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An analysis of the loss of acroporid corals at Looe Key, Florida, USA: 1983–2000

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Abstract The Caribbean reef-building corals *Acropora palmata* and *Acropora cervicornis* have undergone widespread declines in the past two decades, leading to their designation as candidates for listing under the United States Endangered Species Act. Whole-reef censuses in 1983 and 2000 at Looe Key National Marine Sanctuary in the Florida Keys provide estimates of areal loss of live *Acropora* spp. cover. Area (square meters) of live coral cover was quantified from depiction on scaled base maps of extent of coral cover observed by a snorkeler on each reef spur at each census. Certain thickets appear to have been persistent (though none expanded), but the total area of live *A. palmata* at Looe Key is estimated to have declined by 93% and *A. cervicornis* by 98% during this 17-year interval. It is likely that acroporid populations may have already undergone substantial decline prior to our initial census in 1983.

Keywords *Acropora cervicornis* · *Acropora palmata* · Florida Keys · Coral decline

Introduction

For most of the past 500,000 years, *Acropora palmata* and *Acropora cervicornis* were dominant reef-building coral species throughout the Caribbean region (Jackson 1994). The two species also served an important ecological function on coral reefs by providing habitat for numerous reef fish species. However, these two acroporids have undergone widespread regional decline over the past two decades both in the Florida Keys (Jaap et al. 1988; Porter and Meier 1992) and throughout the Caribbean (Aronson and Precht 2001), leading to their designation as Candidate Species for listing as Threatened or Endangered under the US Endangered Species Act (ESA) in 1999 (Diaz-Soltero 1999). Several factors have contributed to the general decline of coral reefs in the Florida Keys, including stresses both natural (e.g., storms, corallivory, coral disease, climatic extremes) and anthropogenic (e.g., water quality degradation, overfishing, ship groundings). Implications of failing *A. palmata* populations include structural instability of reefs and loss of habitat.

While regional coral decline is widely recognized, quantitative studies addressing changes in distribution and abundance over decadal scales are rare (notable exceptions being Dustan and Halas 1987; Porter and Meier 1992; McClanahan and Muthiga 1998). A 1983 resource inventory at Looe Key (Bohnsack 1984) serves as a valuable reference point for reef status in the Florida Keys. Looe Key is a high-relief spur and groove reef in the lower Florida Keys, located approximately 12.9 km, southwest of Big Pine Key, Florida (24°37′N, 81°24′W). In 1981, a 5.3-nmi^2 area surrounding the reef was designated as the Looe Key National Marine Sanctuary (LKNMS), to provide protection for the reef and opportunities for education and research. The interdisciplinary, quantitative resource inventory was undertaken by several agencies and institutions in 1983 to address usage patterns, habitat types, geology and sedimentology, coral growth history, reef fish abundance and distribution, coral abundance and distribution, and status of selected resources (Bohnsack 1984). The information generated by the inventory would provide the basis of future monitoring and management efforts. The distribution and cover of *A. palmata* and *A. cervicornis* over the entire reef was mapped in 1983 as part of this survey.

The objective of the present study was to analyze changes in the abundance and distribution of *A. palmata* and *A. cervicornis* by re-surveying Looe Key in 2000.

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Materials and methods

Field mapping

As part of the 1983 LKNMS resource survey, scaled maps of the reef were constructed from aerial photographs showing the precise location and shape of each spur and groove. The entire fore-reef area of Looe Key was divided into eight detailed, large-scale section maps (lettered A–H, Fig. 1). In 1983, each section map was traced onto an acetate sheet. A snorkeler then swam along each spur within a section of the reef and used colored grease pencils to depict their visual estimate of areal coverage of each coral species (*A. palmata*, *A. cervicornis*) on the scaled base maps (Bohnsack 1984). At the time of the 1983 survey, *A. palmata* and *A. cervicornis* were present in dense thickets, often covering entire sections of a spur (Fig. 1). Though the reef had been mapped across eight map sections (A–H), only sections A–F were surveyed for acroporid presence. For the 2000 survey, the original section maps were copied onto underwater paper. During October–November 2000, the location and estimated area of *A. palmata* and *A. cervicornis* colonies were similarly depicted on each section base map by snorkeling over the entire reef (Fig. 1). In 2000, *A. palmata* and *A. cervicornis* occurred primarily as low-density or solitary colonies.

For the 1983 census, individual colonies (dots) and thickets (larger colored areas) were distinguished, from the depictions on the survey maps. For the 1983 survey, arbitrary areal estimates were assigned for dots interpreted as individual colonies (1 m^2 for *A. palmata* colonies, 0.5 m^2 for *A. cervicornis* colonies); whereas, in 2000, individual colonies were specifically identified on the base maps and individually estimated in the field in 0.25-, 0.5-, 1-, and 2-m^2 categories. Map sections from each census depicting thickets were scanned into a digital image file. Image analysis was performed using SigmaScan Pro v.4.0 software (Jandel Scientific). After applying the appropriate scale to each section map, the colored areas representing thickets of each coral species were traced to estimate the area of thicket cover (square meters) for each map section. Thicket area and the individual colony areas were summed for each map section for each census. This quantitative analysis of visually estimated depictions of coral cover on a scaled base map yields a "semi-quantitative" estimate for reef-wide *A. palmata* and *A. cervicornis* abundance in the two censuses.

Results and discussion

The loss of *A. palmata* and *A. cervicornis* coverage at Looe Key since 1983 is dramatic. Table 1 compares the abundances and distributions of each coral species found in 1983 and 2000. For *A. palmata*, the loss exceeds 97% for four of the six map sections. A large stand of *A. palmata* remained in section B; loss in that reef section was only 25%. Overall loss of *A. palmata* is estimated at 93% or over 4,200 m^2. Many of the remaining colonies did not appear in good condition, exhibiting extensive areas of dead tissue and populations of coral-allivorous snails. Many standing colonies were predominantly dead, with live tissue remaining only on the

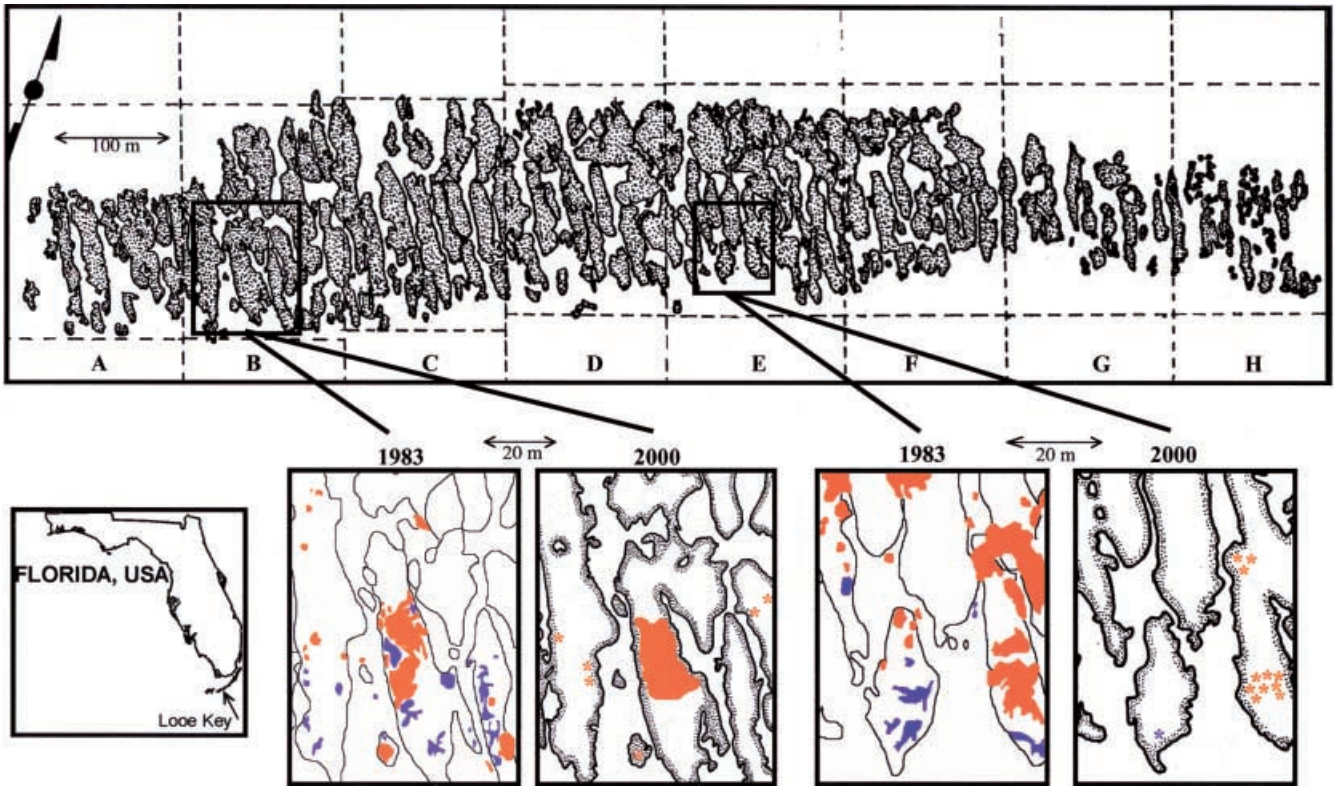

Fig. 1. A scaled base map of the reef at Looe Key, Florida, drawn from aerial photographs and depicting reef sections (*A–F*) in which coral abundance is reported. *Insets* show examples of the coral censuses, *Acropora palmata* in *red* and *A. cervicornis* in *purple*, from which the abundance estimates were made (see text). In the 1983 maps, *small dots* were counted as individual colonies and assigned a fixed area. In the 2000 maps, individual isolated colonies were recorded as *asterisks*. Areas for larger thickets were quantified by image analysis. Note that the *west inset* shows both a relatively persistent *A. palmata* thicket and an area of *A. cervicornis* that had completely disappeared by 2000

Table 1. Estimated abundance (in m^2) and change in *Acropora* species at Looe Key between 1983 and 2000 stratified by reef section as depicted in Fig. 1

Section	*A. palmata*				*A. cervicornis*			
	1983	2000	Loss (m^2)	Loss (%)	1983	2000	Loss (m^2)	Loss (%)
A	45.00	16.73	28.27	62.82	69.00	33.65	35.35	51.23
B	338.00	250.30	87.70	25.95	462.87	0.25	462.62	99.95
C	515.46	1.25	514.21	99.76	366.55	0.00	366.55	100.00
D	1,832.62	8.50	1,824.12	99.54	644.83	0.50	644.33	99.92
E	1,486.80	32.25	1,454.55	97.83	251.70	1.25	250.45	99.50
F	329.07	7.25	321.82	97.80	1.00	0.00	1.00	100.00
Total	4,546.95	316.28	4,230.67	93.04	1,795.95	35.65	1,760.30	98.01

tips of branches, a pattern observed to result from 1998 bleaching impacts in *A. palmata* stands in the upper Keys (M.W. Miller, personal observation).

A. cervicornis colonies appear to have fared even worse since the 1983 survey (Table 1). In five of the six map sections, loss was 99–100%. Most of the persistent *A. cervicornis* was found in section A, where only 51% loss was seen. Overall, *A. cervicornis* suffered a 98.01% net loss during this survey interval. Only the tips remained alive in many of the colonies, most colonies were small, and no dense *A. cervicornis* thickets were observed.

While Indo-Pacific coral reefs contain a plethora of fast-growing acroporid species, *A. palmata* and *A. cervicornis* are the only significant ones in the Caribbean. This lack of species richness heightens the ecological importance of these two species as primary constructors of Caribbean reef accretion and habitat complexity. Being fast-growing, fragmenting corals, *A. palmata* and *A. cervicornis* are expected to have relatively "fast" population dynamics. As such, wide population fluctuations have been noted over historical time scales (e.g., Davis 1982; Jaap 1998), and McNeill et al. (1997) suggest that the rapid growth and accretion rates of *A. palmata* make it well adapted to rapidly fluctuating environments. Reef cores revealed that *A. palmata* contributed substantially to reef-building at Looe Key approximately 800–1,000 years ago (Shinn et al. 1981). The 1983 survey of Looe Key reported sparse *A. palmata* populations relative to those revealed in the geologic record (Bohnsack 1984).

These published observations highlight the likelihood that substantial acroporid decline had already occurred at Looe Key prior to the 1983 census and, hence, that the dramatic decline documented in the present study under-represents the total decline. On a broader temporal and geographical scale, Jackson et al. (2001) infer from paleoecological and ecological evidence that the percentage of Caribbean reef sites dominated by *A. palmata* had declined substantially (~80% to ~40%) from the Holocene to 1983. Pre-1983 decline was less dramatic for *A. cervicornis* (Jackson et al. 2001).

Well-recognized disturbances that are presumed to have strongly affected *Acropora* populations at Looe Key and throughout the Florida Keys during the current study include the Caribbean-wide white band disease outbreak in the early 1980s (Aronson and Precht 2001), and the co-incidence of severe bleaching and Hurricane Georges in 1998 (M.W. Miller, personal observation). There was a major ship grounding at Looe Key which demolished sections of four spurs in section C (Fig. 1) in 1994. However, it appears that most acroporid loss at Looe Key had occurred prior to this event as the damage assessments performed at that time did not find any live acroporids in survey areas adjacent to the grounding used to estimate loss from the grounding (Jaap et al. *circa* 1994).

This study is comprised of only two snapshots 17 years apart. It is possible that the *Acropora* spp. populations at Looe Key have undergone repeated declines and rebounds as suggested by Jaap (1998). However, other studies suggest the declines have greatly outweighed the rebounds in the Florida Keys during this time. Jaap et al. (1988) report a 96% decline in *A. cervicornis* at Molasses Reef in the Florida Keys between 1981 and 1986 but observed no dramatic decline in *A. palmata*. Porter and Meier (1992) report a 44% loss of *A. palmata* in a 4.5-m^2 photo plot at Looe Key between 1984 and 1991 in the noted absence of major storms. Rigorous monitoring of coral populations in the Florida Keys has intensified over the past 5 years with the institution of the Sanctuary Coral Reef Monitoring Program begun in 1996 (Jaap et al. 2000, available at ftp://ftp.fmri.usf.edu/pub/uploads/CRMP/). This program has found little change in *A. palmata* but a statistically significant decrease in the number of sampled stations in which *A. cervicornis* was present between 1996 and 2000. By 2000, *A. cervicornis* had disappeared from four out of the five stations at Looe Key where it was present in 1996 (Porter et al., unpublished data, ftp://ftp.fmri.usf.edu/pub/uploads/CRMP/UGA%20files/). The absolute decline reported in the current study for Looe Key appears to have been more or less monotonic and representative of the region. Little sign of recovery is apparent.

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References

Aronson RB, Precht WF (2001) White band disease and the changing face of Caribbean coral reefs. Hydrobiologia 460:25–38

Bohnsack JA (ed) (1984) Final report: resource survey of Looe Key National Marine Sanctuary. Sanctuary Programs Division, NOAA, US Department of Commerce, Silver Spring, Maryland

Davis GE (1982) A century of natural change in coral distribution at the Dry Tortugas: a comparison of reef maps from 1881 and 1976. Bull Mar Sci 32:608–623

Diaz-Soltero H (1999) Endangered and threatened species; a revision of candidate species list under the Endangered Species Act. Fed Regist 64(210):33466–33468

Dustan P, Halas J (1987) Changes in the reef-coral community of Carysfort Reef, Key Largo, Florida: 1974–1982. Coral Reefs 6:91–106

Jaap WC (1998) Boom–bust cycles in *Acropora*. Reef Encounter 23:12–13

Jaap WC, Halas JC, Muller RG (1988) Community dynamics of stony corals (Milleporina and Scleractinia) at Key Largo National Marine Sanctuary, Florida, during 1981–1986. Proc 6th Int Coral Reef Symp 2:237–243

Jaap WC, Miller LJ, Schmahl GP (*circa* 1994) Evaluation of benthic biota at the Columbus Iselin grounding, Looe Key Reef, Florida Keys National Marine Sanctuary. Report to the Florida Department of Environmental Protection and NOAA. WC Jaap, Florida Marine Research Institute, St. Petersburg, Florida, 10 pp

Jaap WC, Porter JW, Wheaton J, Hackett K, Lybolt M, Callahan M, Tsokos C, Yanev G, Dustan P (2000) Coral reef monitoring project executive summary. Report to Sanctuary Science Advisory Panel. WC Jaap, Florida Marine Research Institute, St. Petersburg, Florida

Jackson JBC (1994) Community unity. Science 264:1412–1413

Jackson JBC, and 18 others (2001) Historical overfishing and the recent collapse of coastal ecosystems. Science 293:629–638

McClanahan TR, Muthiga NA (1998) An ecological shift in a remote coral atoll of Belize over 25 years. Environ Conserv 25:122–130

McNeill DF, Budd AF, Borne PF (1997) Earlier (Late Pliocene) first appearance of the Caribbean reef-building coral *Acropora palmata*: stratigraphic and evolutionary implications. Geology 25:891–894

Porter JW, Meier OW (1992) Quantification of loss and change in Floridian reef coral populations. Am Zool 32:625–640

Shinn EA, Hudson JH, Robin D, Lidz B (1981) Spurs and grooves revisited: construction versus erosion, Looe Key Reef, Florida. Proc 4th Int Coral Reef Symp 1:475–483