LETTERS

PCR Products and CITES

Brian Bowen and John Avise's letter, "Conservation research and the legal status of PCR products" (4 Nov., p. 713) questions the policy of the Office of Management Authority (U.S. Fish and Wildlife Service) on whether polymerase chain reaction (PCR) products require permits under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) or other wildlife or plant conservation laws of the United States.

It is the policy of the Fish and Wildlife Service that DNA samples derived directly from animal or plant tissues are subject to all permitting requirements of CITES, federal conservation statutes, and implementing regulations. Although the CITES parties have not discussed DNA samples directly, the issue of whether blood and tissue samples to be used for DNA studies are covered by CITES was discussed at the Eighth Conference of the Parties in Kyoto, Japan, in 1992. The CITES parties rejected Denmark's draft resolution and agreed that such tissues should not be exempted from CITES controls. The parties agreed, however, to endeavor to achieve efficient and timely issuance of permits for perishable samples.

However, the issue of the application of CITES to DNA samples derived from animal or plant tissues is distinguishable from the regulation of synthetic DNA samples under CITES. Synthetic DNA samples contain no part of the original template. If PCR products are cleaned using techniques such as the magnetic bead procedure, the resulting amplified DNA is 100% synthetic. Therefore, it is the policy of the Fish and Wildlife Service that synthetic DNA samples are *not* subject to permitting or other requirements of CITES or federal conservation statutes, such as the Endangered Species Act, the Marine Mammal Protection Act, or the Migratory Bird Treaty Act.

The purpose of CITES and other wildlife conservation laws and treaties is to regulate trade in animals and plants and their parts and products so that the survival of a listed species is not jeopardized. The Fish and Wildlife Service is satisfied that trade in synthetic DNA samples will not adversely affect the conservation of, or the effective regulation of, trade in CITES-listed species and their parts and derivatives.

The Fish and Wildlife Service recognizes the contribution of DNA synthetics in wildlife forensic investigations and the conservation of endangered species.

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Coral Reef Catastrophe

The article "Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef" by Terence P. Hughes (9 Sept., p. 1547) relates the sad story of the decline of scleractinian coral populations in Jamaica over the past two decades. The article is a rare example of the long-term research needed to document trends on reefs; however, the monitoring program design appears to have excluded at least one potentially important causal factor, and the solution offered does not address sociopolitical reality.

The data in the study by Hughes show a rapid decline of coral populations initiated by a 1980 hurricane. Coral cover declined further after the reduction of an herbivorous sea urchin, *Diadema antillarum*, resulting from disease, while the cover of fleshy macro-algae bloomed. Thus two natural events, hurricanes and disease, have decimated Jamaica's coral reefs. It is not clear what effect human activities have had on fleshy algae on these reefs and what, if anything, we can do to help the coral.

Hughes makes the logical case that overfishing of herbivores and the die-off of urchins have allowed macro-algae to outcompete corals. No recent fish stock assessment data are presented, so the relation between differential fishing pressure on predators and herbivores, and variations in urchin populations, is not clear. Reefs in other places such as the Philippines [where fishing pressure is maximal (2), *Diadema* are not particularly abundant, and typhoon damage is frequent] have not experienced similar events (2, 3). Not all coral reefs in the Caribbean that experienced overfishing and the *Diadema* die-off have experienced the same pattern of coral loss. For example, the 10- and 30-meter zones in Saint Croix maintained coral populations between 1982 and 1988 despite overfishing, increased algal growth, and few *Diadema* (4).

Although Hughes notes that on land, "nearly all native vegetation [has been] cleared for agriculture and urban development" (p. 1547), he does not present data on nutrification by increased runoff, sewage discharge, and fertilizer use. Nutrient enrichment is usually required to support high rates of algal productivity on reefs (5).

Hughes concludes that Jamaican reefs face a "gloomy future unless action is taken immediately" (p. 1550), and his major management recommendation is to "control overfishing." Although Jamaica could benefit from slower human population growth and integrated coastal zone (including fisheries) management, the primary scientific evidence used as a basis for recommending better fisheries management should be reduced fish stocks, not problems facing corals. As evidence of overfishing was available 20 years ago (6), there are probably still social, economic, and political roadblocks to successful implementation of fisheries regulations. Transforming scientific observations into management strategies requires scientists to work with local managers familiar with local constraints. If fishing cannot be controlled, there may be other approaches.

For example, if increased herbivory from urchins and fish would help coral population recovery in Jamaica, perhaps a pilot restocking program for both *Diadema* and herbivorous fishes could be tried on a reef fronting a diving resort. If successful, the program could be expanded.

Unfortunately, remedial measures could fail if nutrification is a major cause of algal dominance and remains uncontrolled. What is needed is a monitoring and management approach that considers linkages between land and sea (7). If practical management strategies are still blocked by sociopolitical problems, then it is time for scientists and managers to cut their losses and focus on other islands where there is public support for coral reef conservation.

Finally, while the news from Jamaica is bad, Hughes' multiple-listing citation (*1*, p. 1550) seems to suggest that one conclusion of The Colloquium on Global Aspects of Coral Reefs was that "global reef growth is currently being outpaced by reef degradation . . ." (p. 1550). But, the major written conclusion of the colloquium was that "There are significant declines in the condition of many of the world's reefs, but vast areas of remote reefs have not been studied, thus an accurate global evaluation is not possible," and "there is an urgent need to provide a comprehensive assessment of reefs" (8).

The activities proposed for the "Year of the Reef, 1996" (8) should help our understanding of the causes of algal blooms and coral declines.

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Terence P. Hughes' analysis of the degradation of the coral reefs of Jamaica over 17 years ("Catastrophes, phase shifts, and large-scale degradation of Caribbean coral reef," 9 Sept., p. 1547) emphasizes the value of long-term monitoring and research and suggests that control of overfishing, particularly of herbivores, is a key to managing these fragile ecosystems. This conclusion should be placed within the context of how Caribbean coral reefs might respond to changing environmental conditions.

The CARICOMP (Caribbean Coastal Marine Productivity) network of 24 Caribbean marine laboratories, parks, and reserves in 19 countries implemented in late 1993 a standardized monitoring protocol of synoptic observations designed to detect thresholds and rates of responses of ecosystems to global change (*1*). Before data collection began, researchers at some of the sites responded to a qualitative questionnaire about change in coral reefs over the past decade (*2*). Of 14 sites responding, the five reporting no change in coral cover (Belize, Bermuda, Cayman, Saba, and St. Lucia) were located within parks, reserves, or areas where control of fishing is the major management tactic. The remaining nine sites reported varying rates of decline in coral cover and tentatively implicated a wide variety of factors, including fishing, nutrient pollution, sedimentation, storms, diseases, and coral bleaching. Thus, different synergies of natural and human disturbances may contribute to changes in coral cover.

A key problem for ecosystem management is to discriminate human impact from natural variation (*3*). If Caribbean reefs are to be managed for sustainable use, studies and management efforts at single sites must be extended to encompass the time and geographic scales of natural and anthropogenic processes and the rates of responses of target ecosystems across the full range of their development. Regional international research networks could collect data critical to management and encourage governments to apply the new knowledge to a regional ecosystem management strategy.

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Response: In my article "Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef," I showed that the causes of degradation in Jamaica were complex and interactive, with major impacts resulting from overfishing, hurricane damage, and a die-off of the echinoid *Diadema antillarum*. I argued further that the current paucity of herbivores (sea urchins and fish) was the principle cause of a protracted, nationwide algal bloom. I did not present new data on fish stocks, but instead cited a series of studies by John Munro and colleagues (*1*), which are widely regarded as the most comprehensive investigations of any coral reef fishery (*2*). Already by the late 1970s there were so few fish remaining on the north coast of Jamaica that experimental fish traps yielded an average catch of only 100 grams per trap per day, mostly of unmarketable fishes (*1*). In more recent years, fishing intensity has increased even further, causing a virtual collapse of stocks (*3*).

As well as being depleted of herbivorous fish, Jamaican reefs lost about 100 million *Diadema* from disease over an 8-week period in 1983 (*4*), an event that was followed immediately by a large-scale algal bloom that was unprecedented in three decades of intensive study (*3*). Hodgson cites a unique study of urban pollution in Kaneohe Bay, Hawaii (*4*), to argue that eutrophication was a major contributor to the proliferation of algae in Jamaica, because "nutrient enrichment is usually required to support high rates of algal productivity on coral reefs." However, algal primary productivity actually *declined* by more than 60% after the mass-mortality of *Diadema* in St. Croix, U.S. Virgin Islands, where algal biomass increased by 20% after only 5 days (*5*). Furthermore, it has been demonstrated repeatedly that the experimental removal of herbivorous fish or echinoids results in algal blooms that are destructive to corals, without any difference in background nutrients between removal and adjacent control sites (*6*). Algal blooms and declines in coral cover occurred throughout the Caribbean immediately after the die-off of *Diadema*, especially on reefs that were also depauperate in herbivorous fish [(*7*); see also accompanying letter by J. Ogden *et al.*]. Hodgson's reference to apparent stability of coral cover in St. Croix is misleading, as the study he cites (*8*) explicitly points out that herbivorous fish are more numerous and larger there than in Jamaica: it also reported a 50% decline in coral cover at depths of 1 to 5 meters from 1982 to 1988. In 1989, Hurricane Hugo caused further extensive damage (*9*).

It would be a mistake to view undergrazing of algae and eutrophication as mutually exclusive causes of algal blooms. For example, a polluted reef would presumably have higher algal biomass if it were also overfished. However, the geographic scale of algal blooms in the Caribbean and their synchrony with the *Diadema* die-off point to herbivory being the major contributor. Localized pollution does occur in Jamaica and elsewhere, but it is generally confined to shallow embayments dominated by mangroves and seagrass beds, or close to major urban centers (*10*). Virtually all of my sites were rural, on exposed fore-reefs with water clarity in excess of 30 to 40 meters. There was no sudden increase in nutrient runoff all around the island-nation in 1983 that simply happened to coincide with the die-off of vast numbers of the major herbivore, *Diadema*, as Hodgson suggests. Major land clearing in Jamaica was completed in the last century (*11*).

It is not entirely surprising that coral reefs in the Philippines have responded differently to overfishing. The reefs there are at the center of diversity in the Indo-Pacific, with many guilds having five to seven times more species than the Caribbean. The relative paucity of echinoids in the Philippines compared to the Caribbean is a fundamental and well-known biogeographic difference between tropical oceans (*12*). Detailed long-term studies from Jamaica could not be expected to predict much about the dynamics of different systems that have no species in common.

In my article I suggested that destructive algal blooms in Jamaica could be reversed at least partly by controlling overfishing. Hodgson states instead that it may be time to "cut [our] losses and focus on other islands where there is public support for coral reef conservation." To abandon Jamaica at this stage would be irresponsible and even to suggest so undervalues efforts that are already underway there for improved reef management (*13*).

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Corrections and Clarifications

Figure 1, parts A and C (p. 1349), of the Research Article "Calcium-calmodulin modulation of the olfactory cyclic nucleotide-gated cation channel" by Mingyao Liu *et al.* (25 Nov., p. 1348) were incorrectly printed. The correct figures appear below. On page 1351 of the same article, in line 25 of the first column of text, "GMP" should have been "AMP." In the second line of the text on page 1352, the first "$(C.L_n)_o$" should have been "$(C.L_n)_c$."