1996 when water temperatures were 37.3°C at Fasht Al Dibal and most corals on Fasht Al Adhom bleached then died. Now many of the corals at Abul Thama that survived 1996 have bleached and died.

(Roger Uwate)

### **Eritrea**

Water temperatures around Massawa and Green Island have been extremely high (40 °C ) in August and September, resulting in bleaching on deep and shallow reefs. After the temperatures cooled, most corals recovered to their original state, but some in shallow water have died. No bleaching at all was seen around the islands of Assab.

(Marco Pedulli)

### **Oman**

Extensive bleaching was observed, with temperatures between 29.5°C and 31.5°C, at eight sites around Mirbat, southern Oman, between 22 and 26 May 1998. Between 75% and 95% of *Stylophora* (the most abundant coral genus) bleached, and 50% of large *Porites* colonies were partially bleached. About 95% of coral were still living despite losing their zooxanthellae. But no bleaching was observed at Sudh, 40 km to the east of Mirbat, where seawater temperatures varied between 25°C and 25.5°C, nor in the Muscat Area, Gulf of Oman where water temperatures in early June were 30.5°C. Also no bleaching was observed on the Hallaniyat islands, February to April 1998, about 75 km north-east of Sudh. Normally, upwelling during the southeast monsoon drops temperatures to 19°C. This was described as a pristine area with coral cover from 10% to 90% growing down to 35 m where macroalgae and corals co-exist in waters which vary between very cool to very warm. No recovery of bleached colonies was seen in mid-October when temperatures increased to 25°C after the summer upwelling period.

(Robert Baldwin, Simon Wilson, Peter Collinson)

### **Saudi Arabia**

Widespread coral bleaching was seen on four patch reefs in the Gulf (seawater temperatures 35-36°C) in mid-August, 1998. There was very high mortality (about 95%) in *Acropora* and other species (especially *Platygyra daedalea*, a

common nearshore coral) that had survived bleaching in 1996. Bleaching was minimal on an offshore island reef with seawater temperature below 34°C. Severe bleaching in 1996 killed high percentages (>90%) of *Acropora* on nearshore platform and patch reefs, as well as damaging the Porites dominated reefs in the north.

(Yusef Fadlallah, Reynaldo Lindo)

#### **United Arab Emirates (UAE)**

Bleaching started in a marine protected area off the UAE in 1996, and this year (1998) the entire reef appears to be dead. This used to be a beautiful coral reef. (Fareed Krupp)

#### **Yemen (Socotra)**

Extensive coral bleaching was seen on the islands of Socotra off the Horn of Africa in May, 1998 with high mortality. (Catherine Cheung, Lyndon de Vantier)

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## **INDIAN OCEAN**

The extent of bleaching in the Indian Ocean during 1998 is unprecedented in both the extent and severity. Warm surface waters have migrated from south to north during the first 6 months, with considerable coral reef bleaching occurring in each locality. The warm pool of water was observed in satellite images from the National Oceanic and Atmospheric Administration of USA in January 1998, with the first bleaching being seen in April. This bleaching is similar, but more severe than the 1987 El Nino in the Indian Ocean, which caused some mortality, but the reefs recovered quite quickly in the Maldives.

#### **Chagos**

The atolls apparently escaped bleaching as none has been reported in the past 2 years. No details known.

(Charles Sheppard)

#### **Comores**

In late May, bleaching was observed on the 2 islands: Grande Comore (near the airport); and Galawa (near beach hotels). Bleaching was seen from the air, possibly linked to freshwater runoff.

(Jean-Pascal Quod)

#### **India**

The outer-atoll seaward slopes of Kadmat in the Lakshadweep Islands, India had live coral cover around 80-90% in places. A Reef Check survey showed heavy mortality with only 3% live coral cover and 87% dead branching and table forms at 3m. At 10m, live coral cover was 7%, with 43% dead coral cover, and 38% rocky substrate. Bleaching at Kavaratti Island, Lakshadweep islands in May appears similar to what was seen in the Maldives, perhaps less severe. Not all reefs in Lakshadweep have been so severely affected. Some bleaching, between 10% to 30%, was seen in the Gulf of Kutch on the northerly Gujarat coast in early to mid-May. Reports are coming of bleaching in the Andaman islands.  
(Arjan Rajasuriya, Jason Rubens)

### **Kenya**

Bleaching started north of Lamu (2°S), on 18 March 1998 when temperatures reached 32°C and continued during April. Bleaching around Mombasa started around the same time and was as low as 50%, but mostly near 100% on almost all reefs seen, where there had been 20-50% coral cover. Bleaching was most extreme in shallow water, but was also 50% or more at 20 m. Coral mortality ranges between 50 to 90%, with reefs now having 1-10% coral cover, with 10 - 50% of the remaining live corals still bleached in mid-October.  
(David Obura)

### **Madagascar**

There was bleaching of 30% of corals at Belo sur Mer (mid-west coast), with water temperatures of 32-33°C in February and March, 1998 and similar bleaching at Antananbe, Toliara, Nosy Bé, Mitsio archipelago, and Mananara-Nord, Masoala peninsula (northeast coast, 15oS). There was no distinction in species affected at most sites, but at Mananara, *Acropora* corals in shallow water were 40-80% bleached with high mortality, and 10-40% of mixed species corals bleached in deeper water. Another report from Toliara/Tulear for September was of no bleaching nor crown-of-thorns damage with the reefs in a good state of health.  
(Jean Maharavo, David Obura, Charlie Veron)

### **Maldives**

There has been heavy damage to coral reefs in the central tourism region of the Maldives. Relatively severe, rapid bleaching occurred between late April to May, 1998, and now there are signs of partial recovery. Around 80% of corals wholly or partially bleached on the back reef, with around 45% at 10m on the reef slope, and 30- 40% at 20 -30m. Bleaching was also seen at 50m. These observations on North Male Atoll have been effectively confirmed by sea-plane operators who observed similar levels throughout the Maldives. Other reports from North Male and the Ari Atoll were of 95% of mostly *Acropora* communities dead, including soft corals and anemones. Many massive corals are still under stress and partially bleached. Prior to this, coral cover was around 30-50% in shallow water (mostly *Acropora*), decreasing with depth. Bleaching appears to have killed almost all

shallow corals, but effects are less at greater depths, although still severe.

By late May, recovery began for *Porites* species on South Male and Vaavu Atolls, and colour was near normal by September, but *Acropora* species suffered major mortality, some times up to 100%. On South Male Atoll, temperatures were high, being over 30°C at 30 m from April to June 1998. Here 100% of some *Sinularia* soft corals bleached (but not Sarcophyton); corals (*Acropora*, *Fungia* and *Porites* were 60-80% bleached; and even giant clams (*Tridacna*) were partially bleached. Many anemones have since regained their colour. An apparently similar result was seen in the 1970s, with large areas of reefs dead from unknown causes, but recovery was rapid.

(Jason Rubens, William Allison, Norbert Schmidt, Reto Wyss, Zdenka Vapenik)

### **Mauritius**

There was minor bleaching in Mauritius this year, with some small localized areas of moderate bleaching. Surveys showed from 1-15% bleaching in many locations, and up to 50% corals with minor loss of colour. Temperatures were about 3°C above the normal of 27°C. On Iles aux Benities, there was moderate bleaching (about 50% in the lagoon).

(Loic Charpy, Ruby Moothien Pillay)

### **Mayotte**

Corals began to bleach at Mayotte (Comoro Archipelago) in mid-April on the southern end exposed to the tradewinds, and also in the lagoon, which receives cooler water from the north. Very high mortality seen (maybe 80% of *Acropora*) on the outer slope, with other main genera affected being *Galaxea*, *Lobophyllia*, and *Goniopora*. Soft corals were also bleached, but *Porites* were not affected. 'Many bright corals' were seen on nearby small coral islands of Europa and Juan de Nova.

(Jean-Pascal Quod, Bernard Thomassin)

### **Reunion**

During the last 2 weeks of March, there was significant bleaching (approx. 30% to 50%) on the reef flats and reef slopes of Reunion, with *Acropora*, *Galaxea* and *Pocillopora* the genera most affected. Water temperatures were high (but not recorded) and there was very heavy rainfall for most of February. No recovery was seen several months later, with corals now covered with turf algae.

(Michel Pichon, Jean-Pascal Quod)

### **Seychelles**

There was extensive bleaching down to 23 m in the south on Aldabra and Providence Group (9°S; 46 to 51°E), and Alphonse Group (7°S; 53°E) during March-May 1998. Temperatures ranged from 29°C to 32°C, and 34°C in lagoons. Bleaching and mortality affected *Acropora*, *Pocillopora* and *Millepora*, with 40-50% bleached and an additional 20- 55% recently dead with significant algal growth. Soft corals (85- 95% mortality), anemones and giant clams also bleached.

Corals at 14 sites in the Seychelles Marine Park system that were filmed showed that an average of about 75% were recently dead (ranging from 50% to 95%). The dead corals were covered with filamentous algae, which were expanding to cover areas of dying corals. Other reports were of moderate bleaching, which was not exceptional.

(Clare Bradshaw, Loic Charpy, Tom Goreau, Kristian Teleki, Mark Spalding, Tom Spencer)

### **Sri Lanka**

Bleaching started about 10 April 1998 in the southwest at the Hikkaduwa Marine Sanctuary with over 75% bleaching in the beginning, and 90-95% at Buona-vista. Almost all coral species between 1 m and 8 m, except *Montipora* species were affected when water temperatures went from the normal 29°C to 30°C to about 36°C in mid-April and remained above 32°C until late May. Bleaching increased to more than 80% on the reef flat by late April, and on deeper offshore reefs off Colombo. All species appear to have been affected, but some soft corals appear to have resisted the bleaching better, but not *Sarcophyton* and *Lobophyton*. Bleaching was noticeable down to 42 m on the southeast coast near Battilacoa in mid-May. No bleaching was observed 100 km further up on the northeast coast of near Trincolamalee (Green Bay and R°Cky) in May to September with 50-60% live coral cover on the reefs.

Corals remained bleached up to early June 1998, with most branching and tabulate *Acropora* and *Pocillopora* colonies starting to die off and be covered by algae. Some recovery (regaining normal colour) of about 10% of bleached corals was observed in mid-July. Recovery at Buona-vista was more extensive with most bleached colonies regaining some colour in late June when monsoon winds resulted in lower temperatures. But the reef possibly lost over 70% of its coral cover. Bleaching like this has never been seen in Sri Lanka before; any bleached corals in the past recovered within 3 to 4 weeks. (Arjan Rajasuriya, Jason Rubens, Prasanna Weerakkody)

### **Timor Sea Reefs (Scott, Seringapatam, Cartier, Hibernia - Australia)**

The remote atoll reef of Scorr (14°S; 121°E) had extensive bleaching in May 1998. There was between 70% and 100% bleaching and mortality of corals between 1 m and 9 m, and 40% at 30 m depth. Sheltered shallow sites had up to 75% coral cover, which is now down to 15%, with more corals still dying 3 months after bleaching started. Some very large corals suffered several bleaching events and are now covered with patches of algae. Soft corals (*Sarcophyton* and *Lobophyton*) bleached, and some are disintegrating. Other remote reefs, Cartier and Seringapatam, were affected to a lesser extent. Corals on Hibernia were only slightly bleached.

(Clay Bryce, Luke Smith)

### **Tanzania**

Corals bleached in mid-May 1998 along the whole coastline of Tanzania, from



Mnazi Bay (10°S - 15% to 25% of corals bleached) to Zanzibar (6°S - bleaching between 25% and 50%) and Tanga (5°S - about 25% of corals bleached). *Acropora* species bleached most with 80-95% in Chumbe, whereas about 40-70% of *Acropora* in other areas bleached. With *Porites*, some species bleached whereas others were unaffected. Survival after bleaching was about 50% in Mnazi Bay, and 60-80% in Bawe and Chumbe. Survival was very low (less than 40%) in Changuu and Chapwani. Water temperatures were 30.5°C, about 2°C above normal. Bleaching also coincided with much higher rainfalls than other years, and also when spring tidal ranges were about 4.5 m. By the end of October, 80-100 % of corals had died in Mafia Marine Park, which probably was the best coral reef in the country with almost 100% mixed coral community cover over vast areas. On Tutia Reef in the South, there is less than 5% coral still alive, with heavy mortality of *Acropora*, *Porites*, and *Echinopora*. In Chole Bay in the North, 100% of the *Acropora* were dead, and in the 'coral gardens' of Kinasi Pass, 80 to 90% of *Acropora* have died.  
(Olof Linden, Chris Muhando, J.L. Solandt)

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## **SOUTH EAST and EAST ASIA**

Coral bleaching was first observed in Indonesia in January and February, 1998 as warm waters flowed through the Java Sea eastwards towards Lombok where bleaching was seen in March. During April and May, a warm pool of water developed during the northern summer around Cambodia, Thailand and parts of Sabah, Malaysia. Warm water bathed parts of the Philippines, Vietnam, Taiwan, and Japan in June and July, and also spread southwards towards Singapore and the Riau islands off Sumatra in June and July, before cooling in late July. Warm waters continued around Japan until August when the first typhoon in September cooled the waters.

### **Cambodia**

Corals around Sihanoukville, Cambodia were moderately to severely bleached in mid-May. The water was warm (no thermometers available) and very turbid. The predominant corals are massives (poritids, faviids and mussiids), with few *Acropora* and *Pocillopora* species, but most species bleached, with approximately 80% in some places.  
(Vicki Nelson)

### **Indonesia**

Bleaching was initiated by a warm current from the South China Sea that flowed through the Java Sea from the Riau Islands as far as Lombok. There was no bleaching to the north in Spermonde Archipelago, southwest Sulawesi (near Ujung Pandang), and Manado, Bunaken, nor around Bangka, north Sulawesi

where coral cover varied between 25 and 75% depending on location and predominant wind direction.

Coral bleaching of approximately 75-100% of the 25% coral cover was seen around Bali Barat National Park (north-west Bali), and at Tulamben (eastern Bali), with many soft corals seen disintegrating. There was less bleaching at Nusa Penida and Nusa Lembongan. Many anemones to 36 m at Telumban, Bali bleached, but others at 44 m were normal. Bleaching in Pulau Seribu off Jakarta, and Karimunjawa Marine National Park (north of Java) started in January and February, continued through May and corals had either recovered or died by August. Bleaching ranged from zero to 46% at 3 m (mainly *Acropora* and *Galaxea*), and 1% to 25% at 10 m (*Pachyseries*, *Hydnopora* and *Galaxea*), with 50-60% mortality of bleached corals. On the Gili Islands (Air, Meno, Trawangan), facing the Lombok Strait, almost 90% of hard corals bleached (especially *Acropora*) in March 1998, down to 20 m. In August, there was high mortality, but some massive corals, especially *Porites*, were recovering.

There was significant coral bleaching, up to 60-70% at some depths, in East Kalimantan (Borneo) during January, however, water temperatures were much **colder** than normal (approximately 23°C) with extensive plankton blooms. (Irdez Azhar, Imam Bachtiar Clay Bryce, Alastair Harborne, Taufik Hizbul Haq, Bert Hoeksema, Otty Lalamangkit, Gayatri Lilley, Ghislaine Llewellyn, Suharsono, Yempita)

### **Japan**

Coral bleaching started on Okinawa Island (26°N) in mid-July 1998, when temperatures increased from 25-28°C in June to 28- 31.5°C in July. Bleaching increased in August (31°C), but was less extensive on offshore islands (30°C), with shallow water corals (*Acropora*, *Pocillopora*, *Merulina*, *Montipora*, and *Porites*) affected. In September, bleaching continued with all corals, and spread north to the Japanese mainland (33°N), and down to more than 20 m on Okinawa. By mid- October most bleached *Acropora* were dead and covered with algae on Okinawa, however, many *Acropora* colonies in shallow moats of Okinawa and on offshore islands had survived. Many faviids and poritids regained colour by mid-October with temperatures around 28°C.

Bleaching was conspicuous on Ishigaki Island (24°N; 50-70% bleached) and Amakusa, Kyushu (32°N) when water temperatures went over 30°C in July and August. It was unusual that water temperatures remained high until the first Typhoon in September. Most species were extensively bleached, except for minor bleaching in the blue coral *Heliopora*. Earlier, a few mushroom corals (*Fungia*) bleached with water temperatures of 28-29°C, which is apparently a regular, annual occurrence. No bleaching was seen down to 30 m in September off the southwest of Shikoku Island (33°N), where there is 75% coral cover of plate *Acropora* down to 10 m. Previous bleaching was in 1980 and 1983. (Charles Delbeek, Hajime Kayanne, Tadashi Kimura, Keven Reed, Rob van

Woesik)

### **Malaysia (Sabah)**

Coral bleaching has been highly localized and not very significant in Sabah. In mid-May, there was bleaching of 30-40 % of all live coral cover in 1-2 m at Pulau Gaya, Sabah (near Kota Kinabalu) with water temperatures of 32°C. In Pulau Sakar up to 30% of all species bleached with 10% mortality down to 20 m. *Acropora* colonies were about 90% bleached and also some giant clams with about 20% showing bleaching. Less than 5% of corals were bleached in Pulau Baik down to 15 m, especially large polyp species (*Symphyllia*, *Lobophyllia* and *Lithophyllon*). There was minor to insignificant bleaching on Mamutik Island (Tunku Abdul Rahman Park), Turtle Islands Park, and off Semporna, Sabah during surveys in July and August. Intensive surveys of Darvel Bay (Lahad Datu) east Sabah (4-5°N, 118°E) in September showed no significant bleaching at 20 reef sites (Pulau Sakar, Pulau Maganting, Pulau Bohayan, Pulau Tabawan, Pulau Baik, Pulau Laila, Bakapit, Bagahak and Shoal Point). (Don Baker, Ranjith de Silva, Ridzwan Abdul Rahman)

### **Philippines**

Massive bleaching started in mid-July, and may be still ongoing in western regions where reports are coming in from Bolinao (northwest Luzon), to Puerto Galera and southern Negros Island, central Philippines (Dumaguete, Campomanes Bay, Danjungan Island, El Nido (Bacuit Bay) and Coron Island (Palawan), and Pag-asa Island (Spratleys). Temperatures of 33-34°C degrees were reported, and bleaching went as deep as 28 m (temperatures of 30-31 °C) and completely affected soft corals and some anemones. Bleached hard corals were primarily the plating, branching and foliose forms, with up to 75% of the community bleached in some areas. Massive corals were also affected; faviids were bleached, but large *Porites* appeared to resist bleaching below 5 m, but not on shallow reef flats of Bolinao and Negros. Black-band disease was observed on a few bleached colonies. Mortality, however, of bleached corals appears to be low. On the well-known Apo Island, some large colonies of *Galaxea fascicularis* showed some patchy bleaching. Massive bleaching also reported in Danao Bay, near Baliangao, northwest Mindanao in October 1998, with bleaching mostly affecting branching corals and significant rotting of soft corals, but fire coral (*Millepora*) not affected. (Jade Fraser, Fiona Gell, Gillian Goby, Rex Montebon, Laurie Raymundo, David Medio)

### **Singapore**

There was mass bleaching in June and July, 1998 probably due to elevated seawater temperatures (33°C when they are normally 28 to 30 °C). The bleaching affected all species of hard corals and extended throughout the entire depth of coral growth. Soft coral mortality was high. When temperatures dropped in July, some corals started to show recovery. This is the first time bleaching has been seen on this scale.

(Loke-Ming Chou, Jeffrey Low)

### **Taiwan**

Coral bleaching was first observed in June, around Penghu Islands (Pascadores Is) during Reef Check 1998. About 30-40% of corals were bleached in 1-5 m, some corals were dead with water temperature around 30°C. In August, extensive coral bleaching was observed around Posunotao, an offshore island in southeast Taiwan. Over 80% of corals bleached down to 20 m, with water temperatures of 31°C at 20 m and 34°C at 1 m. Posunotao is in the Kuroshio current, and other regions down current (Kenting Reef and HisaoliuChio) bleached afterwards. (Allen Chen)

### **Thailand**

Warm water temperatures in April 1998 caused widespread coral bleaching in the Gulf of Thailand from Narathivat province (South) and Trat province (far east), up to Chonburi province (the inner part of the Gulf). But there was no bleaching on the other side in the Andaman Sea. Water temperatures in the Gulf increased from the normal of 28-29°C to above 32°C, such that on Ko Samui it was 35°C. It was first noticed in the tourist centres of Chumphon and Surat Thani. Then bleaching spread north to reefs in the inner part of the Gulf (Koh Samet, off Samaesan) and off Pattaya. In some places, bleaching has affected 100% of *Acropora*, 80% of *Pocillopora damicornis*, and about 60 to 70% of massive *Porites*, especially in shallow water. Around Chumphon (Ko Kai, Ko Samet and Ko Tao - 10°50'N), 30-50 % of corals bleached. Around Sichang Island (inner part of the Gulf) and Mun Islands (Rayong), the impact was 50-60% of corals bleached, with mortality of about half. This is the first report of widespread bleaching in the Gulf of Thailand. (Tenshi Ayuki, Vipoosit Manthachitra, Suraphol Sudara).

### **Vietnam**

Extensive coral bleaching began in mid-July 1998, in the areas off of Nha Trang (south-central Vietnam), with moderate levels of mortality in shallow water, especially *Acropora* species. Major bleaching was reported further south in Con Dao National Park (200 km south of Ho Chi Minh City -Saigon, and 80 km off the Mekong Delta) with 70% of corals affected at most reefs down to 15m. These were particularly impressive coral reefs, which had been damaged by Typhoon Linda, November 1997. At most sites, 90% of the dominant table *Acropora* and many other corals were dead by mid-September, with total losses of about 70-80% of the shallow water coral cover (1-2 m). Bleaching was equally bad in deeper water with 90% mortality of the dominant massive *Porites* and many other large colonies, for example *Lobophyllia*. Coral cover loss in deeper water was 60-70%, and hundreds of 2-3 m diameter, massive *Porites* were killed, including 9 m diameter colonies which were several hundred years old. No bleaching was seen at Hon Mun Island (off Nha Trang) where there is frequent cold upwelling, nor was bleaching seen at Halong Bay (far north off Vietnam). (Gregor Hodgson, Vo Si Tuan, Sue Wells)

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## PACIFIC OCEAN (west)

Throughout the bulk of the Pacific, water temperatures were close to normal during 1997 and 1998, however up against the Australian mainland, warmer temperatures were recorded in January and February, 1998. The majority of the bleaching over the Great Barrier Reef peaked during the last two weeks of February. This did not coincide directly with El Nino, which normally means warmer temperatures in the east Pacific, not the west. The similarity of 1988 and 1998 bleaching, especially in the eastern hemisphere, makes a case for a possible indirect relationship to El Nino. Later in the year in the northern summer, warm water appeared in the far northwest Pacific around Japan and Philippines in July, around Taiwan in August and Palau in September. Typhoons late in the season (September to October) resulted in reductions in temperatures as the high winds and waves mixed warm surface waters with cooler waters from the deep.

### **Australia**

Sea surface temperatures warmed considerably off eastern Australia during early 1998. Aerial surveys of 654 reefs show that extensive bleaching occurred along the entire length of the Great Barrier Reef (GBR) from Elford Reef (17°S), to Heron Island (23°S). The intensity of bleaching was much greater on inshore reefs than mid- shelf or outer-shelf reefs. Overall 87% of inshore reefs showed at least some bleaching, compared to 28% of offshore reefs. Heavy bleaching was seen on 55% of inshore reefs (with greater than 30% coral cover), compared to 5% of offshore reefs. However, ground truth surveys suggest that these figures are conservative.

Over 100 coral species bleached, including bleaching and partial death of large *Porites* colonies that were centuries old. This bleaching appeared to be a combined effect of raised temperatures, exacerbated in the central GBR by massive flows of rainwater in January. Soft corals were extensively bleached on these inner reefs with almost all species bleached. In the upper 5 m, soft corals are 100% bleached and about 20% bleached at 8-12 m depth. Mortality was high, even in the normally resistant *Sinularia*. On Orpheus Island, between 84% and 87% of corals bleached, but 5 weeks later, mortality was between 2.5 and 17%, with the *Acropora* species being most affected. *Pocillopora* species were hardly affected. However, 10 km away on Pandora reef, there was virtually 100% mortality of corals down to 6 m depth, where bleaching followed both a temperature rise and extensive fresh water flows over the reef.

In March, bleaching also extended to southern Queensland (Gneering Shoals; 26°S) and northern New South Wales (28°30'S) on rocky reefs with populations of corals up to 50% coral cover. Water temperatures were around 28°C (maybe as

high as 30°C), whereas they are normally in the mid 20°Cs. *Pocillopora damicornis* and *Stylophora pistillata* were most affected with 60-70% of these species bleached to 15m depth. In the central GBR, inshore average daily sea temperatures near Townsville exceeded 31.5°C on the reef slope (the likely 1°C bleaching threshold) at 6 m on 12 days and reached a maximum of 32.7°C. No bleaching was observed on the Flinders Reefs (27oS), between these two sites. (Andrew Baird, Simon Banks, Ray Berkelmans, Daniel Bucher, Lyndon Devantier, Katharina Fabricius,)

### **Fiji**

No bleaching was seen during the past year over about 180 km on the South side of the Great and North Astrolabe Refs (18°S), which have extensive coral cover. (Joan Koven)

### **Federated States of Micronesia**

About 20% of corals bleached down to 20 m on the northwest and northeast side of Yap, in the beginning of September 1998. Many Genera were observed to bleach including: *Acropora*, *Goniastrea*, *Platygyra*, *Diploastrea*, *Mycedium*, *Goniopora*, *Porites* (massive), *Physogyra*, *Psammicora*, *Montipora*, *Pocillopora*, *Turbinaria*, *Hydnophora*, *Astreopora*, *Echinopora*, *Stylophora*, *Favia*, *Leptoria*, *Seriatorpora*, *Pavona*, and *Fungia*. Soft corals (*Sarcophyton*, *Lobophyton*), anemones (*Heteractis*), and *Heliopora* also bleached. Water temperatures were 30-3 °C. No bleaching was seen in the lagoon in Chuuk. (Sandra Romano)

### **French Polynesia**

During a bleaching event on Moorea in 1991, 20% of corals died on the outer slopes, and during another in 1994 bleaching was less severe and more dispersed. Monitoring on another 14 islands has been added to Moorea as a contribution to the GCRMN. Bleaching in early 1998 was variable among atolls and in locations on atolls. Strong bleaching was seen in some areas like Takapoto, where 20% coral cover in 1994 was reduced to 12% after 1998 bleaching. There was also severe bleaching on Rangiroa and Manihi with significant mortality. On Moorea and Bora Bora, coral cover remains at 30 to 50% (normal for French Polynesian outer slopes at 15 m) with minimal bleaching, if any. Non- bleaching mortality was seen on Tikehau Atoll, with a drop in coral cover from 40% in 1994 to 4% in 1998 because of strong cyclonic waves. (Yannick Chancerelle, Bernard Salvat)

### **Hawaii**

No bleaching was seen in Hawaii and this has been the coldest summer measured (average close to 26 °C). (Cindy Hunter)

### **Johnston Atoll**

No bleaching was seen, but there was evidence of recovery from a bleaching

event a few years earlier. These reefs have nearly 100% live coral cover in suitable areas. No elevated water temperatures were observed by satellite.  
(Les Kaufman)

### **Palau**

Major coral bleaching occurred in Palau in September, 1998 with water temperatures from 30-32°C. About 75% of corals shallower than 15 m bleached, and in Arakabasan and one of the rock islands ('Cemetery') there was 20-70% bleaching and high mortality. The eventual impact is not known, but the area looks awful. About 70- 80% of the corals were bleached down to 30 m off of Peleliu, the Blue Corner, the Big Drop-off (all in the south), as well as Iwayama Bay in the Rock Islands near Koror. Everything that could bleach was bleaching. The hard corals were not yet dead for the most part, but many of the soft corals were dead. This was in mid-September, and there was minimal bleaching at the 'Blue Hole'.

(Pat Colin, Eric Guinther, Sandra Romano)

### **Papua New Guinea**

Water temperatures below 10 m around Kimbe Bay (New Britain) in August 1998 were 31-31.5°C, and on the surface they were 32-33 °C. High mortality of corals was observed with 75% of *Acropora* affected, and bleaching in many other genera including *Porites*, *Platygyra* and *Montipora*. Some others were partially bleached, and effects were observed down to 50 m. On the southwest side of Kimbe Bay, water was 29.5 to 30°C, and there was only 10% bleaching of *Acropora* and only isolated cases of bleaching on other species.

In March 1998, large areas of reefs south of Normanby Island through to Cape Vogel, and Tufi (far southeast PNG) showed coral bleaching from mid-February. Bleaching extended down to 20 m, but was most extensive in shallow water (almost 100% in some areas, including soft corals and anemones). Water temperatures were 29-30°C from December to February, which is not exceptional for Milne Bay. Reefs to the north Normanby and Fergusson Ids were apparently not affected by any bleaching.

(James Cervino, John Rewald)

### **Samoa (Western)**

Between 60 to 70% of all *Acropora* on the reef top bleached within 5-6 days just before the end of February 1998, at Palolo Deep, National Marine Park near Apia. Corals in deeper water appeared healthy. Some bleaching in Samoa was linked to extreme low tides and exposure to air.

(Mike King)

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## **PACIFIC OCEAN (east)**

Bleaching was first noticed in the Pacific when the 1997 El Nino event resulted in warm water pooling up in the mid to eastern tropical Pacific along the coastline of Central America. Water temperatures of 27-28°C were recorded from June to October 1997 off Panama and coasts further north, which are 8°C warmer than normal. As this pool of warm water expanded, it then affected the Galapagos islands (on the Equator) in December to February, when surface waters were up to 3°C warmer than normal. Bleaching of the corals started at the extreme temperatures around 30°C.

### **Colombia (Pacific Coast)**

The first signs of bleaching were in late-May 1997 with small white patches on *Pocillopora* when water temperatures were 29°C. More bleaching was observed in July and August 1997 with increased signs of bleaching at similar temperatures. In September 1997, up to 30% of some *Pocillopora* was bleached, whereas similar corals nearby appeared normal.

(Fernando Zapata)

### **Galapagos**

The first bleaching reports were in mid-December 1997, when water temperatures of 28°C were recorded from satellites. Water was 2°C warmer in February and bleaching continued. Nearly all corals on the Galapagos were bleached to some extent by March 1998. The most strongly affected were *Porites* and *Pavona*. The genera *Psammocora*, *Diaseris* and *Cycloseris* were bleached on top, but many still had pigment around the bases. Corals bleached down to 30m, but bleaching was more extensive shallower than 10 to 15 m depth. *Pocillopora*, which was most impacted during the big El Nino of 1982-83, seems to be largely resisting this time.

(Andrew Baker, Joshua Feingold, Jerry Wellington, Al Strong)

### **Mexico (Pacific Coast)**

Bleaching was first noticed in July 1997 from the Gulf of California (25°N) to Jalisco (19°N) and in the remote Revillagigedo Islands (18°N). Bleaching peaked in August-September 1997 involving about 25% of total coral cover (water temperatures were 31-34°C). The most extensive bleaching occurred at Nayarit (20°N), of about 60% of corals mostly shallower than 4 m. Bleaching was 10-15% in the Revillagigedos, with some mortality, but had finished in October. The only significant recovery in the Gulf is from new *Pocillopora* recruits settling on the old skeletons. This the first time that bleaching has been reported on the Pacific coast.

Very minor bleaching was seen at Oaxaca (16°N) in 1997 with water temperatures at 31°C; all colonies recovered. A sudden **drop** in surface water temperatures in mid-September 1998 caused extensive bleaching and this is being followed. No



bleaching or death was observed on Clipperton Atoll in November 1997.  
(Gerardo Leyte-Morales, Hector Reyes)

### **Panama (Pacific Coast)**

There was significant coral bleaching in mid-September 1997 at Uva Island, Gulf of Chiriqui. All coral species were affected down to 20 m. *Millepora intricata*, the most common species remaining after the 1982-1983 El Nino, bleached and died. Other species were still alive but bleached.

Almost all coral species in the Gulf of Chiriqui region started bleaching in mid-April 1998 with 50% to almost 90% of corals with at least partial bleaching. This follows the bleaching above, but is much less intense than in 1983. Bleaching occurred when water temperatures were 29-31°C, more than 1.5°C above normal. Corals from nearby Gulf of Panama showed much less bleaching.  
(Andrew Baker, Mark Eakin, Peter Glynn and Juan Maté)

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## **CARIBBEAN SEA**

The most notable prior bleaching events were 1983 and 1995. In 1983, there was large-scale mortality of corals along the Caribbean coasts of Panama and Costa Rica. Many of the affected reefs have not recovered their previous levels of coral cover, with the predominant shallow water corals of *Agaricia* and *Acropora* now being much reduced. Bleaching this time appears to be spread over a very long time span and in widely separate locations.

### **Bahamas**

Corals of the central Bahamas showed extensive bleaching in August 1998, with over 60% of all head corals bleached to 20 m around New Providence Island. Extensive bleaching of around 80% was seen between 15-20 m depth. *Montastrea cavernosa* was not bleached, and *Acropora palmata* bleached on the upper sides only of branches in shallow water. Near complete bleaching of all the corals and some gorgonians seen at Little Inagua, Sweetings Cay, Chubb Cay, Little San Salvador, San Salvador and Egg Is. Samana Cay was much less effected. Hurricane Bonnie then dropped water temperatures by 2°C. There was also extensive bleaching at Walker's Cay in the northern Bahamas, with many types of coral affected.  
(Benjamin Mcpherson, Eleanor Phillips, Bill Precht)

**Belize** Large areas of the Belize coral reef ecosystem experienced massive coral bleaching in early September 1998 and is continuing in October 1998. There was severe bleaching to at least 8 m on the fore-reef, and on the reef top and back-reef of the following: the main barrier reef at Ranguana Pass; patch reefs at Bird,

Crawl, Laughing Bird, Scipio, South Water, and Cocoplum Cayes; pinnacle reefs between Ranguana Pass and Lighthouse Caye off Placencia; offshore reefs of Glover's Reef Atoll and Ambergris Caye; and shallow banks off Rum Point. On Glovers, bleaching was measured at 76% on the western fore reef (near Baking Swash) at 12-15m, and estimated at 70-80% on the shallow patch reefs in the lagoon and on the eastern fore reef down to at least 25m. Bleaching was between 25-30% on barrier reef sites (Gallows Reef, near Goffs and Alligator Cayes and near Calabash Caye, Turneffe Atoll) to depths of 14-18m. The bleaching is correlated with exceptionally warm water, and calm weather. Water temperatures have been consistently between 30-32°C, and on the surface near some of the cayes, it was between 36-38°C. Almost all hard corals and the zooanthid *Palythoa* exhibited some bleaching. Total to high bleaching was prevalent in *Millepora*, *Agaricia*, and *Porites*. High to moderate bleaching affected *Montastrea*, *Siderastrea*, and *Diploria*. Moderate to low bleaching occurred in *Dendrogyra* and *Acropora*, although *A. palmata* was only moderately bleached on the main Barrier Reef, but some totally bleached colonies were seen lagoon patch reef. Low to moderate bleaching was seen on the Central Barrier Reef and Turneffe Atoll. Mortality of bleached corals throughout Belize appears to be about 20-25%. Similar bleaching was seen in 1995, but not to this extent.  
(Tom Bright, Melanie McField)

### **Bonaire (Dutch Antilles)**

Less than 15% of corals bleached in August and September 1998, with partial bleaching in *Montastrea annularis* between 10 and 20 m and in *Agaricia* below 20 m. Only a few, small corals in shallow water appear to have bleached. Later in September, nearly 100% of all *Agaricia* bleached from 8 m to 30 m, but bleaching was not observed in other species with water temperatures of 30°C at the surface to 30 m and 29.5°C below that.  
(Kalli De Meyer, John Ware)

### **Cayman Islands**

Unprecedented bleaching has occurred during late September 1998 on Little Cayman and Grand Cayman, with all species affected and possibly 90% of all corals heavily bleached. There was some bleaching of *Acropora palmata* and *Montastrea annularis* at 1-5 m depth, and widespread bleaching and some mortality to the abundant *Millepora*. Even previously resilient *Montastrea cavernosa* partly bleached. Between 50 and 60% of large colonies of *Montastrea faveolata* bleached around Grand Cayman, but with less bleaching on the West Wall.  
(Phil Bush, Jason DeSalvo)

### **Colombia**

Only a few bleached corals seen at Isla San Andres in September 1998. By early October, there was minor bleaching (5-10%) at Islas del Rosario affecting *Millepora*, *Acropora palmata*, *Siderastrea*, *Agaricia*, *Porites*, *Montastrea* and

some gorgonians. No significant bleaching seen in the Santa Marta area, in October.  
(Jeremy Woodley)

### **Cuba**

No bleaching has been reported on southern Cuba, however there is a report of extensive bleaching at Herradura and Varadero (west and east of Havana respectively) in late August 1998 for 2 weeks. *Millepora* was extensively bleached, as well as some *Montastrea annularis*, (colony tops), *Porites* and zooanthids (nearly 30% of all colonies). Near Santiago, there was bleaching down to 35m depth, probably of *Agaricia*. Bleaching was seen in places where it was rare or never seen before.

(Pedro Alcolado, Judy Lang, Alan Logan, Peter Sale)

### **Dominican Republic**

No mass bleaching was seen by dive operators who dive all over the country.

(Paul Medley)

### **Florida (USA)**

Scattered bleaching was observed in inshore waters of the Florida Keys in early August 1997, with some colonies partially bleached and others extremely mottled or blotched. Small colonies were entirely bleached. Extensive bleaching to large coral heads in the Gulf of Mexico area of the Keys (Boca Grande Channel, between Boca Grande Key and the Marquesas Keys) was also reported. There was significant recovery.

In July and August 1998 there was bleaching at Coffins Patch Light in the Florida Keys, with water temperatures of 30-31°C. Minimal bleaching was observed in *Millepora* colonies, but there was none on nearby Coffins Patch Special Protected Area (SPA). In late August 1998 extensive bleaching was seen in Western Sambo Ecological Reserve, Florida Keys. Surface water temperatures were 30-32°C, but only 26°C at 10 m. Bleaching was seen in up to 90% of *Acropora palmata*, with some mortality, 50-80% of *Montastrea annularis* and *A. cervicornis*, and 40-60% of other corals. There was moderate bleaching between 10 and 30 m in Dry Tortugas National Park and on the Tortugas Banks in early September 1998. Approximately 15-25% of colonies were affected with water temperatures around 30°C. There was also evidence of bleaching at Ft. Jefferson. In September there was significant recovery of corals on an inshore patch reef known as the Rocks, that had been severely bleached in June and very little mortality was evident. Hurricane Georges dropped temperatures to 28°C and did little physical damage. However corals in many areas still appeared bleached with brain corals not showing the recovery seen in other species.

(Billy Causey, George Garrett, Ben Haskell, Walt Jaap, Alina Szmant)

### **Guadeloupe**

Severe bleaching is reported.

(Claude Bouchon)

### **Haiti**

An extensive coral bleaching event was reported after Hurricane Georges in September.

(Jean Wiener)

### **Honduras**

Up to 50% of live coral cover showed bleaching from 10 to 25 m around Roatan from mid-September 1998, with most species affected, especially *Agaricia*, *Montastrea* and some *Diploria*. Small amounts of *Acropora* and *Millepora* were only slightly affected. No bleaching seen around the Bay Islands.

(Marea Hatzios)

### **Jamaica**

Temperatures rose to 29-30°C in late September, at Discovery Bay below 30 m. By early October, 70-75% of all *Montastrea* colonies were bleached, and were still mostly white by mid-October (temperature maximum of 31.5°C). In Portland Bight (south coast) in early October, divers were astonished to see both bleached corals and white gorgonian sea-whips.

(Jeremy Woodley, Ian Sandeman)

### **Mexico**

Bleaching started in late August in Quintana Roo with temperatures around 30°C, and near 33°C in the lagoon. They were still high in September (29.5°C - 30.5°C). By mid-October, 15 coral species had some bleaching, but it was variable, with *Agaricia* and *Millepora* more affected than *Montastrea* and *Diploria*. *Acropora* not affected so far. By October 16, bleaching was widespread. Earlier some bleaching was reported for the Yucatan coast, but no bleaching was seen near Cozumel. This bleaching event is less severe than in 1995.

(Eric Jordan, Judy Lang, Peter Sale)

### **Panama**

Extensive bleaching was reported in October in western Panama.

(Hector Guzman)

**Puerto Rico** There was no bleaching in 1997. There was, however, moderate bleaching in 1996 after Hurricane Hortense hit the south coast, and all colonies recovered well from partial or total bleaching. In 1998, there has been sporadic, but low frequency bleaching, in several species down to 30 m deep. The most affected were a zooanthid (*Palythoa caribbaeroun*), and *Millepora*, but most other corals were normal.

(Ernesto Weil)

### **St. Lucia**

Bleaching in the Soufriere area is the worst ever seen with 100% of all *Diploria*

affected and bleaching in other species including *Monrastreia annularis*, *Porites astreoides*, and *Agaricia*. No mortality yet, but it is expected.  
(Allan Smith)

#### **St. Vincent and the Grenadines**

There are second hand reports of severe bleaching.  
(Allan Smith)

#### **Virgin Islands (UK)**

Widespread coral bleaching was seen in mid-September 1998 on 5 reefs south of St. Thomas, which were unaffected in early August. At least 50% of colonies of numerous species were affected, including *Montastrea annularis*, *Porites* (branching and massive), *Colpophyllia*, some *Millepora*, *agaricids*, some *Siderastrea*. But bleaching was patchy with some normal coloured tissue remaining and there was little evidence of mortality by mid- October. There was moderate bleaching on Virgin Gorda, affecting about 20% of the coral population. The coral community was healthy and probably recovering from an earlier, possibly more serious, beaching event.  
(Les Kaufman, Barbara Kojis, John Ogden)

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## **ATLANTIC OCEAN**

Localized regions of warm water were observed in the southern Atlantic Ocean off Brazil in January 1998. Warmer water was then observed off Bermuda in August.

#### **Barbados**

A large area of the Carribee Bank Reef at 25 to 30m on the south coast has bleached, apparently in September 1998.  
(Renata Goodridge)

#### **Bermuda**

No bleaching observed in May, but it started in early August 1998 and continued into October. Sea surface temperatures were 28°C in early August and rose to 30°C, and then dropped to 27°C by end of September. This was abnormally warm for Bermuda (32oN). There was approximately 2-3% bleaching of the 25% coral cover at 8 m on rim reefs, and 5-10% bleaching of 40% coral cover at 15 m on offshore terrace reefs. It was higher on lagoon reefs (2-6 m depth) at about 10-15% bleaching of the 15-20% coral cover. *Millepora* was most affected, along with some *Montastrea*. Mortality was low, perhaps 1-2% of affected colonies. Extensive bleaching occurred in 1988 and 1991, with mild bleaching in 1993 and 1997.

(Alan Logan, Robbie Smith)

### **Brazil**

There was mass bleaching on patch reefs off the northern coast of Bahia State (12oS; 38oW) on 14 April 1998. There was bleaching of: more than 60% of *Mussismilia hispida* (endemic coral); 80% of *Agaricia agaricites*; and 79% of *Siderastrea stellata* (endemic). Other corals may have been less affected when water temperatures reached 29.5°C on the bottom of these reefs at 9 to 12 m, the highest temperature measured during the last 3 years. By October, all colonies have recovered. On the Abrolhos Reefs (18°S; 40°W) in late April, bleaching was seen in 50% of *Mussismilia hispida*; 91% of *Agaricia agaricites*; and 25% of *Siderastrea stellata*; with 6 other species showing bleaching between 25% and 90%.

(Ruy Kenji Papa)

### **USA (Washington D.C.)**

A colony each of *Fungia*, *Pocillopora damicornis* and *Manicina aerolata* have remained severely bleached, but not fouled with algae, on desk substratum in the World Bank. Temperatures can exceed 35°C for up to 10 days in August in this hostile environment. An experimental attempt will be made to determine recovery potential by relocating these corals to a new marine aquarium being established by a 6-year-old.

(Andy Hooten)

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## **CONCLUSIONS**

The most extensive coral bleaching ever reported has occurred during the 1997-1998 period. There has been bleaching in most parts of the coral reef world with extensive mortality of fast growing, as well as some slow growing corals in places. Some areas have reported bleaching for the first time. However, large areas have not been affected and in others, there has been widespread recovery of bleached corals.

This event will result in poor coral cover and possibly fewer new coral recruits on many reefs for the next 10 years until recovery gains speed. In the short-term, this will impact adversely on the economies of many tropical countries, particularly those reliant on tourism income. If this is a rare event, the long-term consequences for coral reefs around the world are relatively minor. There will be a shift in the composition of coral communities; some will have greater dominance by slow growing massive corals, whereas some others the reefs will lose century old colonies. But such shifts have occurred in the past and are part of the normal variability of many coral reefs. If, however, the recent bleaching event is linked to

global climate change and will be repeated regularly in the immediate future, the consequences would be serious for many coral reefs if sea surface temperatures show a continuing upward trend.

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