Reef-building Corals Red List Assessments

Methodology for estimating population decline rates and generation lengths

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IUCN Red List Criteria

The IUCN Red List Categories and Criteria were applied to 845 reef-building coral species, comprised of 827 zooxanthellate coral species (Order Scleractinia), and 18 species from the families Helioporidae, Tubiporidae and Milleporidae.

The vast majority of coral species were assessed under Criterion A, which is based on population reduction. Six species were assessed under Criterion B, which is based on geographic range size, and is relevant for species with smaller distributions and with a few or highly fragmented populations. Three species were assessed under Criterion D, which is only used for species with very small or restricted populations. No Criteria were applied to the 141 species that were listed as Data Deficient, due to taxonomic discrepancies or to insufficient information on distribution or life history traits for further assessment.

Application of Criterion A

Criterion A is based on rates of population reduction measured over the longer of 10 years or three generation lengths. The IUCN definition of generation length is the average age of parents or mature individuals of the current cohort of newborn individuals (IUCN 2000). The use of generation length as a timeframe to measure population reduction accounts for the reproductive capacity and life span of each species and acts as a way of scaling reduction across all taxa with differing life history traits. As the vast majority of corals are colonial and "mature individual" and "average-age" are not easily defined, a tailored method to estimate generation length was universally developed and applied by coral experts at the Red Listing workshops.

The IUCN Red List guidelines (IUCN 2000) state that "reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone (e.g., corals)". The coral colony was assumed to be the basic unit of survival, as it typically lives, is injured, or dies as a unit, and therefore is the mature individual. Although parts of the colony can survive as unattached fragments, this is a reproductive event rather than survival of the original colony, as the fragment forms a new colony or individual.

Under the assumption that a fragment is a reproductive event and not a means of allowing the original colony to persist forever, over time the original colony will die due to 'natural' or other causes (disease, predation, etc.). The average age of natural survival of a coral colony was therefore defined as the average age of a mature individual or one generation length. Based on available knowledge of coral species' biology and life history, the average age of a coral colony for the majority of species was determined to be approximately 10 years (Hughes *et al*. 2003, Wallace 1999, Connell *et al*. 1997), although 19 species were estimated to have an average age of between 4 and 8 years, and two species of 15 or more years. For the majority of species, Criterion A of population reduction was therefore estimated over approximately 30 years, representing three generations lengths.

Species-specific population trend data are not available for the vast majority of coral species across their distribution ranges. Only, five species had sufficient species-specific population trend data (Hughes and Tanner 2000, Patterson *et al.* 2002, Sutherland *et al*. 2004, Koenig *et al.* 2005) and were therefore assessed under sub-Criterion A2, which is based on rates of population decline measured in the past. For the majority of species, loss of coral cover within a species distribution in combination with life history traits were used as a surrogate for population reduction using sub-Criterion A4. Sub-Criterion A4 allows for population reduction to be estimated or inferred from decline in extent of occurrence or habitat quality over a period of two generation lengths in the past and one projected into the future. The underlying assumption is that current stressors contributing to coral cover loss and population reduction (such as climate change, coastal development, disease, bleaching, predation, extraction, etc) have not ceased, and future rates are conservatively assumed to be the same as past rates.

Estimation of population reduction

Under sub-Criterion A4, population reductions can be estimated or inferred from a "decline in extent of occurrence or habitat quality," and were therefore based on conservative interpretation of the most current global and regional estimates of total coral cover loss and critically threatened reef from a comprehensive assessment of coral reef status in 17 regions across the world (Wilkinson 2004). Although the GCRMN reports (Wilkinson 1998, 2000, 2002, 2004) often provide more qualitative estimates of reef loss and decline, which can be overestimated or underestimated in any given region, they incorporate the results of numerous quantitative studies, compiled from the work of 240 scientists and data from hundreds of reef surveys, and represent the best global state of knowledge on reef status currently available. The GCRMN series (Wilkinson 1998, 2000, 2002, 2004) are widely cited for the estimates of global and regional reef status and threats to corals (Hughes *et al.* 2003, Burt *et al*. 2008, Baker *et al*. 2004, Mundlay 2004). Many scientific studies and conservation reports also reliably cite the estimated global and regional declines of reef area (Sutherland *et al*. 2004, Guzman and Cortes 2007, Hoegh-Guldberg 2007, Lindén *et al*. 2002, Pante *et al*. 2008). Furthermore, estimates of coral cover loss, at least in the Indo-Pacific, are corroborated by a more quantitative study of coral cover loss (Bruno and Selig 2007). Scientific experts at the Coral Red List Workshops expressed consensus in the use of these regional estimates of destroyed reef and loss of coral cover. This process of peer-review and consensus should not be overlooked as a valid methodological tool (Regan *et al.* 2005).

Estimates of coral cover loss, defined as the percentage of reefs with greater than 90% coral cover loss over at least the past 15 to 20 years (Wilkinson 2004); and of critically declining reef, defined as the percentage of reefs with between 50-90% coral cover loss and likely to join the total coral loss category within 10 to 20 years (Wilkinson 2004); were used as a surrogates for population reduction in combination with each species' life history traits. For each species, a weighted average was calculated by multiplying the area of reef within the species distribution by the percent of total coral cover loss or the combined percent of total coral cover loss and critically declining reef reported from 17 different geographical regions defined by the 2004 GCRMN report (Wilkinson 2004). Only partial or complete occurrence of a species in a region was used and marginal inclusions were discounted. This method assumes that the percent coral cover loss reported for a region is the same across the entire region.

The relationship between coral cover loss and population reduction is not always linear, however, as coral cover loss can occur in areas of lower or higher population density, and therefore can represent a slower or faster decline of the actual population size (Rodríguez and Gaston 2002). Similarly, some species re-colonize rapidly after disturbance events such as bleaching or disease. For this reason, expert knowledge on life history traits of each coral species, including susceptibility to disease and bleaching, were taken into account, as well as the potential effect of other threats such as harvesting for the aquarium or curio trade, pollutants, sedimentation, and predation by crown of thorns starfish (CoTS) (*Acanthaster planci*). These life history traits for each species were used to support the Red List assessment for each species, first by determining if a species population reduction was better estimated from total coral loss or from the combination of total coral loss and critically declining reefs within its distribution.

For species restricted to reef habitat, found in narrow depth ranges (primarily shallow waters less than 20 m), particularly susceptible to bleaching, disease, sedimentation, targeted for trade, or preferentially preyed upon by CoTs, and/or had low recruitment, the combined percentages of both total coral cover loss and critically threatened reef were used. The combined estimates were also used for species that occurred in very restricted or isolated populations, such as those endemic to the Red Sea. Such coral species were considered to have increased probability of extinction, as species with low effective population sizes (Wright 1931, Avise 1994) are likely to possess limiting traits such as overlapping generations, non-random mating, differential fertility and fluctuations in population size. In addition, species with isolated and effectively small population sizes often have low levels of genetic variation (Karron 1987) and reduced gene flow (Ayre and Hughes 2004), reducing the species' ability to adapt to changing environment conditions, and increasing the likelihood of inbreeding and loss of reproductive fitness.

For species that survived outside of reef habitat in rocky or sandy areas adjacent to reefs, that had a wider depth range and/or could be found in deeper waters (at least over 20 m), and/or were quick to re-colonize after disturbances such as bleaching or disease events, and/or exist or dominate in very shallow marginal habitat, only the percentage of total coral cover loss within the species distribution was used to estimate population reduction. This assumes that all mature individuals would be removed from an area of total coral cover loss, and that on average, the number of individuals on reefs are equal across its range and proportional to the total coral cover loss in the past and into the future. These species were also assumed to survive in coral reefs already at the critical stage of degradation given their relatively wide distributions with an inferred large effective population size that is highly connected and/or stable with enhanced genetic variability.

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