# Proactive management for conservation of *Acropora cervicornis* and *Acropora palmata*: application of the U.S. Endangered Species Act

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**Abstract** *Acropora palmata* and *Acropora cervicornis* are important framework-building corals that provide a critical structuring role on shallow Caribbean reefs. In recent decades both species have declined from white-band disease and other factors. To increase awareness about their decline, the National Marine Fisheries Service in June 1999 identified *A. palmata* and *A. cervicornis* as candidate species for the United States Endangered Species Act (ESA). Candidate status does not add legal protection, but is designed to promote efforts to obtain reliable information on the species and to encourage voluntary conservation strategies for the protection of remaining populations. Application of the ESA to marine invertebrates presents several challenges. While distinct vertebrate populations can be listed, a marine invertebrate must be threatened throughout its range. Both *Acropora* spp. are widespread, however a survey of available information revealed gaps that prevent a synoptic overview of their status. Furthermore, measures of rarity have been developed for individuals, and may not be applicable to clonal organisms that rely on asexual fragmentation as a primary mode of propagation. An ESA listing requires implementation of a recovery plan and action by Federal agencies to conduct conservation programs, and to promote research, restoration and protection for these species, thereby benefiting associated coral reef organisms and the ecosystems upon which they depend.

**Keywords** *Acropora palmata*, *Acropora cervicornis*, reef-building coral, US Endangered Species Act, candidate species listing

## Introduction

There are over 110 species of *Acropora* of which only three, *A. cervicornis* (staghorn coral), *A. palmata* (elkhorn coral) and *A. prolifera* (fused staghorn coral), are found in the Caribbean (Wallace and Willis 1994). *Acropora cervicornis* and *A. palmata* are the most common of the Caribbean species, forming monospecific, high relief assemblages (thickets) at shallow and intermediate depths in environments occupied by few other corals. Both are key structural components, and play a critical role in the maintenance of healthy, productive reefs by providing vital habitat for a large number of associated organisms (Gladfelter and Gladfelter, 1978). Because of their dominance in shallow water and their rapid rate of growth, they contribute significantly to reef growth (Adey 1975; Gilmore and Hall 1976; Gladfelter 1982; Tunnicliffe 1983). Thickets of *A. palmata* form a buffer zone that protect coastal communities from storm waves. Storms have caused considerable damage to *Acropora* assemblages, but populations often exhibit rapid recovery due to a high survivorship of fragments and rapid tissue regeneration (Glynn et al. 1964; Highsmith 1982; Bak 1983). Accumulations of storm-generated *Acropora* rubble also contribute to the formation of coastal ramparts and islands (Williams et al. 1999).

Until the late 1970s, Caribbean reefs displayed a zonation pattern dominated by three common scleractinian corals, *A. palmata*, *A. cervicornis* and *Montastraea annularis* (Jackson 1992). Populations of *A. cervicornis* and *A. palmata* underwent a region-wide decline during the 1980s and 1990s, with losses of 95% or more in some areas (Gladfelter 1991; Bythell et al 1993; Aronson and Precht 2001). The loss of these species may lead to an increased dominance of macroalgae, reduced rates of reef accretion, and erosion of the reef framework, associated cays, and coastal environments (Williams et al. 1999; Aronson and Precht 2001).

Despite growing threats to reef-building corals and their associated ecosystems, few coral species are actively managed, and none are fully protected throughout their range (Laist et al. 1986). The

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purpose of this paper is to discuss the application of the U.S. Endangered Species Act (ESA) to reef-building corals, and whether this mechanism could help protect populations of *A. cervicornis* and *A. palmata*. We discuss the ESA listing process, criteria used to classify a species as threatened or endangered, difficulties in applying the ESA to clonal marine invertebrates, and gaps in the available information for acroporids that must be fulfilled to justify an ESA listing. Finally, the advantages of the ESA as a strategy to conserve these species and their habitat are summarized.

*Existing mechanisms to protect corals*

In recent years, significant progress has been achieved towards protecting coral reefs and promoting sustainable use of reef resources, and a range of international initiatives and agreements support coral reef conservation. Internationally, the non-binding *Framework for Action* developed under the International Coral Reef Initiative (ICRI) includes key strategies to improve management, capacity building, monitoring and targeted research to protect, restore and sustain coral reefs. Parties to the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) recognized that unregulated harvest of corals for international trade may be detrimental to their survival in the wild. A CITES Appendix II listing for stony corals authorizes international trade only if corals are sustainably harvested. However, in most of the Caribbean, including U.S. reefs, it is illegal to damage, remove or collect scleractinian corals. Installation of moorings and navigational buoys is helping reduce damage associated with anchoring and vessel grounding, and the establishment of marine protected areas, including no-take areas offer further protection by reducing fishing pressure and other extractive activities. Management measures have reduced the potential for physical damage from human activities, but anthropogenic pollutants and sediment remain a significant threat. To our knowledge, no protections exist that take into account the vulnerabilities of selected species, even ones that are as important as *Acropora* spp.

*The U.S. Candidate Species Program*

An effective program for the conservation of a species requires a means of identifying species not yet listed on the ESA that face immediate, identifiable risks. A candidate species listing provides a red flag to warn management authorities and the public of the concern for a particular species before that species becomes threatened with extinction. The candidate species listing helps 1) identify species that may need protective measures under the ESA; 2) increase public awareness about the species; 3) stimulate voluntary conservation efforts for these species by Federal agencies and other parties; and 4) identify uncertainties associated with their status.

Based on the large losses sustained by Caribbean acroporids, NMFS proposed that *A. cervicornis* and *A. palmata* may warrant listing on the ESA and identified them as candidate species in June 1999. These and eight other corals were tentatively listed as candidate species in 1991; although individual populations had declined, they were removed from the candidate list in 1997 because no species was identified as threatened throughout its range. Since 1973, the only other marine invertebrates proposed for listing on the ESA were two abalone species.

*Applying the U.S. Endangered Species Act to Acropora spp.*

A species may be proposed for listing through a formal petition process or through a candidate species assessment process. Within 90 days of receiving a petition, NMFS must make a finding as to whether there is sufficient scientific and commercial data to warrant listing. If the preliminary finding supports listing, a status review is conducted. This includes an analysis of criteria that may contribute to decline of the species, including: 1) habitat destruction or modification; 2) overutilization for commercial or recreational purposes; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; or 5) other natural or man-made factors affecting its continued existence. For a species of particular concern, a listing proposal is drafted that contains information on its biological characteristics, population status, range, and habitat requirements; a summary of the threats affecting the species; and examples of available conservation measures and types of activities that would be prohibited. This document is published in the *Federal Register*, undergoes public comment and peer review, and is followed by publication of a final rule containing the listing decision. A recovery strategy must be developed and implemented for listed species within one year of listing.

*Decline in acroporid populations: the degree of threat*

*Acropora palmata* and *A. cervicornis* are distributed throughout the wider Caribbean. In the United States, they occur in the U.S. Virgin Islands, Puerto Rico, Navassa Island and Florida, including the Florida Keys and Biscayne National Park; *A. cervicornis* also extends up the east coast of Florida to Boca Raton. A growing list of threats is contributing to widespread reductions in living cover, abundance and condition of *A. cervicornis* and *A. palmata* and a disappearance of characteristic monospecific thickets (Fig. 2).

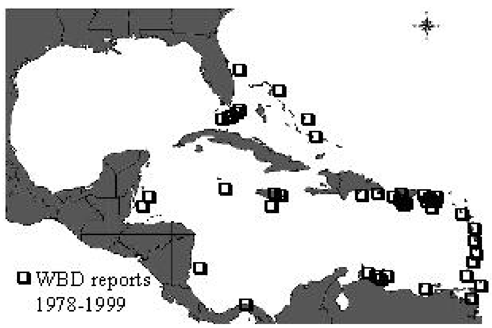


**Fig. 1** Reports of white-band disease published between 1979-1999, indicated by open squares.

White-band disease outbreaks are believed to be the most important factor responsible for the decline of these species (Fig. 3). Localized destruction has also been associated with hurricane damage, predation, hyper-and hypothermic stress, siltation and pollution associated with runoff, overgrowth by macroalgae, bioerosion, boat groundings and anchor damage, and other factors (Table 1). Harvest for building materials, curios and aquarium specimens was common in the 1960s and 1970s, but coral extraction no longer presents a significant threat. Isolated recruitment has occurred in recent years, but populations have failed to recover to their former abundance, and continued degradation from anthropogenic and natural factors is occurring. Based on the decline criteria used in the ESA, both corals appear to qualify for listing.

*ESA listing requirements for vertebrates and invertebrates*

Individual populations of a vertebrate species can be listed on the ESA, provided that they are reproductively isolated from other populations, and they represent important components of the evolutionary legacy of the species. Distinct population segments are defined based on 1) the discreteness of the population relative to the rest of the species; 2) the significance of the population segment to the species; and 3) whether the population segment is threatened when treated as if it were its own species.

In contrast, marine invertebrates qualify for listing only if threatened throughout their range. Invertebrates are exploited locally and are impacted by localized threats, but most species have life cycles that are presumed to be relatively resilient to exploitation, and are unlikely to be threatened with biological extinction because of their wide distribution and high fecundity. Even though many invertebrates are sedentary as adults, those with pelagic larvae have the potential for long-distance dispersal, and species are presumably interconnected by water currents.

The requirement that a species must be threatened throughout its range to qualify for ESA listing may not be the best conservation strategy for reef-building corals. First, it is impractical and very unlikely that sufficient information on the status of acroporids can be obtained from every reef where they occur. In addition, acroporids cross international boundaries, but U.S. legislation cannot be applied in other countries. Also, Carribean acroporids may be less resilient to emerging threats because of 1) low levels of sexual recruitment and limited genetic exchange among populations; 2) a reliance on asexual reproduction; and 3) special habitat requirements.

**Fig. 2** Characteristic thicket of *Acropora palmata*

**Fig. 3** Colony of *Acropora cervicornis* with white-band disease (WBD)

*Population parameters*

The degree of species endangerment is related to population size and intrinsic variability in population growth rates. For most animals, trends in abundance are based largely on differences between birth and death rates, and populations can persist only if the rate of increase is equal to or greater than zero. Age at sexual maturity, birth interval, annual reproductive rate, and survival rate of different age classes provides an indication of population dynamics in most animals, but it is difficult to apply these criteria to clonal organisms such as *Acropora* spp.

*Acropora palmata*, *A. cervicornis,* and other corals can be affected by partial mortality at any time during their lifespan and colonies can survive physical separation through fragmentation. A clonal mode of life has important implications for genetic diversity, dispersal capabilities, responses to environmental perturbations, and the ability of populations to persist under changing environmental conditions. There is evidence suggesting that patterns of mortality are related to colony size, and that partial mortality may affect reproductive potential (Hughes and Jackson 1985). Thus, colony size and extent of mortality may be more relevant than age when estimating the potential for population expansion and recovery.

*Reproduction and genetic exchange*

Marine organisms are often described as short-lived and opportunistic, or as long-lived, persistent species. Opportunistic species produce large numbers of small offspring at an early age, and these often exhibit high rates of recruitment. Large bodied, long-lived animals often delay reproduction and produce fewer offspring, but offspring receive a high degree of parental care and have a greater potential for survival. *Acropora cervicornis* and *A. palmata* can be long-lived, they may reach a large size, and they reproduce annually, with large colonies broadcasting millions of gametes into the water (Bak and Engel 1979). However, colonies delay reproduction until reaching a certain size (approx 20-50 cm diameter) and sexual recruits are rarely observed, suggesting low survivorship of larvae. Colonies are also frequently damaged during storms and reproduction may cease in fragmented colonies (Highsmith 1982; Rylaarsdam 1983; Szmant 1986). The widespread decline of these species further compromises sexual reproduction as acroporids are now rare, and population density may be too low to ensure high fertilization success (Aronson and Precht 2001).

Colonies of *A. cervicornis* and *A. palmata* are widely distributed, but they occupy very specific habitats within their range. Nevertheless, these species are opportunistic in that they monopolized large areas of reef, which is achieved primarily through fragmentation. Growth in *Acropora* spp. is potentially indeterminate, but it may be constrained due to water depth or degree of wave exposure. Periodic pruning associated with storms allows the biomass of a genotype to increase beyond an individuals physical limits by the constant formation of fragments. This may promote dispersal to new areas, with colonization occurring more rapidly than by sexual recruitment, and in habitats not conducive to sexual recruitment (Tunnicliffe 1981). The continued growth and fragmentation of remaining colonies may facilitate localized recovery. However, a reliance on fragmentation as the primary reproductive strategy may retard recovery after large-scale disturbances, such as a severe hurricane that removes most colonies from an area.

Another consequence of fragmentation is that it promotes reduced genetic variability. In light of emerging disturbances, this may lower the potential for adaptation to changing environmental conditions, and this may have been a key factor contributing to the regional spread of white-band disease, and the near total loss of these corals. However, fragmentation may allow adaptation to new conditions, through the retention of resistant clones to replace those lost to disease or other environmental perturbations.

**Benefits of an Endangered Species Act listing**

The ESA provides a means for conserving species that are threatened or in danger of extinction, and for the conservation of the habitats upon which those species depend. Once listed, the ESA mandates implementation of a recovery program capable of restoring a species in its natural habitat to a level at which it can sustain itself without further legal protection. The goals of the recovery program are to 1) identify the ecosystems and organisms that face the highest degree of threat; 2) determine actions necessary to reduce or eliminate the threats; and 3) implement strategies to recover the species. A recovery program involves activities associated with resource management and can include research, monitoring, habitat acquisition, and strategies to

Table 1. Degree of threat to *Acropora palmata* and *A. cervicornis* using criteria established for the ESA

| ESA Criteria | source of decline | degree of threat |
|---|---|---|
| Habitat destruction or modification | dredging, vessel groundings, anchor damage, pollution and sedimentation from shoreline development and land use | moderate; localized |
| Overutilization | collection for curios, aquarium specimens and building materials | high during the 1970s; collection now prohibited in most locations |
| Disease | white-band disease, new coral syndromes | high; disease epizootics occurred throughout the region in the 1970s-1990s; disease remains a significant threat |
| Predation | Corallivorous gastropods, polychaetes, parrotfish, damselfish | moderate; regional; corallivores populations have increased presumably in response to reduced predation pressure |
| Existing regulatory mechanisms | water quality | high; localized near population centers |
| Other natural threats | bleaching, hurricanes, temperature extremes | high; localized, may be regional |

maintain, propagate and/or transplant the species.

The ESA requires that protective measures are applied to the habitats supporting a listed species, with emphasis on areas that are critical to the persistence of the species. Recovery programs target areas with a unique genetic diversity or a high abundance, populations that may provide a significant source of recruits to other areas, or populations at the geographic limits of the species. Also, federal activities can not contribute to the degradation of the habitat utilized by a listed species. For instance, protection under the ESA could prevent dredging or discharge of sediment near coral reef environments.

## Discussion

Coral reefs are resilient ecosystems that can rebound to a healthy state through better management decisions, improved water quality, habitat protection and proactive conservation. Management regimes have begun to focus on ecosystem-based conservation measures, instead of a species-by-species approach. One strategy involves zoning of reefs for different activities. including the establishment of no-take marine protected areas (MPAs). MPAs are designed to restore depleted fisheries and protect biodiversity from extractive activities, and they may also help maintain a high diversity and abundance of species outside of the reserve. While recent efforts are promoting conservation of biodiversity through non-destructive, sustainable management of resources, more efforts need to be directed towards land-based strategies to reduce anthropogenic pollutants and sediments, as these may be much more substantial factors exacerbating coral mortality.

Living marine resources include many sessile species with distributions that cross geographical boundaries, complicating management regimes. Thus far, there are no regional management schemes for conserving corals and there has been no systematic overview of the status of key species such as *A. palmata* and *A. cervicornis*. Only limited information exists on the abundance and condition of Caribbean acroporids, and the degree of genetic differentiation among and within populations is poorly understood. The ESA is the most powerful environmental protection law in the U.S. that can help fill gaps in our understanding of these species. An ESA listing would ensure that additional resources are allocated towards research and monitoring. It can also assist in the implementation of strategies to reduce habitat degradation and avoid impacts from future activities, including coastal modifications that may affect water quality.

*Acropora palmata* and *A. cervicornis* are the first coral species to be listed as candidates for the ESA. Proactive conservation through the candidate species program minimizes the cost of recovery and allows management flexibility to stabilize or restore these species and their habitat. However, a candidate species listing alone provides no legal protection. In contrast, a full ESA listing would require the development and implementation of a recovery plan thereby reducing the likelihood of extinction by alleviating threats affecting these species and promoting strategies to increase population size. Key research and management strategies applied in the U.S. can be utilized in other countries, thereby promoting the recovery of acroporid corals throughout the region. By protecting declining coral species such as *A. cervicornis* and *A. palmata* through the ESA, unique species assemblages dependent on reefs will also benefit.

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