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CORAL BLEACHING
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Analysis of the Coral Bleaching Phenomenon, Its Potential Severe Loss of Biological Diversity and Consequent Socio-Economic Impacts

A. Background

1. The Conference of the Parties, in its decision IV/5, expressed their deep concern at the recent extensive and severe coral bleaching which occurred in the Indian Ocean, caused by abnormally high water temperatures experienced since January 1998. It also recognized the potentially severe loss of biological diversity and consequent socio-economic impacts of coral bleaching and noted this occurrence as a possible consequence of global warming.

2. In light of this, as well as of a precautionary approach to this issue, the Conference of the Parties decided on two kinds of action: (i) firstly, it requested SBSTTA to make an analysis of the coral bleaching phenomenon and to provide relevant information to the fifth meeting of the Conference of the Parties; (ii) secondly, it instructed the Executive Secretary to express its concern to the Executive Secretary of the United Nations Framework Convention on Climate Change (UNFCCC) and the Secretary-General of the Convention on Wetlands and to convey it to the Conferences of the Parties to UNFCCC and the Convention on Wetlands. The Conference of the Parties of the CBD also invited UNFCCC to urgently address this issue in its deliberations. The Executive Secretary conveyed those messages to the Secretariats of the two Conventions in writing shortly after the fourth meeting of the Conference of the Parties; and reiterated the message of the latter to the Conference of the Parties of UNFCCC at its fourth meeting (Buenos Aires, November 1998) and to the tenth meeting of the UNFCCC Subsidiary Body on Scientific and Technological Advice (Bonn, June 1998).

3. In line with the mandate given to him through decision IV/5, the Executive Secretary has prepared this section of the note, which summarizes the issue of coral bleaching, its causes, potentially severe loss of biological diversity, and consequent socio-economic impacts, in order to assist SBSTTA at its fifth meeting in its deliberations.

4. This section of the note benefited from inputs of experts involved in an expert consultation on coral bleaching organized by the Executive Secretary in order to assist him in the identification of the main scientific, technical and technological aspects related to the problem.

This was in line with recommendation IV/1, paragraph 6, of SBSTTA at its fourth meeting that the Executive Secretary should make rapid progress on the issue of coral bleaching.

5. The meeting took place in Manila, Philippines, from 11 to 13 October 1999, with the generous contribution of two Parties, one Government and one international organization. The related report is provided in document UNEP/SBSTTA/5/Inf.6, which expands on some specific aspects of the problems and should therefore be read in conjunction with the present section of the note.

B. Importance of, and impacts on, coral reefs

6. Coral Reefs are among the most important and extensive ecosystems in tropical regions of the world, and often the most significant ecosystem, both ecologically and economically. For example, in the Pacific region, the reefs are vital to the survival of the atoll countries, as they constitute the primary coastal protection structures on most tropical islands and provide sand for the construction of islets and beaches. They are also the source of subsistence food resources, reservoirs of some of the highest marine biological diversity in the world, and environmental health indicators. The social, cultural and economic prosperity of these other regions has been and will continue to be dependent upon the health of their coral reefs and related ecosystems. 1/

7. Reef-building corals, the main group of organisms structuring healthy coral reefs, are currently experiencing stressed living conditions in many parts of the world as a result of a combination of natural and anthropogenic (direct and/or indirect) disturbances. Corals become stressed if exposed to an increase (1-2°C) or decrease in water temperature, sedimentation, salinity, UV and visible light. Moreover, coral reefs experience impacts from human activities such as overfishing, trawling, dynamite fishing or unsustainable tourism. Under experimental conditions, exposure of symbiotic invertebrates to extremes in almost any environmental variable would lead to bleaching.

8. “Coral bleaching” is the disassociation of the symbiosis between reef-dwelling invertebrates and their symbiotic algae (zooxanthellae). This phenomenon manifests itself as a discoloration of the animal tissue and can be the result of reductions in the density of symbiotic algae and/or of a loss in the cellular concentrations of photosynthetic pigments. It is not known however, if bleaching could happen as a natural process by which the polyps renew their zooxanthellae populations, or the dinoflagellates themselves leave the polyps to complete their own life cycles as free living organisms.

9. Bleaching events have increased in intensity, frequency and local and geographic distribution in the last two decades (Egana and DiSalvo 1982; Goreau 1964; Glynn 1993, Hoegh-Guldberg and Salvat 1995, Brown 1997; Wilkinson, 1999; Hoegh-Guldberg, in press). In 1998, the worst

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1/ Adapted from the International Coral Reef Initiative (ICRI) Pacific Regional Strategy, 1996.

year on record, complete loss of live coral in some parts of the world occurred. A recent analysis of reports of bleaching (Wilkinson, 1999) indicates that there is wide variability on factors such as bleaching intensity, number of species affected, local, depth and geographic distribution and, most importantly, how much mortality a bleaching event causes.

10. Bleaching reports span the world's three major oceans, in over 50 countries, which proved the global nature of the event (Wilkinson, 1999). Records include first time events, such as the one that occurred in Japan in August 1998, which caused an unprecedented mass mortality of 85% of the stony and soft coral populations, a drastic decrease in coral diversity and the local extinction of some previously abundant coral species, with no evidence of recruitment (Loya et al., in press).

11. In some parts of the world, such as in the Pacific, coral bleaching is a sporadic and poorly documented phenomenon. Throughout the Pacific islands, bleaching phenomena have been recorded for some countries (e.g. Samoa) and not others (e.g. Fiji) during the recent and prolonged El Niño Southern Oscillation. Recovery from some bleaching events has been rapid in some cases (e.g. Samoa, 1998) (South, pers. comm.).

12. In the Caribbean, during the wide spread mass bleaching of last year, most populations of Agaricia tenuifolia were dead after bleaching in many reefs of Belize. This mortality brought about yet another major change in the community structure of these reefs (Precht & Aronson, 1999). In Puerto Rico on the other hand, even though bleaching was intense and widespread, almost all bleached colonies of corals, zoanthids, anemones, octocorals and hydrocorals recovered. Even colonies that were totally bleached for over 6 months recovered completely. Few corals were killed and some experienced only small partial mortality. (Weil, pers. comm.).

13. In 1998, the Indian Ocean experienced an unprecedented bleaching event in both extent and severity (Wilkinson, 1998; Wilkinson et al., 1999). Warm surface waters were observed through satellite imagery migrating from Southern to North of the Indian Ocean during the first six months of 1998. Records concern virtually all Indian Ocean countries. While relatively rapid signals of recovery are being observed, the socio-economic consequences of this massive event may be extremely serious in the years to come.

14. It is because of this increasing intensity, frequency and widespread geographic occurrence that mass bleaching events are now considered by most reef scientists to be a serious challenge to the health of the world’s coral reefs. Many scientists now believe that corals are living to close to their upper thermal tolerance levels, and that small changes in water temperatures now usually triggers massive bleaching events.

15. The role of high temperatures in triggering coral bleaching and in increasing the frequency of bleaching events is supported by the

fact that sea surface temperatures in the tropics have increased by almost 1°C over the past 100 years and are currently increasing at the rate of approximately 1-2°C per century (Hoegh-Guldberg, in press). Currently there is a consensus that the massive coral bleaching events recently observed on a word-wide scale are the result of exposures to temperatures above the long-term summer average.

16. Currently, two non-exclusive mechanisms have been proposed to explain how thermal stress is linked to coral bleaching. On the one hand there are suggestions that thermal stress results in either detachment of the animal endodermal cells bearing the symbiotic algae or the direct exocytosis of the symbiotic algae. These two suggested mechanisms would be mediated directly by the host. On the other hand, there is ever-increasing evidence that elevated temperature results in a disruption of the photosynthetic capacity of the symbiotic algae. Given the importance of algal photosynthesis to the well been of intact corals, the temperature-dependent disruption in the flux of photosyntetates may lead to coral bleaching.

17. Depending on the severity (duration or intensity) of the thermal stress, bleaching can be a reversible condition without major ecological consequences or result in massive mortality and therefore major changes in coral coverage, community structure and reef calcification.

18. If changes in climate are the main causative factors of coral bleaching, then such factors are external to many countries hosting coral reefs, such as the small island developing States. While the island countries control enormous exclusive economic zones and an ocean area representing some 12% of the globe, their contributions to climate change are infinitesimally small and their ability to mitigate changes are negligible. This particular aspect makes in principle the phenomenon a concern to the whole international community.

C. Potentially sever loss of biological diversity due to coral bleaching

19. Coral bleaching represents a serious threat to coral reefs worldwide if we assume that bleaching always brings about massive mortality of reef-building corals and other important sessile invertebrates with the potential consequence of loss of biological diversity, loss of reef communities and all the other cascading events that a process like this will produce. There are however, only a few cases, most of which of recent occurrence, in which extreme high mortality rates of corals occurred following coral bleaching.

20. Bleaching certainly determines drastic changes in biodiversity, in terms of: mean living cover of coral species; number of species and number of colonies/m^2; local extinction of coral species; and absence of recruitment (Loya et al., 1999). However, loss of biodiversity during coral bleaching events is generally not well documented. Furthermore, in certain regions, baseline knowledge of coral reef biodiversity is at best rudimentary or poor, and at worst non-existent. In the Pacific islands, biodiversity studies have been carried out at very few of the

8,000 or more islands of the region, and comprehensive biodiversity studies of selected sites are rare (e.g. the Suva Lagoon, Fiji). Even in such well-documented areas, only a fraction of the total biodiversity has been documented.

21. The indicators of change following bleaching events include: increase in macro-algal biological diversity and biomass, decrease in fish biological diversity, increases in the incidence of ciguatoxic blooms and consequent human health consequences, plus many other less obvious and poorly understood impacts.

22. Certain corals are more resistant to bleaching than others are, and there are several hypotheses to it, generally related to differences in physiological responses. This is demonstrated for example by Loya et al. (in press) in the case of the Japan 1998 event, where the juveniles of the branching Acropora species showed greatest resistance to bleaching if compared with the most vulnerable adult corals.

23. In terms of effects at the ecosystem level, to date, information on changes to coral communities following coral bleaching is very limited, and there have been no projections on the long term effects of bleaching on coral community structure (Brown and Suharsono, 1990; Gleason, 1993; Hoegh-Guldberg, in press). Scientists are making efforts towards narrowing this gap.

24. In light of our poor knowledge of potential impacts of coral bleaching on biological diversity, it seems important at this point to concentrate some efforts into gathering quantitative information on the relative proportions of bleached colonies within populations of the different species, their mortality and recovery rates, as well as on the local and geographic variability of these aspects.

D. Socio-economic impacts consequent to coral bleaching 2/

25. Most of the coral reefs in the world are situated in and around countries where the majority of the population is poor and dependence on fisheries for income and animal protein intake is high. Overfishing is already a major threat in most tropical countries and the coral bleaching effect could worsen this. For instance, along the reef coastline of Eastern Africa, around 50% of the estimated 100,000 full-time fishers and several hundred thousand part-time fishers risk losing their livelihood if the overfishing trend is allowed to continue. In other areas, diving and other coastal tourism are the main income generating activity, such as the Maldives where 45% of GNP stems directly and indirectly from tourism revenues. Besides, coral reefs serve as natural barriers to protect the coastline from erosion. In Sri Lanka, severe coastline erosion has already occurred in areas where coral mining is taking place, and further damage to the reef structure from bio-eroded dead coral could carry a heavy financial cost.

2/ (contributed by Dr. Herman Cesar)

Revetments, and breakwater schemes to prevent further erosion are already costing the Sri Lankan government around US$ 30 million.

26. Given this dependency on the functions and services that the coral reef ecosystem provides to hundreds of millions of people around the tropical oceans, the socio-economic impacts of massive coral bleaching is likely to be severe. However, a precise estimate of the human impacts is difficult to make at this stage. This is due to the uncertainty surrounding many of the relationships between coral bleaching and mortality on the one hand and ecosystem services, such as fisheries, tourism and coastal protection on the other hand.

27. Besides, the recovery rate of reef areas after wide-spread mortality is difficult to predict. Also, many of the socio-economic impacts will only appear in the medium term, and have yet to be observed. Finally, it is not clear yet whether coral bleaching will become more and more frequent and severe or whether it will stay only as an occasional sad side effect of El Niño.

28. Given these uncertainties, the range of possible losses due to coral bleaching is large. A preliminary attempt to estimate an economic value to the coral bleaching event in the Indian Ocean in 1998 put the losses in the range of US$ 706 million to US$ 8190 million (Wilkinson et al., 1999). However, the full human suffering as a result of the coral bleaching and mortality event, due to possible malnutrition and worsened poverty damage as well as unemployment is more than dollar values can express. Given the large uncertainties that exist with respect to the impact of bleaching on ecosystem services and their socio-economic consequences, more applied research and field work is urgently needed to assess the damages to the peoples and to the economies around the tropical oceans.

29. The socio-economic impacts of irreversible coral bleaching in regions such as the Pacific islands would be severe, since the majority of the people are coastal dwellers with a largely subsistence life-style. There is an urgent need to quantify these impacts both nationally and regionally. Apart from the impacts on food security, lifestyle, and traditional values, considerable and long-term financial loss would be experienced in the commercial sectors such as tourism and fisheries. In the Pacific region, the relatively pristine state of the region’s coral reefs compared with that of reefs in other parts of the world is one reason for the rapid growth of the dive tourism industry in some of the countries.

E. Examples of current measures to address the phenomenon

30. The International Coral Reef Initiative Renewed Call to Action contains the consensus of participating countries on how to address the protection and sustainable management of their coral reefs. This

instrument will continue to advice countries on how to deal with phenomena such as coral bleaching; they are also relevant in the regional and global context, as they incorporate cooperation measures.

31. A Global Coral Reef Monitoring Network (GCRMN) was established back in 1994 3/, with the role to document the status of coral reefs of the world with major reports every two years as the basis for improved coral reef conservation. The 1998 report contained a compilation of data and anecdotal information gathered from e-mail correspondence on where (or where not) coral bleaching had occurred in 1997/98. This proves that much can be done through non-costly means such as electronic communication.

32. The GCRMN is in the process of updating that report and placing it on the Internet as public information for use by decision-makers, scientists, etc. The next report will concentrate on case studies reported in 1998, but focus on more detailed assessments. Initial reports from 1998 were of massive damage in many areas, especially the Indian Ocean, East Asian Seas and parts of the Caribbean. Since then, some reports indicate considerable recovery, whereas others accurately document major death of corals and apparent local extinctions of the more susceptible species.

33. Monitoring of coral bleaching can be achieved through all sorts of techniques, from ground-truthing activities (diving) to more sophisticated activities such as remote sensing technology. Recent highly specialized remote sensing methods that can detect bleaching to a depth of 10m have been developed. If these methods can be perfected, it should be possible to monitor bleaching phenomena in both time and space using satellite imagery.

34. Options for recommendations on how to deal with coral bleaching are presented in section IV. of this note. Document UNEP/SBSTTA/5/Inf.6 also contains recommendations, specifically on the identification of crucial scientific gaps and uncertainties and of gaps in information about, and the knowledge of, the problem. The document also suggests measures to fill those gaps, and a related research agenda is proposed. Priorities for action and constraints are also identified, along with options for mitigation as well as the application of the ecosystem approach to the problem of coral bleaching, which refers to the need to develop an integrated knowledge of, and an integrated approach to, the issue that encompass ecological, traditional, and socio-economic aspects. As part of mitigation measures that may be needed, there is a strong need to increase public awareness to the severity of the problem.

3/ IOC, UNEP, WMO and IUCN have joined forces to co-sponsor the GCRMN, which is hosted jointly by the Australian Institute of Marine Science and the International Center for Living Aquatic Resources Management. These bodies, along with the Secretariat of the International Coral Reef Initiative, form the GCRMN Management Group. Advice is provided by a widely representative Scientific and Technical Advisory Committee (GCRMN-STAC).

F. Options for Recommendations

The Subsidiary Body on Scientific Technical and Technological Advice may wish to:

- Consider the recommendations elaborated by the Expert Consultation on Coral Bleaching (Manila, Philippines, 11-13 October 1999), as contained in document UNEP/SBSTTA/5/Inf.6, including the outline of a programme of work for better understanding the causes and minimizing the effect of coral bleaching, as a basis for advising the Conference of the Parties on this phenomenon;

- Recommend that the Conference of the Parties invite Parties to make available necessary resources to research and monitoring programmes on coral bleaching, mitigation measures and public awareness and education activities.
