DEVELOPMENTAL STAGES OF BIANQUIZAL DUE TO HERBIVORY BY THE SEA URCHIN *DIADEMA ANTILLARUM* PHILIPPI (ECHINOIDEA: DIADEMATIDAE) IN THE CANARY ISLANDS

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With 3 figures

ABSTRACT. In the Canary islands the populations of the sea urchin *Diadema antillarum* PHILIPPI 1845 (ECHINOIDEA: DIADEMATIDAE) have experienced a great increase in density and distribution. This herbivore has transformad large rocky areas previously covered by photophillous algae into what is called "blanquizal" (iso-yake in the japanese literatura), areas characterised by complete lack of algae and major changes in community structure. In this study the samping stations were located around the island of Gran Canaria and in the islets North of Lanzarote. Density of the benthic invertebrate species and sizes of *D. antillarum* specimens were measured.

The transformation process into blanquizal is progressive, and by use of a set of quantitative parameters, listed below, is ¡t possible to differentiate successive phases. The primary production decreases from 1-4 $gCm^{-2}d^{-1}$ in algal covered areas to almost zero. The changes in density of *D. antillarum* describe an asymptotic curve starting at less than 0.01 ind/m^{-2} and stabihsing at about 15 ind/m^{-2}. The populations of this sea urchin experience a change in mean sizes (diameter of the test) related to food competition. When the food becomes limited, mean size decreases. In low density populations, 90% of sea urchins have a diameter > 5.5 cm, whereas in mature blanquizales the mean size only reaches sizes of 3.5-5.5 cm. Biodiversity also decreases during the development of the blanquizal, but in the last stages the diversity can increase somewhat due to the establishment of new trophic relations in the mature blanquizal.

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INTRODUCTION

The rocky subtidal ecosystems of the Canary Islands are characterised by a zone of photosynthetic algae, which in some places extends to a depth of more than 30 m. This algal band sustains a very rich and diverse fauna in spite of the ofigotrophic character ofthe surrounding waters (GIIL RODRIGUEZ *el al.,* 1992).

However, these ecosystems in many places at the Canary Islands have changed into so-called "blanquizales" (PEREZ SANCHEZ & MORENO BATET, 1991), characterised by a severe reduction or a complete eliminatio of the algal cover, as a result of high densities of the herbivorous sea urchin *Diadema antillarum* PHILIPPI, 1845 (ECHINOIDEA; DIADEMATIDAE) (CARRIILO M., CRUZ T. 1992). The over-exploitation of coastal fisheries resources has resulted in the removal of natural predators and a modification of the competition conditions, favouring the fast growth of the long-spined sea urchin populations. The densities of *D. antillarum* may reach more than 10 ind/m^{-2} in the blanquizal area (also called in the literature with the japanese term iso-yake), like in some places in the caribbean before mass mortality (LESSIOS, 1988).

lt is possible to distinguish several successional stages in the transformation from an initial stage, with an abundant algal cover to a final stage with a barren ground. These successional stages can be describes by some quantitative parameters. Until now, no experimental infonnation exists concerning the grazing effects of *D. antillarum* on the coastline of West Africa (JOHN *et al,* 1992).

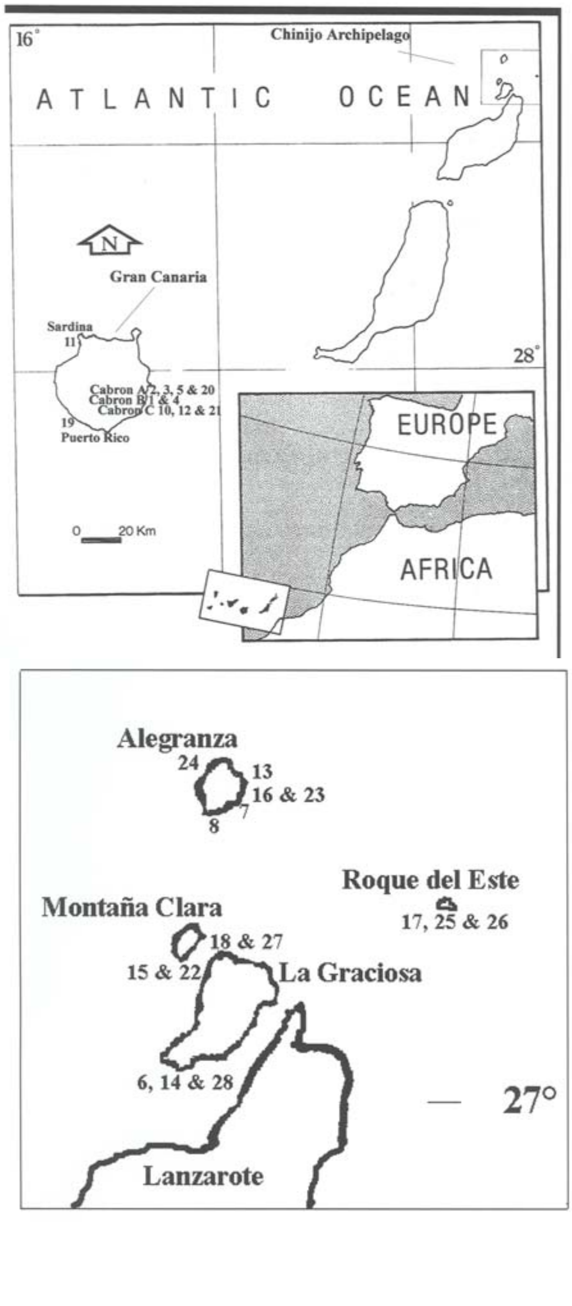
The main objective of this contiibution is to characterise the structure of *D. antíllarum* populations at severas locations of the Canary Islands. In each station, several parameters were measured, as the density of each invertebrate species, and sizes classes of *D. antillarum.* In adittion, an analysis of one station where all *Diadema* specimens have been removed (Cabrón A) is included.

MATERIALAND METHODS

The sampled stations are located at Gran Canaña Island (Sardina, Puerto Rico and El Cabrón), and in the islets of the Chinijo Archipelago (La Graciosa, Alegranza, Montaña Clara, Roque del Oeste and Roque del Este), North of Lanzarote (Fig. l).

The samples were taken at 15 m depth and data are collected in 50 m^2 (2 x 25 m) transects. In each transect the following parameters were noted: the presence and the number of all non-sesile macroinvertebrate species and the percent of algal cover. *D. antillarum* specimens were grouped into four size classes depending on the horizontal diameter of the test (class I< l. 5 cm.; class II between l. 5 and 3.5cm.; class III between 3.5 and 5.5 cm. and class IV> 5.5 cm).

Based on the number of individuals of each specie, the following parameters were calculated for each station: the Shannon-Weaver Diversity Index (H = - $p_i log_2 p_i$) (MARGALEF, 1991); density and the percent of *D. antillarum* related to the total number ofindividuals of all invertebrate species in each sample, as well as size distribution of *D. antillarum.*



a

b

Fig. 1 - Geographic location of the sampled stations in the Canary Islands. Fig. 1a - Gran Canaria Island (Sardina, El Cabrón and Puerto Rico stations); Fig. 1b - Chinijo Archipelago (Alegranza, Montaña Clara, La Graciosa and Roque del Este stations). The station's number correspond to those shown in Fig. 3.

Pearson correlation coefficient (MARGALEF, 199 l) between the different stations, and a Cluster analysis method using an Average Linkage (between-groups) with the SPSS statistical software program were calculated (SACH, 1992).

RESULTS

Biodiversity, density and percentage of *D. antillarum* related to the total number of invertebrates obtained in the different sampled stations are shown in Fig. 2. The stations are shown in the same order as obtained in the cluster analysis. The dendrogran shown in Fig. 3 presented the distances between the different stations.

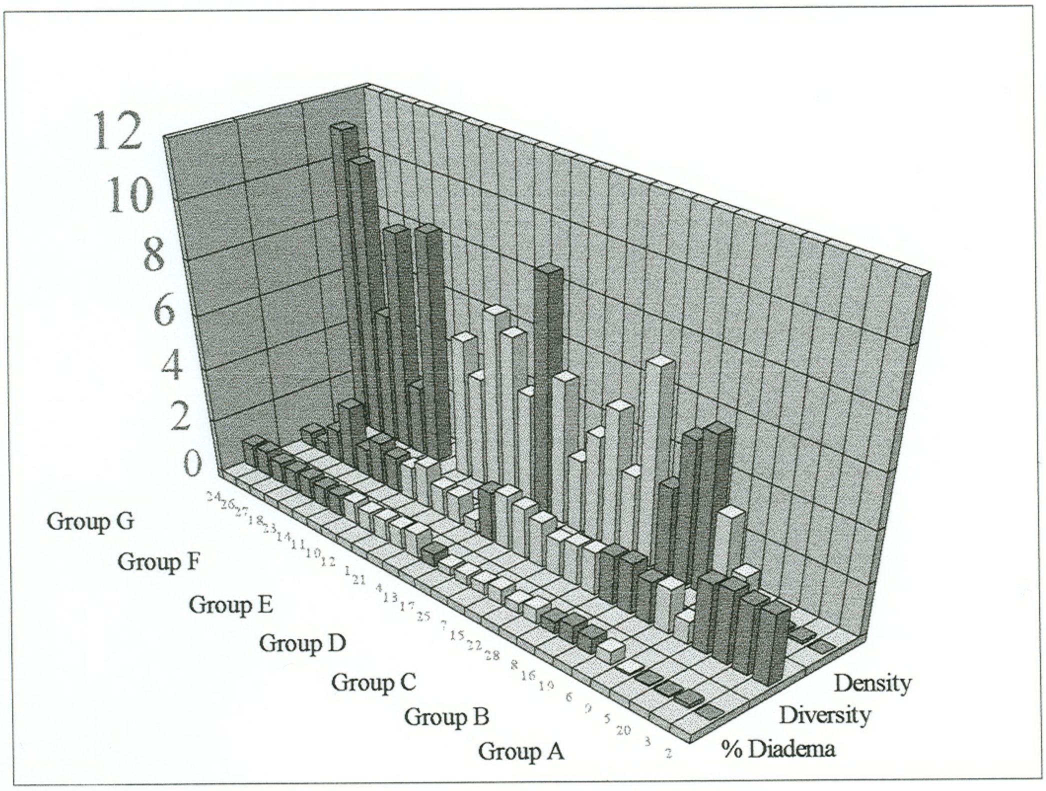


Fig. 2 - Biological parameters of the *D. antillarum* populations in sampled stations: Relative Percent of *D. antillarum* (0-1 scale, which is equivalent to 0-100 %), Shannon-Weaver Diversity Index, and density of *D. antillarum* (ind/m^2). The stations are repesented in the same order as obtained in the cluster analysis (Fig. 3).

From this analysis, we could observe that in the bottom of the dendrogram there is a first group (group A) of four stations which is separated from all the others, corresponding with the transects done on the stations were *D. antillarum* was eliminated (Cabrón A). Almost no *Diadema* were observed and the algae cover was the highest of all sampled stations.

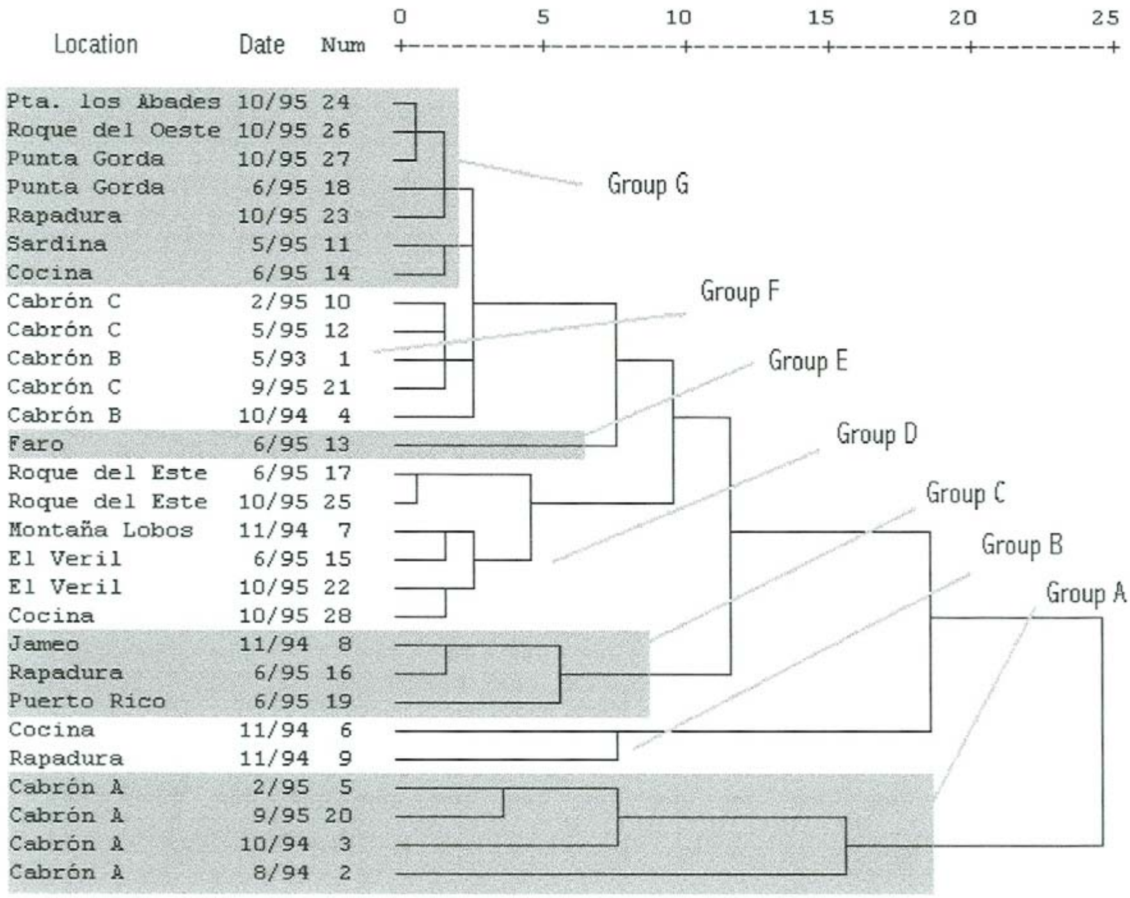


Fig. 3 - Dendrogram of the Cluster Analysis, with isolation of the different stages (A – G groups) in the blanquizal development.

The group B, with two stations, corresponds to La Rapadura (South of Alegranza), and La Cocina (South of La Graciosa). The distance to the other stations is due to the exaggerated number of small moluscs of the genus *Jujubinus,* that were the quantitative dominant species of the ecosystem while in the rest of the stations *Diadema antíllarum* is the most common species. The abundant sand observed on these stations during the sampling period, could favour the presence of these gastropods. In both stations the density of *D. antillarum* is less than 3 ind/m^{-2}.

In group C we have three stations, one in Puerto Rico (SW of Gran Canary), another in La Rapadura (E of Alegranza) (sampled 7 months later, and without sand on blanquizal and without *Jujubinus*), and another one near El Jameo (S of Alegranza). These three zones have some common characteristics. The indices of diversity are similar and relatively high; the proportion of *D. antillarum* is not very high, with densities between 4 and 6 ind/ m^{-2}, and with a prevalence of the size class IV. This size distribution is typical of stages of not very advanced transformation into blanquizal. In Gran Canaria, the predominant size of *Diadema* in blanquizales is size III, and there is no vegetation.

The forth grouping in the clustering (group D) consists of six stations with similar characteristics: lower diversity values, medium proportions of *D. antillarum* compared o the total number of invertebrates, and densities between 3 and 7 ind/m^{-2}. The percentage of individuals of size class IV is higher than 90 % in all the stations, which is a typical characteristic of populations in growth, without competition for the food.

Finally, we have the stations with highest densities of *D. antillarum* and lowest diversity index, which can be considered as mature blanquizales. Two groups can be differentiated: group F, that correspond to the stations at Gran Canaria island with prevalence of the size class III and 0 % of algal cover, which are the most mature blanquizales (climax stage); and group G, with the stations located on the islets N of Lanzarote, where there is total dominance of the size class IV, but still with abundant vegetation with small blanquizal clearings, indicating a less advanced state. However, within this clearings, densities of *D. antillarum* are higher than those registered in the most mature blanquizales, which is due to the way this species colonise new areas.

DISCUSSION

The colonisation of a new area by *D. antillarum* begins with a small clearing in the algal vegetation, usually in places with caves or holes where the sea urchins are better protected. In these clearings of only a few square meters, as in some stations on the Chinijo Archipelago (cluster group G), *D. antillarum* can reach very high densities, resulting in total elimination of the vegetation. The border between the zone with algae and the naked rock is clearly defined. When the sea is calm, the sea urchins leave their refuges in order to feed on the algal border, thereby extending the clearings. Finally, all the naked areas unite to form more extensive blanquizal areas. Only the shallowest areas may have an algal cover, because the wave action here excludes *D. antillarum.* This outlined process may explain the progressive extension of blanquizal areas along the canarian coastlines.

The mean size of *D. antillarum* population experiences changes related with feeding competition. In the first developmental stages, when there is an abundant algae cover, size class IV is the most common (group G). When the food becomes scarce, the growth rate of the population diminishes, and thereby the sea urchins experience negative growth reducing their test diameter and as a consequence, the total biomass. In this stage, they maintain a lower somatic metabolism allowing them to direct part of their energy intake toward reproductive functions (LEVITAN 1988). In stations without intraspecific competition for food, more than 90 % of the individuals in the population have a test diameter bigger than 5.5 cm. The size class proportions vary when food becomes a limiting factor. At the end, when the algal cover is eliminated the sea urchins can only feed on a thin layer of growing algae, and as consequence more than 95% of the individuals of the population belong to class size III, which indicates a state of mature blanquizal. Thereby the benthic primary productivity of these ecosystems is reduced graduafly until is practically undetectable, affecting the biology of all benthic species whose food chains develop from these algae.

Diadema antillarum experiences an asyrnptotic growth in density along this process, until it stabilise on a leves that depends on the energy that the system can offer to maintain sea urchin biomass. As we can see, this value is lower in Puerto Rico (SW Gran Canaria) than in other mature blanquizales. The primary production in the latter station seems to be lower than in the other studied areas.

The biodiversity also decrease significantly along the evolution of the blanquizal, due to the quantitative dominance of one species. Although when the ecosystem has reach a mature stage, this diversity could show slight increases probably due to the establishment of new trophic relationships in the benthic community.

Conclusions

The evolution of Blaquizal area from one developmental stage to the next is a progressive process, which does not only depend on biological factors such as absence of predators, but also on non-biological factors as for example the hydrodynamics of the zone. In the exposed areas, other sea urchin species are better adapted, whereas *D. anfillarum* populations are restricted to deeper areas or to more protected waters.

The combined use of the following parameters: diversity, density an class size, from any D. *antillarum* population could be used to estimate the development stage of the ecosystem and to forecast how and with which speed it will evolve. This method will be used to cartograph the successional stages of the blanquizales in the shallow subtidal ecosystems of the Canary Islands.

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