

## Decline of crinoids on the reefs of Curaçao and Bonaire, Netherlands Antilles

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**Abstract.** Since 1996 at the latest, comatulid crinoids on the leeward reefs of Curaçao and Bonaire have declined drastically in population size and diversity. Prior to this decline, five species inhabited the forereef slope from depths of 6 to >30 m. *Davidaster rubiginosa* and an undescribed species of *Davidaster* were common from about 6 to 15 m depth, and *D. discoidea* was common below about 15 m. *Nemaster grandis* and *Ctenantedon kinziei* were found in lower abundance at about 30 m depth. Transect data from Bonaire showed that a drastic decline in numbers of the *Davidaster* taxa occurred between 1989 and 1996. Transects in Curaçao in the late 1990s through 2001 documented a similar decline. In 2007, sites in Curaçao where species of *Davidaster* were formerly common were practically devoid of crinoids. In particular, *D. discoidea*, once the most numerous crinoid in these islands, has all but disappeared. The cause of this decline on both islands is unknown. It is possible that heating associated with the severe coral bleaching event of 1995 also affected the crinoids. As far as we are aware, reef crinoid populations across the broader western Atlantic region have not shown a similar decline.

**Key words:** Crinoids, Curaçao, Bonaire

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### Introduction

Underwater censuses conducted in the late 1960s showed that five species of comatulid crinoids (feather stars) were common on the leeward fringing reefs of Curaçao and Bonaire in the Netherlands Antilles (Meyer 1973). *Davidaster rubiginosa* (Pourtalès) and an undescribed species of *Davidaster* were common along the edge of the forereef slope from about 6 to 15 m depth, and *D. discoidea* (P. H. Carpenter) was common below about 15 m. *Nemaster grandis* Clark and *Ctenantedon kinziei* Meyer occurred in lower abundance at about 30 m depth. Subsequent work in Curaçao by Liddell in the late 1970s (Liddell 1980, Liddell and Ohlhorst 1982) found similar patterns in crinoid distribution and abundance. Quantitative censuses conducted in Bonaire by Llewellyn in 1989 (Llewellyn 1991, Llewellyn and Meyer 1991) found evidence of continuing crinoid abundance. Following a hiatus in observations, in 1996 Meyer was alarmed to find an apparent decline in the numbers of crinoids in both Curaçao and Bonaire. In 1999, Lask and Meyer resurveyed the Karpata reef in Bonaire where Llewellyn had inventoried every crinoid within an area of approximately 1000 m<sup>2</sup> in 1989 (Lask and Meyer 2001). Llewellyn reported a total of 70 crinoids within this sampling area, but the 1999 survey found a single crinoid. Lask and Meyer (2001) revisited 13 sites in Bonaire and compared

crinoid occurrence with records from these and other sites accumulated over the period 1971-1996. The comparison showed that *D. rubiginosa* had become much less common and that *D. discoidea* had totally disappeared from sites where it had previously been common (see Fig. 1). In this paper we present a similar comparison of crinoid occurrence at sites along the leeward reefs of Curaçao in the late 1960s with surveys made since 2000, and changes in population density at one site, Jan Thielbaai, that Meyer surveyed in the late 1960s.

### Materials and Methods

During the period 2000 – 2007, scuba dives at 14 sites along the leeward coast of Curaçao recorded crinoid occurrence to depths of about 30 m (Fig. 2). Nine of these 14 sites had been inventoried for crinoids during the late 1960s. These dives commenced just above the top of the forereef slope at about 6 m, descended to about 30 m, followed by a short traverse at the maximum depth, and return to the shallows along an oblique course across the forereef slope. Crinoids encountered were recorded by species and depth. The total reef area surveyed at different sites was variable.

A census within an area marked off into depth zones was conducted at the Jan Thielbaai site in 1968 – 69 (Table 1, Meyer 1973). This census extended from a depth of 8 m along the top of the forereef slope to 38 m and covered a total area of 1905 m<sup>2</sup>. Crinoids were

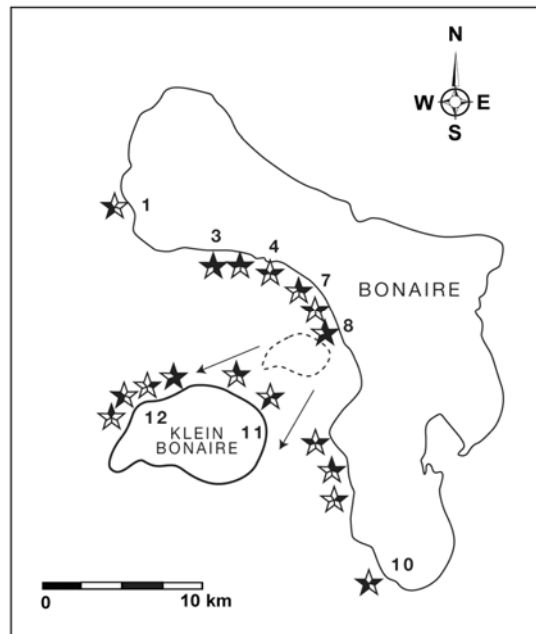
recorded within marked depth intervals and the results were plotted as bathymetric changes in population density. In 2001 and 2007 a large areal census at this site was not repeated, but several strip transects were inventoried at different depths parallel to the reef slope at the same location of the earlier survey. In 2001, two transects each 50 m long were surveyed at two depths 10 m and 15 m, with two divers each surveying a band one meter above and below the tape, for a total of 200 m<sup>2</sup> per transect. In 2007, the census followed the AGRRA protocol of six transects, each 1 m wide by 10 m long, at a depth of 8 m along the top of the reef slope (Ginsburg 2005). Crinoids were also inventoried at Jan Thielbaai during 2000 – 2007 on several dives to about 30 m that did not control for survey area.

### Results

In 1968-69, the most common crinoids, *Davidaster rubiginosa* and *D. discoidea*, could be found at most sites along the leeward reefs of Curaçao (Fig. 2) as well as Bonaire in 1971 (Fig. 1). At that time the undescribed species of *Davidaster* was considered to be an intraspecific variant of *D. rubiginosa*. Therefore the records of occurrence for *D. rubiginosa* for 1968-69 include forms now regarded to be a separate species. Only at the Jan Thielbaai site do photographic records and the tally of distinct variants of *Davidaster* (Table 1) provide a definite record of the undescribed species in 1968-69. Surveys conducted from 2000-2007 revealed that both *D. rubiginosa* and *D. discoidea* have declined in occurrence in Curaçao as they have in Bonaire (Fig. 2). One or both species have disappeared from several sites where they occurred in 1968-69.

The presence/absence data in Figure 2 alone do not convey the drastic decline in crinoid populations on the Curaçao reefs. Beginning in 1996, it was apparent that crinoid abundance was conspicuously reduced in Curaçao as it was in Bonaire (Lask and Meyer 2001). In 2001, we resurveyed the Jan Thielbaai site where Meyer had conducted a census of population density in 1968-69 (Table 1). Transects along the reef slope at 10 and 15 m covered depth intervals where crinoids had maximum density in 1968-69. *D. discoidea* was absent from these sampling areas, and both *D. rubiginosa* and *Davidaster* n. sp. were greatly reduced in numbers. *Nemaster grandis* was encountered in low numbers at 10 and 15 m, where it had been rare historically. This species was observed in greater numbers around 30 m depth. Although we were unable to obtain population density data at depths below 15 m, the *N. grandis* population appeared to be at levels similar to 1968-69. We revisited the site in 2002 2003 2004, and 2005, and found the same three species to be present. In 2007 we conducted an

1971-1996



1999

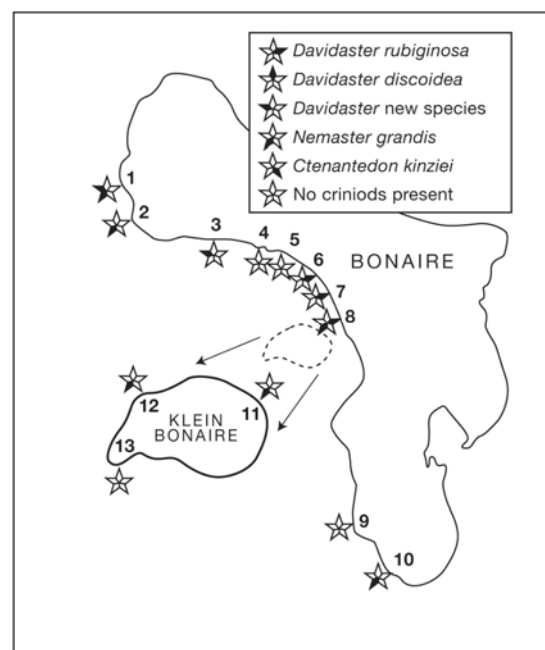
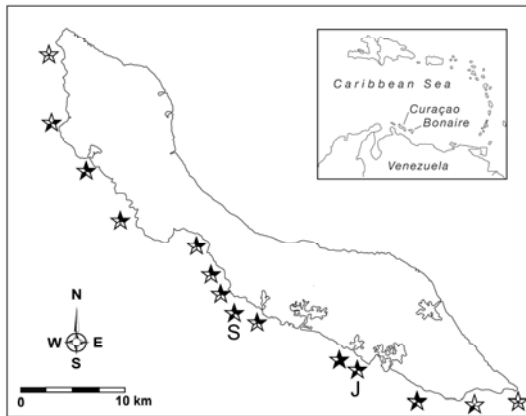


Figure 1: Crinoid species distribution at sites in Bonaire surveyed in 1971-96 (left), and in 1999 (above). Species occurrence is indicated by a black infilling of each of the five segments of the arrow symbol as shown in the legend. Modified after Lask and Meyer (2001).

AGRRA survey at Jan Thielbaai which included a series of transects at 8 m depth along the top of the reef slope. Although crinoids had not been very

common at 8 m historically, we were surprised not to encounter any crinoids at all in those sampling areas. In 2007 we also conducted AGRRA transects at Slangenbaai, another site where crinoids were very common in 1968-69. No crinoids were encountered within 6 transects, each 1 x 10 m, parallel to the reefslope at 8-10 m depth. Two individuals of *Davidaster* n. sp. were encountered outside these sampling areas at about 10 m depth. Clearly the population density of crinoids at this site was also drastically reduced from levels observed in 1968-69.

1968-1969



2000-2007

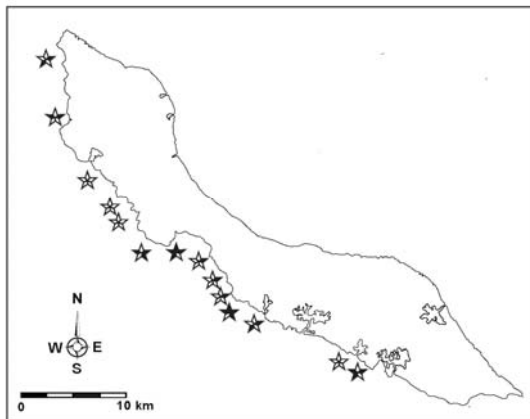


Figure 2: Crinoid species distribution at sites in Curaçao surveyed in 1968-69 (bottom of left column), and in 2000-2007 (above). Species occurrence as in Fig. 1. J = Jan Thielbaai, S = Slangenbaai.

## Discussion

An alternative hypothesis is that the observed decline since the early to mid-1990s represents part of a long-term cyclical fluctuation in crinoid populations, occurring on a timescale greater than the 40 yr span of underwater observations of crinoids in the Netherlands Antilles. Although such a possibility cannot be discounted, we feel it is unlikely given the apparent stability in crinoid populations from the late

1960s until the mid-1990s. The possibility that the timing of our surveys could have coincided with some short-term seasonal fluctuation in crinoid populations is also unlikely because surveys prior to 1996 when crinoids were more numerous usually occurred during the summer, and surveys after the mid-1990s drop in crinoids were also taken in the summer months.

The exact timing and cause of the decline in crinoids on the leeward reefs of Curaçao and Bonaire remain unresolved. We know that the decline occurred between 1989 and 1996, but we do not know where or when the decline started or how rapidly it progressed, as there was a six-year hiatus in our visits to the islands. By 1996 it appears the decline was well underway as we did not observe any recently dead

depth (m)	<i>D. rub.</i>	<i>D. disc.</i>	<i>D. n. sp.</i>	<i>N. grd.</i>	date
8.5	0.009	0	0	0	1968
10.7	0.041	0.002	0.005	0.002	1968
13.7	0.038	0.019	0.005	0.005	1968
16.8	0.121	0.114	0.017	0.003	1968
21.3	0.01	0.13	0.01	0.005	1968
25.9	0.022	0.211	0	0	1968
29	0.025	0.2	0	0.013	1968
34.3	0.013	0.157	0	0.026	1968
10	0.005	0	0.003	0.003	2001
15	0.005	0	0	0	2001
8	0	0	0	0	2007

Table 1: Population density (individuals/m<sup>2</sup>) at depth intervals along forereef slope at Jan Thielbaai, Curaçao. Depths for 1968-69 data are mid-points of depth intervals. *D. rub.* = *Davidaster rubiginosa*, *D. disc.* = *D. discoidea*, *D. n. sp.* = undescribed sp. of *Davidaster*, and *N. grd.* = *Nemaster grandis*.

crinoids in 1996. Because crinoids decay and disarticulate within a few days after death, it is likely that skeletal remains of crinoids would be rapidly dispersed in the reef sediments (Meyer and Meyer 1986). Unless an observer encountered moribund crinoids directly, it is quite possible that a mass die-off could pass unnoticed. In 2000, Lask observed a single moribund individual of *D. rubiginosa* at 11 m depth at one site in Curaçao, but was unable to obtain further information about the cause of this condition. The crinoid die-off may have followed a pattern similar to that of the mass mortality of the reef-dwelling echinoid *Diadema antillarum* (Bak et al. 1984). Meyer observed scores of moribund and recently dead echinoids when the mass mortality occurred in Bonaire in November 1983. By August of 1984 the skeletal remains of enormous numbers of echinoids had been effectively dispersed into the reef sediments (Greenstein 1989).

It is noteworthy that the crinoid decline occurred in both Curaçao and Bonaire. Curaçao has a human population about an order of magnitude higher than that of Bonaire, accompanied by a much higher degree of industrialization and coastal development. In contrast, Bonaire has little industrialization but increasing levels of coastal development. The entire fringing reef of Bonaire, contained within the Bonaire Marine Park, is one of the world's best-protected reef tracts. Because Curaçao usually lies downstream from Bonaire in the path of the Caribbean Current, pollution outfall from more-developed Curaçao will most likely be carried westward. Occasional reversal of the normal westerly flow could carry pollutants from Curaçao to Bonaire. It should also be noted that despite the increased likelihood of anthropogenic impacts on the Curaçao reefs, two sites where crinoids were surveyed, Jan Thielbaai and Slangenbaai, were both treated as control sites with little or no upstream coastal development in Nagelkerken's 2006 study of human impact and bleaching-related coral mortality.

One possible environmental perturbation that could have affected the crinoid populations on both islands was a protracted interval of seawater temperature elevation in late 1995. This thermal stress resulted in widespread coral bleaching and subsequent mortality along the leeward reefs of Curaçao and Bonaire (CARICOMP 1997; Nagelkerken 2006). In 1996, Meyer observed the ongoing effects of this bleaching as partial mortality and incipient recovery of coral colonies. Seawater surface temperature data reported by Nagelkerken for several sites along the leeward coast of Curaçao, including Jan Thielbaai, showed that temperatures rose in August and attained a maximum close to 30 deg. C by late September, returning to normal levels by late December. Although the physiological tolerance of comatulid crinoids for elevated temperatures is not well known, it is quite likely that many crinoids could have succumbed to this thermal stress. The fact that crinoids previously common along the shallower parts of the forereef slope, from 6- 15 m, seem to have been most severely reduced in numbers is consistent with heating of the shallow part of the water column. Deeper populations of *N. grandis* at about 30 m depth apparently persisted in numbers comparable to those observed in 1968-69, insofar as our limited opportunities to assess them have permitted. A thermal cause is consistent with crinoid decline at sites along the leeward coasts of both Curaçao and Bonaire. Other, as yet unidentified causes for the crinoid decline should not be discounted. For example, the outbreak of the aspergillosis epizootic among sea fans also occurred in the Netherlands Antilles reefs in 1995 (Nugues and Nagelkerken

2006), just before the decline in crinoids was first noted.

As far as we are aware, the decline in reef crinoids in the Netherlands Antilles has not occurred over the broader region of the tropical western Atlantic. Causey (2008) reported that no crinoids were found during a survey in 2001 on Looe Key Reef in the Florida Keys where they had been seen frequently in the 1960s and 1970s; however, crinoids are still seen on reefs of the Dry Tortugas. Meyer photographed both *D. rubiginosa* and *D. discoidea* on Molasses Reef in the Florida Keys in 1981 (unpublished observations). According to recent reports crinoids are still abundant in such places as St. John, Virgin Islands (C. Rogers, personal communication to DM) and Jamaica (T. J. Goreau, personal communication to DM).

As rheophilic suspension feeders, crinoids may be sensitive to different environmental changes than reef-building corals and other macroinvertebrates. Because crinoids were once among the most common suspension-feeding macroinvertebrates on these reefs, their rapid decline is a cause for concern. Ongoing monitoring of their population fluctuations could provide a different and potentially informative indicator of the overall health of the reef community.

#### Acknowledgements

We thank A Debrot, Director, and the staff of CARMABI, as well as A-M Vermeer at Habitat Curaçao for their assistance and hospitality during our visits to Curaçao. We also thank A Cornett for assistance in the field. We thank T Phillips, University of Cincinnati Department of Geology, for assistance with the figures. Funding was provided by the University of Cincinnati.

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