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Climate of the Past Discussions

Interactive comment on "Coral Cd/Ca and Mn/Ca records of El Niño variability in the Gulf of California" *by* J. D. Carriquiry and J. A. Villaescusa

J. D. Carriquiry and J. A. Villaescusa

jose_carriquiry@msn.com

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Responses to Anonymous Referee #2 Received and published: 13 April 2010

We want to thank referee-2 for his critical and constrictive review. His observations of editorial mistakes clearly helped us to correct some inadvertent omissions as well as to widen the scientific argumentation of our data. We made all the changes and considerations requested. Since some figure changes were requested and the numbering of the figures changed in the final revised manuscript, we are also including in this reply all the figures that compose this paper for the convenience of the review process.

SPECIFIC RESPONSES TO THE REFEREE COMMENTS AND/OR SUGGESTIONS:

Sample collection: 1) Were the whole colonies collected for sampling? Which were

their dimensions? Hadn't it been better to drill cores in the colonies? It would be informative to add representative X-ray sections of the sampled coral slabs. More details on the sampling resolution should be given. Is each data point presented in the figures (e.g. Fig. 3) representative of the calcification during the whole year? Or during a subsection of the year?

R: The Subsection 2.1 (Sample Collection) was completely modified. More detailed information was provided about the dimensions of collected coral colonies, sampling resolution of the coral skeleton, etc. Complete coral colonies were sampled; that was the method used by the entire community prior to the advent of submersible drills (in the mid-late 1990's). The Cd/Ca and Mn/Ca ratios shown in Fig. 3 represent the analysis done on a homogenized, cut-out annual band sample as we explain in subsection 2.1. New text: Live coral colonies of Pavona gigantea (227 mm high), Pavona clivosa (225 mm high) and Porites panamensis (154 mm high) were collected at depths between 5 and 10 m from Pulmo reef, southern Baja California, Mexico, in May 1990 (Fig. 1). In the laboratory, the corals were submerged in 50 % (v/v) sodium hypochlorite in order to remove the organic tissue. The coral colonies were slabbed using a circular saw (MK Diamond Products, Inc.) equipped with a 14" diameter diamond blade. The resulting 7 mm-thick coral slabs were x-rayed (Picker X-ray G850S) to reveal the annual growth bands that were used to develop the age model of each coral colony studied. From the positive impressions of x-ray images, each annual growth band was traced using acetate sheets over the positive prints. The annual skeletal growth rates were calculated from three different transects made in each x-rayed coral colony. The observed growth rates were: 11.3 $\pm$ 2.3 mm/year (1970 – 1989) for Pavona gigantea; 9.76 $\pm$ 2.5 mm/year (1967 – 1989) for Pavona clivosa, and 6.67 $\pm$ 1.1 mm/year (1967 - 1989) for Porites panamensis. The annual growth bands traced on the acetate sheets were transferred into the coral slabs to later cut each annual growth band using a mini-drill (Dremel, Moto-Tool 395), equipped with a flexible shaft (Dremel 225T1) and a circular mini-saw (Dremel 409). Prior to sample treatment and analyses, coral samples were crushed in an agate mortar to a size-range of 250-600 μm.

2) One of the corals seems to have been sampled at higher (seasonal) resolution, but this is mentioned, for the first time, already at the Results and Discussion section (69/21). These higher resolution data are only plotted at the end of the paper, in a figure (Fig. 6) that is not called anywhere in the text.

R: Thanks for pointing out that important omission (during the final edition of the manuscript, prior to submission, we failed to notice that we eliminated some text that referred to Fig.6). A new paragraph has been included discussing the results obtained using a high, seasonal-scale, sampling resolution of the Cd/Ca and Mn/Ca ratios of the coral Pavona gigantea (in subsection 3.2), which is provided next:

New Text: The Cd/Ca and Mn/Ca ratios that were analyzed at seasonal resolution in the Pavona gigantea (Fig. 7) show variability associated to ENSO, in similar way as it is observed in the annual Cd/Ca and Mn/Ca records (Fig. 3a,b). Similarly to the annual Cd/Ca records, the variability of the Cd/Ca sampled at seasonal resolution in Pavona gigantea shows a less evident response to ENSO events (Fig. 7). In contrast, the Mn/Ca ratio in the Pavona gigantea coral analyzed at seasonal and/or annual resolution show a clear increase during ENSO events. It is interesting to note from the seasonal-resolution record that the maxium Mn/Ca values occur during the final phase of the El Niño warming events, which is particularly evident during the El Niño events of 1972-73, 1980-81, 1982-83 (Fig. 7). This aparent delay in the response of the seasonal Mn/Ca series indicate that the hydrographic conditions that favor the increase in the concentration of dissolved Mn in the surface waters of the Gulf of California occurs when the event is at the mature phase of the ENSO warming. This is in agreement with the observed maximum temperature anomalies develop when the event occurs during the winter season (e.g. Castro et al., 2000; Lavín and Marinone, 2003).

Results and discussion: 3) 71/3: The sentence 'It is unlikely that species differences observed in this work is a consequence of sample treatment, although it has been proposed that corals can bio-concentrate metals from their diet (e.g., Fallon et al., 2002)' should be split in two, and further information should be given to substantiate

why the sample treatment is believed to have not been an issue.

R: The text was modified providing arguments for our contention that sample treatment artifacts are responsible for explaining the interspecific differences in the trace metal content of their skeletons.

New Text: The authors did not find a relationship between growth rate and the Cd/Ca ratio, nor an effect due to heterotrophy; concluding that, in their study, sample treatment effects could explain the species' differences. According to these authors, the skeletal structure of Porites is more delicate relative to that of Pavona, favoring a larger loss of Porites samples in their procedures; the losses they observed could explain the differences in the Cd/Ca ratios between the species involved. We did not measured the differences in percentage of sample loss between species, but our results show that in the Gulf of California, corals of the genus Porites concentrate more Cd and Mn, compared with the species of the genus Pavona, which is exactly the reverse of the corals from the Gulf of Panama (Mattehws et al., 2008). Consequently, it is highly unlikely that a larger sample loss during the cleaning protocol of Porites samples could explain why Porites has higher Cd/Ca and Mn/Ca ratios than the two species of Pavona studied here.

4) 71/8: The authors discuss about changes in growth rates, but do not present any data on them. It would be interesting to add these data in a new plot, for better assessment of any correspondences with the elemental ratios. The discussion on this should be expanded. The paragraph now ends with some references on studies assessing possible effects of growth rates on Sr/Ca which, in the way it is written now, I am not sure clarify much about Mn and Cd ratios.

R: Our conclusion is based on the low correlation existing between the trace metal ratios and skeletal growth rate. In support for this we included a new paragraph and a new plot in subsection 3.1 (Interspecific differences in the Cd /Ca and Mn/Ca ratios of corals) in which the correlation is shown between these variables. The correlations found (Spearman rank correlations) between annual Cd/Ca ratios versus annual skeletal growth rate are: in Porites panamensis, rs = -0.33 (p = 0.12); in Pavona clivosa, rs = 0.52 (p = 0.012); and in Pavona gigantea, rs = -0.41 (p = 0.07). For the correlation between annual Mn/Ca ratios versus annual skeletal growth rate were lower: in Porites panamensis, rs = -0.16 (p = 0.45); in Pavona clivosa, rs = -0.02 (p = 0.91); and in Pavona gigantea, rs = 0.02 (p = 0.94). This is summarized in the new text added, as follows:

New Text: Concerning the effects of growth rate on metal uptake, we found that, excepting for the significant correlation between the Cd/Ca ratios and the skeletal growth rate of Pavona clivosa (Spearman rank correlation, rs = 0.52, p = 0.012), the other coral species do not show any relationship between growth rate and the Cd/Ca and Mn/Ca ratios (Fig. 4a,b).

End of the paper: 5) The manuscript ends very abruptly. Looks like it was either finished quickly due to a lack of time, or that some important part is missing. In fact, Figures 5 and 6 are not called in the main text, while a discussion on them, particularly on Figure 6, would add value to the paper. Regarding this figure, which presents data on a higher resolution for the coral Pavona gigantea, the elemental ratios present a variability that does not match that well with the data presented at lower resolution (Fig. 3). A clear maximum in Cd/Ca between 1972 and 1973, for example, occurred during an El Niño event which, according to the hypotheses of this paper should have given a minimum in this ratio. Regarding Mn/Ca, maxima occur at times when there were no El Niño events (e.g. 1974, 1981, 1984, 1989). The authors should discuss more on the discrepancies between high and low resolution records. Also, a final comprehensive conclusion section should be prepared.

R: A new paragraph was included discussing the seasonal variation of the Cd/Ca and Mn/Ca ratios in Pavona gigantea providing the possible explanation for this seasonal varibility, but particularly more focused in explaining why the maximal values of the Mn/Ca ratios do not coincide with the lower (annual) sampling resolution, as follows:

The Cd/Ca and Mn/Ca ratios that were analyzed at seasonal resolution in the Pavona gigantea (Fig. 7) show variability associated to ENSO, in similar way as it is observed in the annual Cd/Ca and Mn/Ca records (Fig. 3a,b). Similarly to the annual Cd/Ca records, the variability of the Cd/Ca sampled at seasonal resolution in Pavona gigantea shows a less evident response to ENSO events (Fig. 7). In contrast, the Mn/Ca ratio in the Pavona gigantea coral analyzed at seasonal and/or annual resolution show a clear increase during ENSO events. It is interesting to note from the seasonal-resolution record that the maxium Mn/Ca values occur during the final phase of the El Niño warming events, which is particularly evident during the El Niño events of 1972-73, 1980-81, 1982-83 (Fig. 7). This apparent delay in the response of the seasonal Mn/Ca series indicate that the hydrographic conditions that favor the increase in the concentration of dissolved Mn in the surface waters of the Gulf of California occurs shortly after the El Niño reaches its mature phase of maximum warming.

We added a 'Conclusions Section (3.3)', which is presented next:

The results of this study shows that the Cd/Ca and Mn/Ca ratios in the corals Pavona clivosa, Porites panamensis and Pavona gigantea display clear evidence of El Niño activity at the mouth of the Gulf of California, although the effect is more evident in the Mn/Ca than in the Cd/Ca ratios in the three species of corals. The seasonal-resolution record of Cd/Ca and Mn/Ca of the coral Pavona gigantea showed inter-annual variability related to ENSO very similar to the observed in the annually-resolved records, nonetheless the maximal Mn/Ca values occur at the end of the warming phase of El Niño episodes, indicating that the hydrographic conditions that favor the increase in the concentration of dissolved Mn develop immediately after the El Niño warming event reaches the mature phase of maxium warming. Our results show that in the Gulf of California, the Mn/Ca ratio in corals reflects better the oceanographic changes generated by ENSO activity. The average Cd/Ca and Mn/Ca in the coral species studied follow the sequence panamensis> Pavona clivosa> Pavona gigantea. The annally averaged seasonal-resolution records of Cd/Ca and Mn/Ca ratios in the coral Pavona gigantea are very similar to the annually-resolved records, indicating that an annual sampling resolution adequately reflects the variability of these elemental ratios through the year. In this study we did not find evidences to support recent suggestions that the incorporation of Cd and Mn in the coral skeletons are affected by sample treatment, heterotrophic feeding rates, or by skeletal growth rate. However, the distribution coefficients of Cd (DCd) and Mn (DMn) differ among the coral species studied here. The DCd and DMn in the coral Porites panamensis, and the DCd for Pavona clivosa, are within the published ranges. On the contrary, the DCd in Pavona clivosa, and the DCd and DMn in Pavona gigantea are smaller than previous estimates, suggesting that the number of factors controlling D in the coral skeletons may be larger than previously thought.

Tables and Figures: 6) Table 2: Instead of marking with an asterisk the probability of those elemental ratios that are significantly different, all data, probability and ratios, could be printed in bold. R: Corrected. The t-student tests that resulted significant were highlighted in bold letters.

7) Fig. 1: Bathymetry contours would be of help. R: Figure-1 was modified. In the new version we show the location of the reef where the corals were collected at much higher retail, including the bathimetry.

8) Fig. 2: Explain the meaning of the grey bars, in this and also the other figures. Also, in the legend, it is 'Slutz' instead of 'Schultz' in the reference. R: Yes, we corrected the spelling to Slutz.

9) Fig. 3: It may be better to plot each coral record on its own scale, to magnify all changes. It is difficult to see changes in P. gigantea, for example, which in the paper conclusions is suggested as the best paleoceanographic coral recorder. R: Figure-3 was modified, plotting the Cd/Ca and Mn/Ca ratios in their own scale for each coral, as suggested.

10) Fig. 4: It is not clear how these anomalies are calculated. I am not sure about the

meaning of the solid line average between all species. Perhaps a line for each species would be better. Also, in the legend, add 'the' after '. . . the Cd/Ca ratio in'.

R: The standardized anomalies were calculated subtracting each annual value from the global mean of each time-series and dividing by the global standard deviation of each series. In this form, the resulting deviations are given in standard deviation units (s.d.u.) facilitating the visualization of the Cd/Ca and Mn/Ca trends of the three coral species in the same scale. Also as suggested, we included a line that connects the points for each coral species. The solid line shows the average of the normalized anomalies of the the Cd/Ca and Mn/Ca ratios for the three species (in s.d.u.). Because of this, the average anomalies would represent the general trend of the response of the trace metal ratios to El Niño events (in the three coral species studied), independently of the differences in the absolute value of the Cd/Ca and Mn/Ca ratios among the three species, as previously discussed Also, the typos in the figure legends were corrected.

11) Figs. 5 and 6: I am surprised that they are not called at all in the main text! See comments above. R: As we explained above, inadvertently during the final edition of the manuscript we mistakenly erased that part, but this error has been corrected in the new version (i.e., the figure is explained and cited in the text). Probably, because of that, as Reviewer-2 commented, the ending of the paper was sudden as if something was missing. We have taken care of this aspect too. 12) Minor changes or typos: - 64/9: 'ENSO and non-ENSO years' in the whole paper. Wouldn't it be better to talk about 'El Niño and La Niña years'?

R: They are not equivalent because: El Niño years represent the warm phase of the ENSO phenomenon while La Niña years are the cold-phase of ENSO; thus 'ENSO-years' is used when referring to those years in which El Niño develops followed by a La Niña event. But the 'non-ENSO' years are the 'normal' years in which the SST of the Eastern Tropical Pacific does not deviate from the 'average' conditions (some people call this 'normal' scenario as 'El Viejo' (the Old Man)).

13) 64/11: Regarding the coral scientific names, since Pavona and Porites start with the same letter, perhaps is better not to abbreviate the genus throughout the paper? R: Corrected

14) 65/8: Cut sentence at 'chronology' and start another afterwards. R: Corrected

15) 65/26: Comma after ENSO. R: Corrected

16) 66/6: After 'Tarawa atoll', a suitable reference should be provided. R: Corrected

17) 66/21: Lat, long separated by comma instead of 'and'. R: Corrected

18) 68/17: Meaning of APDC? R: Corrected

19) 68/27: Is there a better word for 'fortified'? R: Corrected

20) 69/1: Regarding the 91% recovery, did the authors correct for this in the final results? R: Yes, the final data were corrected by recovery percent (this observation was considered while correcting the Materials and Methods section).

21) 69/7: Lat, long separated by comma instead of 'and', correct degrees symbol after 23. R: Corrected

22) 70/1: Remove 'in'. R: Corrected

23). 70/10: Long and complicated sentence that should be rephrased. R: Corregir

24) 70/29: Add comma after 'that'. R: Corrected

25) 72/9: All 'Delgadillo' references should be 'Delgadillo-Hinojosa', search and replace. R: Corrected

26) 73/3: 'is' instead of 'are'. R: Corrected

27) 73/16: Add dot after the reference, and start the following sentence as 'Moreover, from the differences in . . .' R: Corrected

28) 73/20: 'On the other hand'. R: Corrected

29) 73/24: Better 'tracers' in plural. R: Corrected

Interactive comment on Clim. Past Discuss., 6, 63, 2010.

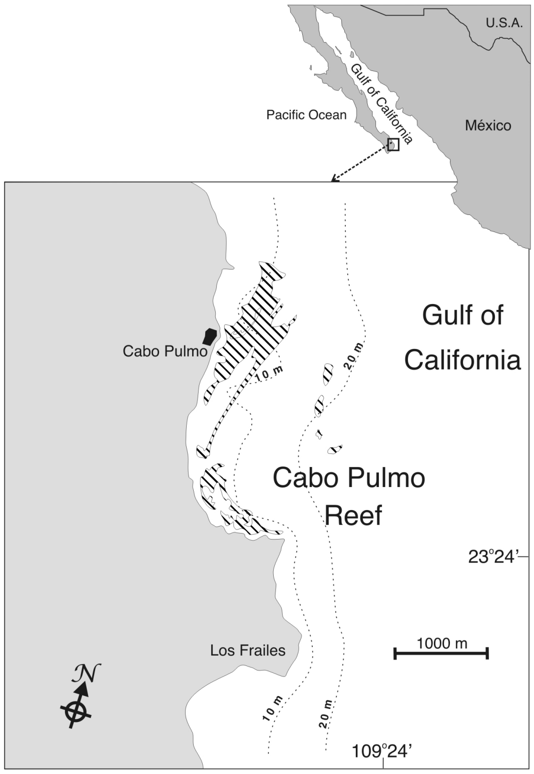

U.S.A.
Gulf of California
Pacific Ocean
México
Gulf of
California
Cabo Pulmo
10 m
20 m
Cabo Pulmo
Reef
23°24'
1000 m
Los Frailes
N
10 m
20 m
109°24'

Fig. 1.

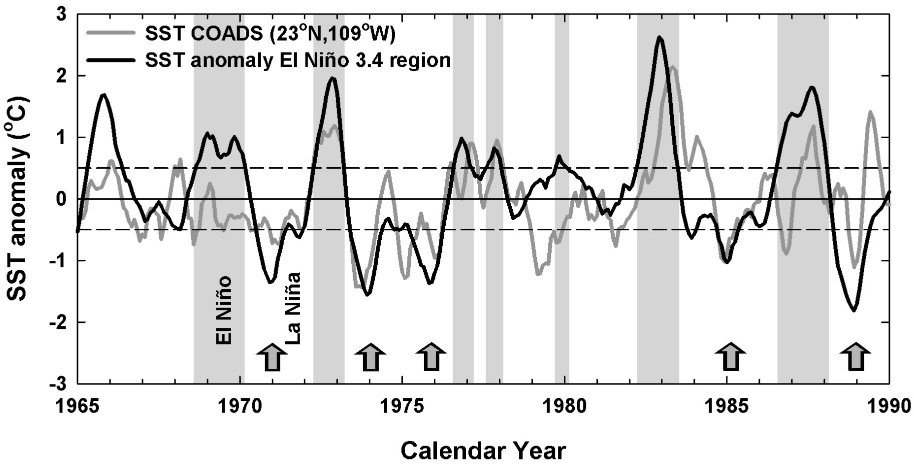
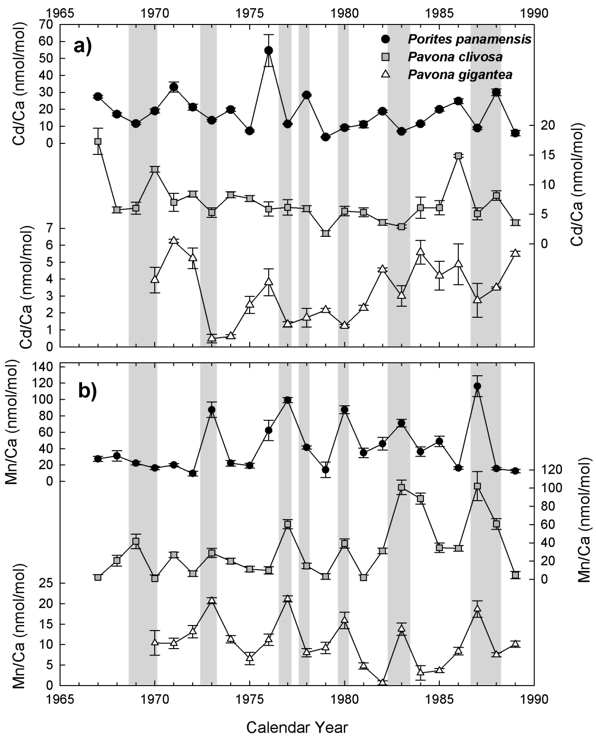
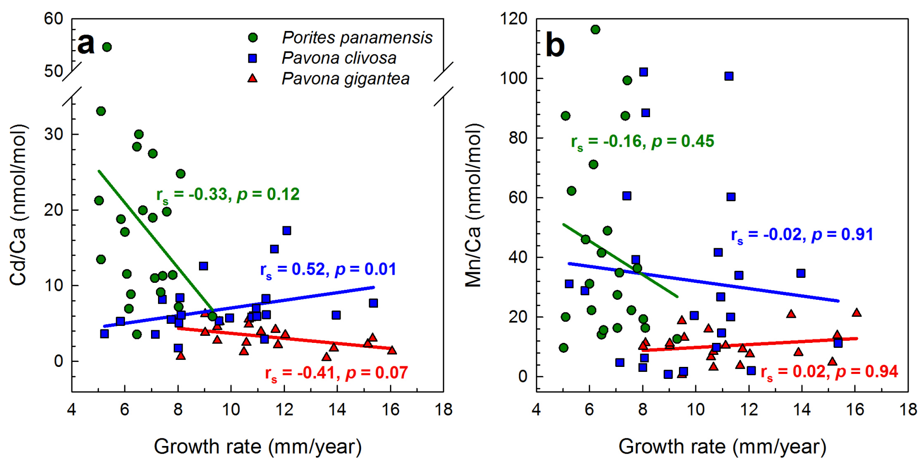

SST COADS (23°N,109°W)
SST anomaly El Niño 3.4 region
SST anomaly (°C)
El Niño
La Niña
3
2
1
0
-1
-2
-3
1965
1970
1975
1980
1985
1990
Calendar Year

Fig. 2.



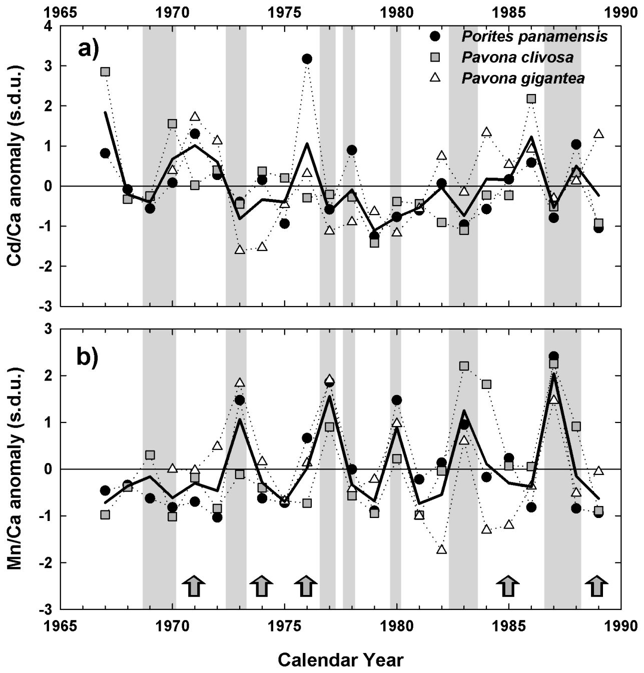
a)
b)
Porites panamensis
Pavona clivosa
Pavona gigantea
Cd/Ca (nmol/mol)
Mn/Ca (nmol/mol)
Calendar Year

Fig. 3.



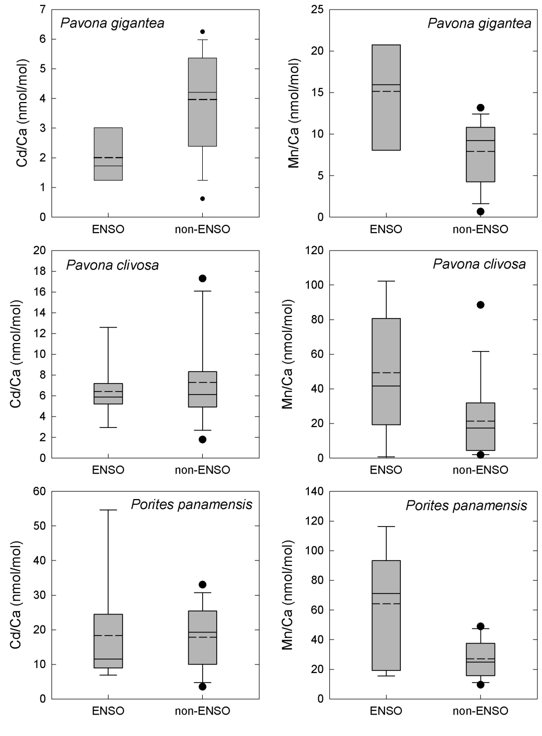
a
b
Porites panamensis
Pavona clivosa
Pavona gigantea
rs = -0.33, p = 0.12
rs = 0.52, p = 0.01
rs = -0.41, p = 0.07
rs = -0.16, p = 0.45
rs = -0.02, p = 0.91
rs = 0.02, p = 0.94
Cd/Ca (nmol/mol)
Mn/Ca (nmol/mol)
Growth rate (mm/year)

Fig. 4.



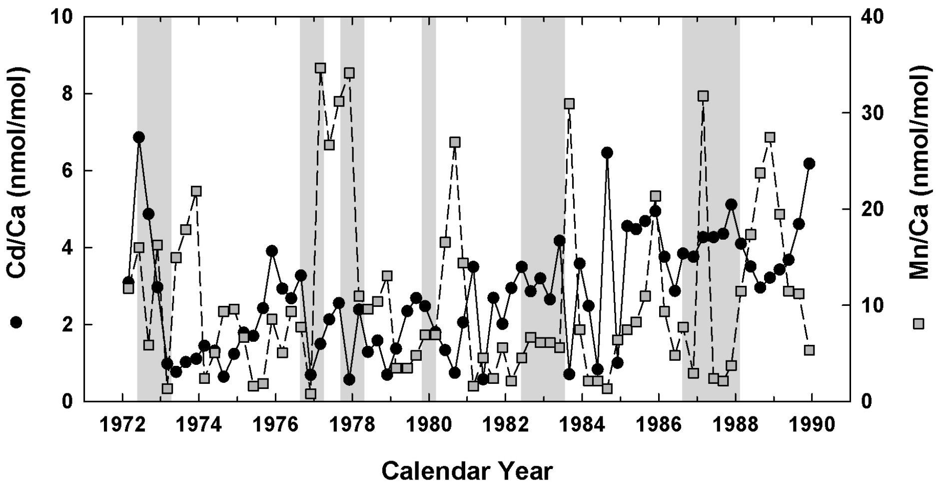
a)
b)
Porites panamensis
Pavona clivosa
Pavona gigantea
Cd/Ca anomaly (s.d.u.)
Mn/Ca anomaly (s.d.u.)
Calendar Year

Fig. 5.



Pavona gigantea
Pavona clivosa
Porites panamensis
Cd/Ca (nmol/mol)
Mn/Ca (nmol/mol)
ENSO
non-ENSO

Fig. 6.



10
8
6
4
2
0
Cd/Ca (nmol/mol)
40
30
20
10
0
Mn/Ca (nmol/mol)
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Calendar Year

Fig. 7.