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AD HOC TECHNICAL EXPERT GROUP ON INDICATORS FOR ASSESSING PROGRESS TOWARDS THE 2010 BIODIVERSITY TARGET
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Item 3.1 of the provisional agenda*

INDICATORS FOR ASSESSING PROGRESS TOWARDS THE 2010 TARGET: TRENDS IN EXTENT OF SELECTED BIOMES, ECOSYSTEMS AND HABITATS – TRENDS IN THE COVERAGE OF LIVING CORAL TISSUE ON CORAL REEFS

Note by the Executive Secretary

I. SUMMARY

1. Coral reefs support remarkable biodiversity. As one of the most ecologically complex ecosystems on Earth, coral reefs are home to over 4,000 different species of fish, 700 species of coral, and hundreds of thousands of other plants and animals: according to conservative estimates, one quarter of all marine species occur in coral reefs. 1/ The health and biodiversity of coral reefs are critical to the cultural values and economic livelihoods of millions of people living in coastal environments. Reefs are the major source of income and food (e.g. tourism and fishing) to these coastal communities, and also afford shoreline protection from the forces of the ocean. Unfortunately, human activities threaten coral reefs the world over 2/ and continue to degrade coral reefs through sedimentation, coastal development, destructive fishing practices and pollution. Ocean warming and the increased acidification of seawater is also precipitating a decline in the health of coral reefs requiring a greater understanding of trends. Assessments which have suggested that 11 per cent of the historical extent of corals reefs has been lost an another 16 per cent is severely damaged 3/ are necessarily qualitative because the means to measure global changes in coral reef extent are not available. However a host of small-scale studies have recorded the coverage of live corals on reefs worldwide, and recently methods were tested statistically to combine these disparate studies into a regional indicator: 4/ changes in absolute percentage coral cover. This research

* UNEP/CBD/AHTEG-2010-Ind/1/1.

1/ Groombridge B, Jenkins M (2002) World Atlas of Biodiversity. California University Press, Berkeley and Los Angeles.

2/ Bryant D, Burke L, McManus J, Spalding, M (1998) Reefs at Risk: A Map-Based Indicator of Potential Threats to the World's Coral Reefs. World Resources Institute, Washington; International Center for Living Aquatic Resource Management, Manila; United Nations Environment Programme-World Conservation Monitoring Centre, Cambridge.

3/ C. R. Wilkinson, Status of Coral Reefs of the World: 2000 (Global Coral Reef Monitoring Network and Australian Institute of Marine Science, Townsville, Australia, 2000).

4/ Toby A. Gardner, Isabelle M. Côté, Jennifer A. Gill, Alastair Grant, Andrew R. Watkinson (2003) Long-Term Region-Wide Declines in Caribbean Corals, Science VOL 301, 958-960.

demonstrated a Caribbean-wide decline in average hard coral cover from about 50 per cent to 10 per cent in three decades (figure 1).

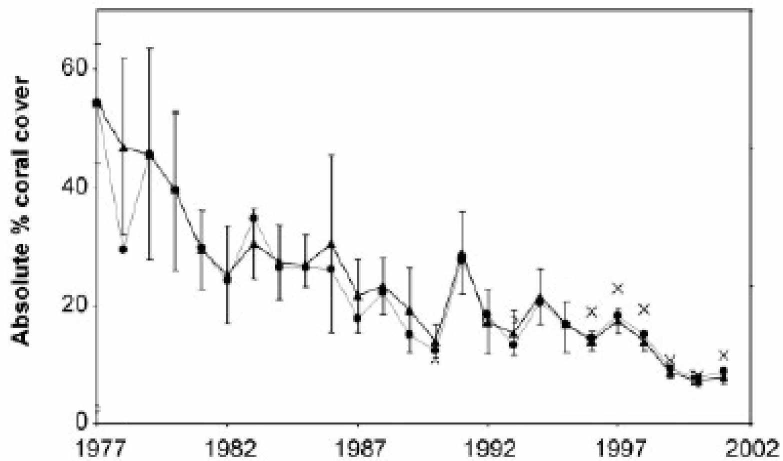

Figure 1. Total observed change in percent coral cover across the Caribbean basin during the past three decades: absolute percent coral cover from 1977 to 2001. Annual coral cover estimates (▲) are weighted means with 95 per cent bootstrap confidence intervals. Also shown are unweighted mean coral cover estimates for each year (•) and the unweighted mean coral cover with the Florida Keys Coral Monitoring Project (1996–2001) omitted (x). Source: Gardner *et al.* (2003).

II. RELATION OF INDICATOR TO THE FOCAL AREA

2. As coral reefs are a very important habitat for marine biodiversity at the global level, the change in coral cover indicator is highly relevant for ascertaining the effectiveness of efforts "*reducing the rate of loss of the components of biodiversity, including ... habitats and ecosystems*". Due to their structural complexity, coral reefs also provide a range of different habitats upon which many species depend, so it complements the information derived from indicators of trends in abundance and distribution of selected species under the same focal area. As providers of essential ecosystem services, the coral cover indicator also relates to "*maintaining ecosystem integrity, and the provision of goods and services provided by biodiversity in ecosystems, in support of human well-being*".

III. GENERAL DESCRIPTION

3. The data from across the Caribbean demonstrate a clear decline in the absolute proportion of reef benthos covered by living coral tissue, and a related negative mean annual rate of change. In other words the living coral fabric of reefs in the region has decreased year on year: the baseline starts in 1977 and the data analysed by Gardner *et al.* (2003) extend to 2001, though more data has presumably become available since. The biomass of scleractinian coral is probably very closely related to this 80 per cent decrease in coral coverage, and possibly also many key ecological functions such as productivity and rates of calcium carbonate accretion. For these reasons a decrease in live coral cover is already very frequently cited as an indicator of a decline in the local 'condition' of a coral reef, although Gardner and his colleagues were the first to quantify the extent and spatiotemporal variability of the decline across a region. In relation to the 2010 target it would not be an unreasonable assumption that the marine biodiversity associated with coral reefs in the region is also being lost at a rate disturbingly similar to the loss of the primary structural and functional group of organisms, scleractinians, as some studies have

shown5. However, the Wider Caribbean region contains 20,000 km^2 of coral reef, just 7 per cent of the global total, 6/ so other regional indicators would be needed to obtain a global picture of the status of coral reefs.

4. The coral cover indicator can be scaled down to subregions: in the Caribbean Gardner *et al.* (2003) demonstrated a higher absolute loss in Jamaica than elsewhere (figure 2).

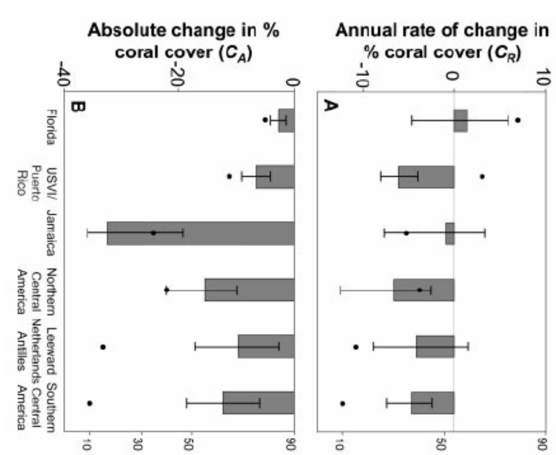

Figure 2. Coral cover change for subregions of the Caribbean, expressed as annual rate of change in percent coral cover, CR (A), and as change in absolute percent coral cover, CA (B). The Leeward Netherlands Antilles includes Venezuela. Temporal averages were taken across all studies whose midpoint fell within each time interval; time periods are indicated by the first year of the interval. For the interval starting in 2000, only 2 years are included. Source: Gardner *et al.* (2003).

5. Coral cover indicators can be derived for regions other than the Caribbean: although coral cover data from reefs elsewhere have not yet been collated and analysed, a great deal of information exists (see Figures 3-5 for examples from the north and south Pacific, and the Indian Ocean): repeated measurements at the same sites is prerequisite of these data. A variety of networks (e.g. the Global Coral Reef Monitoring Network and Reefcheck) through which the necessary data could be obtained. There is no technical reason why the same methods should not be applied to data from other regions gathered from these sources. Collating these data would require a relatively straightforward literature search and correspondence with appropriate scientists and research teams. Indicators could be developed for all the major coral reef region of the world. Each regional coral cover indicator could also be scaled down into subregions.

5/ G.P. Jones, M.I. McCormick, M. Srinivasan and J.V. Eagle (2004) Coral decline threatens fish biodiversity in marine reserves, PNAS vol. 101 no. 21, 8251-8253

6/ Spalding MD, Ravilious C, Green EP (2001). World Atlas of Coral Reefs. California University Press, Berkeley and Los Angeles.

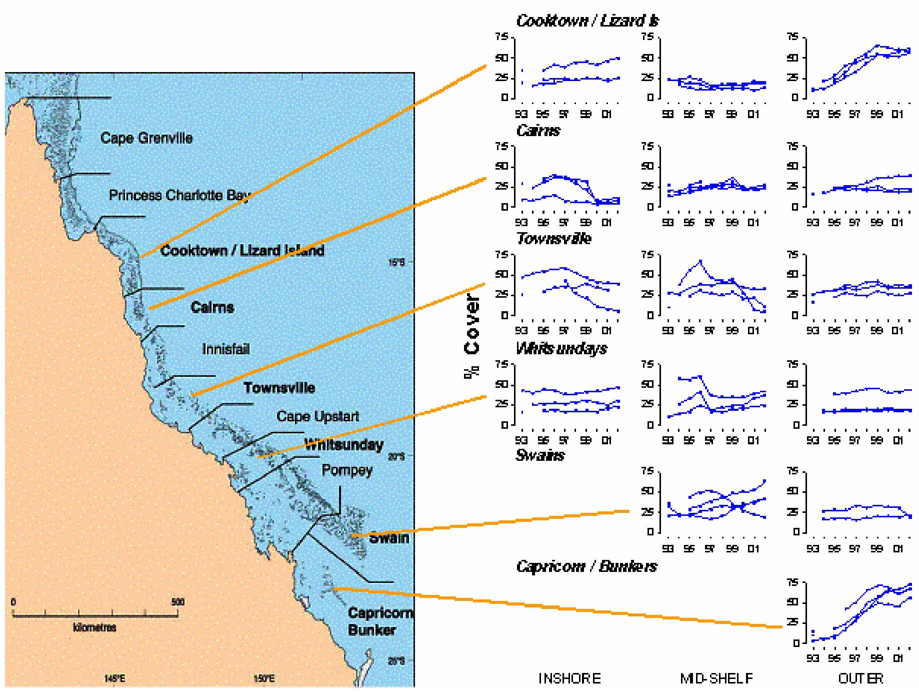

Figure 3. Long-term monitoring of live coral cover on the Great Barrier Reef, Australia. Each blue line represents coral cover for one reef between 1993 and 2002. Source: Chin, A., August 2003. 'Corals', in Chin. A., (ed) State of the Great Barrier Reef On-line, Great Barrier Reef Marine Park Authority, Townsville.

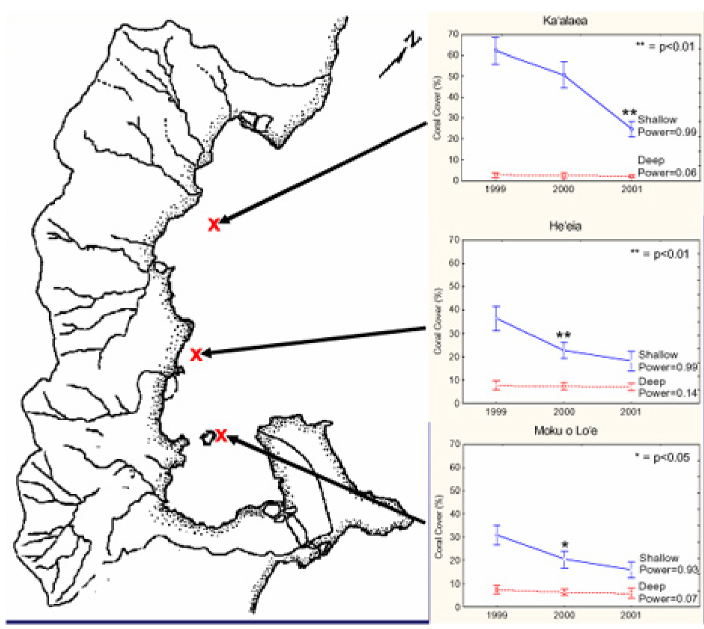

Figure 4. Live coral cover at selected sites in Kaneohe Bay, Hawaii, Coral Reef Assessment and Monitoring Project. Source:
http://www.hawaii.edu/ssri/hcri/files/jokiel_2001_qtr_4.pdf

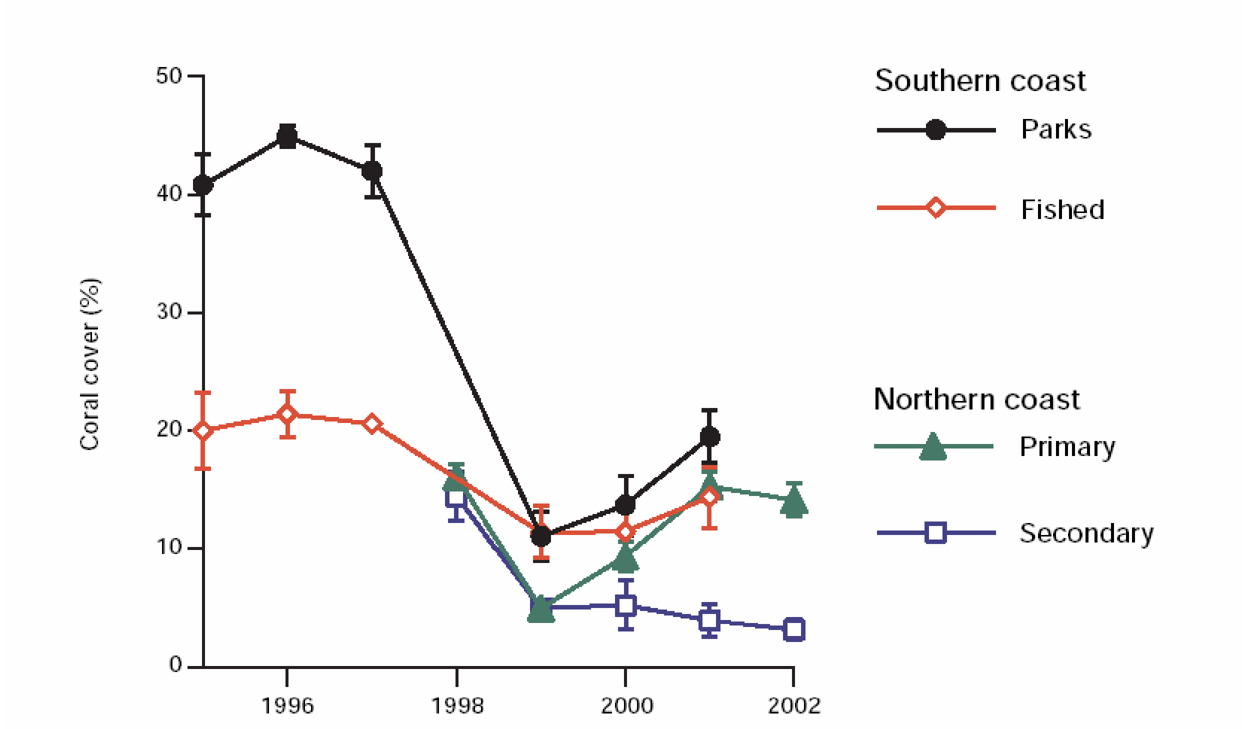

Figure 5. Coral cover from 1995 to 2002 for sites monitored in southern and northern Kenya (mean and standard error). Measurements in 1998 made prior to El Niño impact. Southern sites split between protected (inside MPAs) and unprotected sites. Source: David Obura (2002) Status of Coral Reefs in Kiunga Marine Reserve, Kenya. In: *Coral Reef Degradation in the Indian Ocean Status Report* (Editors: Olof Lindén, David Souter, Dan Wilhelmsson & David Obura).

6. Regional indicators of change in coral cover could be amalgamated to produce a global indicator: there would be gaps in the data for reefs which have not been thoroughly, recently or regularly surveyed – perhaps in some small islands and remote areas. However, this is not considered to be a serious handicap as even short expeditions typically survey live coral cover. The challenge will probably be greater in accessing reports to these areas from the grey literature and assessing the validity of the data. Analytical methods would needed to be adopted to amalgamate in a single indicator data from regions of typically high coral cover with those of typically low values standard techniques to handle these issues have already been adopted in the Living Planet Index and could be applied here. 7/ The use of geometric rather than arithmetic means offers another option. 8/

7. Change in coral cover indicators do not inform us about the ‘health’ of a coral reef directly. Indeed while there is no universal accepted measure of coral reef health, live coral cover is almost ubiquitously recorded and used as a surrogate. The indicators do not tell us about the cause of a decline or indeed any recovery and they should be treated with caution when comparing one reef with another. Coral reefs vary in space: it is not unusual for coral cover to vary greatly between two reefs that are relatively close to each other, as events such as storms or bleaching may devastate one reef while leaving a nearby reef relatively untouched 8. Furthermore, widely differing levels of coral cover and species

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7/ To generate the Living Planet Index, the geometric mean change in all populations is calculated by averaging the logarithm of all data points for each five-year interval and then finding the anti-logarithm. This approach avoids unequal weighting due to population size and the asymmetry associated with using percent change (i.e. a change from 100 to 5 is a 95% decrease, but change from 5 to 100 is a 2000% increase). See 2010-indicator-species-trends-first-review-draft.pdf for more details.

8/ I. M. Côté, J. A. Gill, T. A. Gardner and A. R. Watkinson (In Press) Measuring coral reef decline through meta-analyses Phil Trans.

assemblages (or community composition) are normally encountered at different depths, or on different sides of a reef. Coral reefs also vary in time: coral cover and overall community composition can vary greatly seasonal or in response to episodic disturbances. On some reefs, during the summer, warmer water temperatures may prompt the rapid growth of macroalgae, altering the community composition which is reversed during the cooler winter months when much of this macroalgae dies and corals again become dominant. Temporal variability is further increased by events such as crown-of-thorns starfish outbreaks and storms. These events can reduce coral cover to zero but subsequent recovery and regrowth may return coral cover to pre-disturbance levels. As such, a 'normal' reef could therefore exist in any of the following states:

(a) Low level of coral cover and reduced diversity (e.g. perhaps a reef has been severely damaged by a recent cyclone with the more fragile species being disproportionately affected);

(b) Intermediate levels of coral cover and fluctuating community composition (e.g. reef recovering from the cyclone, some species recovering, pulse of new recruitment and growth to colonize empty space, coral cover gradually increasing and bare substrate being colonized by new corals);

(c) High levels of coral cover (e.g. the reef exists in a relatively stable state or state of gradual change with mildly fluctuating coral cover and community composition).

8. The transition between these states may be as rapid as one or two years and any of these three states could be considered 'normal' for a healthy reef. 9/ A number of studies have demonstrated the level of variability and extent of reef community mosaics. In one 30-year study on Heron Island in the southern Great Barrier Reef, coral cover was found to vary between 0 and 80 per cent depending on the site.

9. This variation warns against the assumption that a baseline coral cover from a few decades ago is 'natural'. It also precludes the scaling down of regional coral cover datasets beyond a few relatively large subregions. Few scientists would agree that reefs across a relatively large area on which live coral cover has declined and not recovered, despite annual variations, over a 5-10 year period are likely to be in "good health". Most management and conservation practitioners would argue that reefs which have experienced a sustained increase in live coral cover over the same period and across the same scale were experiencing improved ecological functionality. The effect of natural variation in coral cover of adjacent reefs or those in close proximity becomes less problematical as the number of different sites and degree of amalgamation, from local to global, increases.

IV. POLICY RELEVANCE

10. The change in coral cover indicator would be a means to assess the achievement in the marine biome of target 2.1(*restore, maintain, or reduce the decline of populations of species of selected taxonomic groups*), target 5.1 (*rate of loss and degradation of natural habitats decreased*) and target 8.2 (*biological resources that support sustainable livelihoods, local food security and health care, especially of poor people maintained*). Habitat degradation and loss being the main drivers for conservation actions, this indicator is also relevant to targets 1.1 (*at least 10 per cent of each of the world's ecological regions effectively conserved*) and 1.2 (*areas of particular importance to biodiversity protected*). The change in coral cover indicator would have the following additional advantages:

(a) Strong public support for saving coral reefs;

(b) Overall concept easily understood;

(c) Allows the general public to participate through volunteer scuba surveys; and

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9 See http://www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/corals/part_01.html for more detail on these issues

(d) Makes best use of the data which are available.

V. TECHNICAL INFORMATION

11. The Caribbean change in coral cover indicator has been criticized on two accounts. Firstly that the widespread degradation of coral reefs has resulted in both scientific motivation and availability of financial resources for surveys, which potentially skew the coral cover datasets as researchers oversample degraded reefs to document declines. This has been partially countered for the Caribbean indicator by reanalysis excluding the largest dataset which accounted for half of the points from 1996 to 2001 and which included largely degraded reefs (the Florida Keys Monitoring Project). This had very little effect on the pattern of decline (see figure 1). The best method to avoid any such bias is, as Gardner *et al.* did, to include datasets irrespective of the purpose of the study so as to include those surveys which are instigated precisely because the reefs are believed to be undisturbed. The second criticism was that the apparent slowing of decline in the Caribbean coral cover indicator might be due to a switch in methods from line to video transects (as the latter becomes more widely available), on the basis that video transects systematically generate higher coral cover estimates. Although the overall rates of coral cover decline did not differ among survey methods in the Caribbean data, such routine analysis would be a sensible precaution against potential intercalibration problems in the development of other regional indicators, and a global composite.

12. Data describing coral cover change over time were obtained from a total of 263 sites from 65 separate studies in more than 20 countries throughout the Wider Caribbean by Gardner *et al.* (2003). Sites were deemed separate as defined by each study, apart from the few instances when a single site crossed a steep depth contour, in which case transects were re-pooled into groups of similar depth. Coral cover data obtained by a variety of survey methodologies (videotransects - with point-count analysis, photoquadrats - including both pointcount and photogrammetric analysis, line-intercept transects - varying intervals, and chain transects) were included.

13. The absolute change in percentage coral cover $C_A = PC_A - PC_B$, where PC_A and PC_B are percentage coral cover at the end and start of the study period, respectively, and the overall annual rate of change in coral cover, C_R:

$$C_R = 100 * ((PC_A - PC_B) / PC_B) / d$$

where d is the study duration in years, were both calculated. Meta-analyses of C_A and C_R were based on the repeated measurements of coral cover at the same sites, using a bootstrapping method 10/ to generate confidence intervals, corrected for bias for unequal distribution around the original value. Meta-analysis 11/ is a statistical procedure that integrates the results of several independent studies considered to be 'combinable' for the purpose of deriving a common conclusion. Well conducted meta-analyses allow a more objective appraisal of the evidence than traditional narrative reviews, provide a more precise estimate of effect and may explain heterogeneity between the results of individual studies. 12/ Ill conducted meta-analyses may be biased owing to exclusion of relevant studies or inclusion of inadequate studies. There are four basic principles to meta-analyses relevant here:

(a) The *a priori* definition of eligibility criteria for studies to be included and a comprehensive search for such studies are central to high quality meta-analysis;

10/ A statistical method for obtaining an estimate of error by generating pseudoreplicate datasets through resampling, the method used was M. S. Rosenberg, D. C. Adams, J. Gurevitch, MetaWin Version 2: Statistical Software for Meta-Analysis (Sinauer Associates, Sunderland, MA, 2000).

11/ L. V. Hedges, I. Olkins, Statistical Methods for Meta-Analysis (Academic Press, San Diego, CA, 1985).

12/ Egger M, Davey Smith G. Meta-analysis: potentials and promise. British Medical Journal 1997; 315:1371-4.

(b) The graphical display of results from individual studies on a common scale is an important intermediate step, which allows a visual examination of the degree of heterogeneity between studies;

(c) Different statistical methods exist for combining the data, but there is no single "correct" method;

(d) A thorough sensitivity analysis is essential to assess the robustness of combined estimates to different assumptions and inclusion criteria.

14. Gardner *et al.* have largely met these criteria. Data were sourced through electronic and manual literature searches, and personal communications with reef scientists, site managers and institutional librarians. To avoid bias in the selection process (I), the only restriction criteria employed were that each study reported at least percent hard coral cover from a site within the region, had observed the same site over more than one year, and had replicated measurements within years. Data from individual studies (II) are presented. 13/ The Q-statistic was calculated to test and reject (III) the null hypothesis that the studies are homogeneous (the Q-statistic has a chi-square distribution with degree of freedom N where N = Number of Studies - 1): the temporal variation in coral decline was highly significant both for rate of change, C_R, (Q_B =33.3, $P < 0.01$) and for the absolute change in percent coral cover, C_A (Q_B = 63.3, $P < 0.001$). Lastly they carried out a number of tests of non-independence within studies (IV). First, when using only one randomly chosen site from each study into the overall meta-analyses, the effect size for both rate of change and change in absolute percent coral cover remained negative and significantly different from zero (C_R = -4.2, *CI* = -7.0 to -1.3, and C_A = -9.7, CI = -11.7 to - 7.8). Second, the removal from the analysis of the largest study, the Florida Keys Coral Reef Monitoring Project, also had little effect on the overall result (C_R = -6.3, CI = -8.8 to -3.6, and C_A = -10.8, CI = -13.1 to -8.6; Fig. 2A). Furthermore, when considering non-independence between studies, both differences in study duration and survey method failed to explain a significant level of variation in annual rate of change in percent cover (Q_B = 5.6, p = 0.98, and Q_B = 5.84, p = 0.17, respectively).

15. To explore spatial and temporal heterogeneity in coral cover change, the overall dataset was divided into classes based on geographic region and five-year intervals (in reference to the mid-point of each study), and the mean effect size and confidence intervals were recalculated for both absolute coral cover and annual rate of change. To maintain a minimum sample size of 10 studies per group, data were pooled into six regional categories: Florida, US Virgin Islands and Puerto Rico, Jamaica, Northern Central America, Southern Central America, and the Leeward Netherlands Antilles and Venezuela. Differences in coral cover change among groups were estimated using the statistic Q_B. The significance of Q_B was tested against a distribution generated from 5000 iterations of a randomization test.

16. The testing of these methods on a large regional database by Gardner and colleagues demonstrate the utility and sensitivity of the approach. There is no apparent reason their approach should not be replicated to create similar datasets for all other coral reef regions and to generate regional coral cover indicators directly analogous to figure 1. These regional coral cover indicators could then both be examined subregionally and combined into a single global indicator. All such indicators could be updated at the same frequency as new information became available from surveys. Although coral reef surveys worldwide are not synchronized it is likely, once the collation process was mature, that sufficient data would become available to update the indicators on an annual basis.

VI. APPLICATION OF THE INDICATOR AT NATIONAL/REGIONAL LEVEL

17. This is a new indicator and has not been used at the national or international level as yet.

13/ www.sciencemag.org/cgi/content/full/1086050/DC1, table 1

VII. SUGGESTIONS FOR THE IMPROVEMENT OF THE INDICATOR

18. This is a new indicator and experience on its application must be gathered before possible areas for improvement may be identified.
