CORAL REEFS OF GORGONA ISLAND, COLOMBIA, WITH SPECIAL REFERENCE TO CORALLIVORES AND THEIR INFLUENCE ON COMMUNITY STRUCTURE AND REEF DEVELOPMENT

By
PETER W. GLYNN, HENRY VON PRAHL AND FELIPE GUHLM

RESUMEN

Este estudio presenta un breve resumen de la estructura y distribución de los arrecifes coralinos de la Isla de Gorgona. Se investigaron los organismos corallívoros, comparándolos con los de otras localidades del Pacífico Americano; de esta forma se establece un criterio, para conocer las diferencias regionales y las interacciones bióticas sobre las diferentes comunidades coralinas.

La Isla de Gorgona se localiza hacia el extremo sur de la provincia de Panamá (Panamá Bight), distante unos 30 km de la franja costera aluvial, lo que la aleja considerablemente del efecto directo de afloramientos y derrames de agua dulce, provenientes de los ríos costeros.

El equinodermo asteroideo, Acanthaster, que es uno de los corallívoros que más estragos causa en las comunidades coralinas del Pacífico, no se ha detectado en la Isla de Gorgona. La ausencia de Acanthaster, parece estar determinada por un frente de baja salinidad que se forma hacia la región norte del Pacífico colombiano y que seguramente impide, con sus condiciones desfavorables la migración de las formas larvales de esta estrella. Las formaciones coralinas de Gorgona, corresponden a arrecifes verdaderos, los cuales presentan un gran desarrollo en la franja costera de Sotavento (costa oriental), aunque en la franja costera de Barlovento (occidental), también aparecen formaciones. El arrecife de La Azufra es el más extenso y mide aproximadamente 1000 m de largo, por 150 m de ancho y unos 8 m de espesor. En este arrecife, las masas de corales vivos se presentan hasta unos 15 m de profundidad. La cresta y demás zonas altas del arrecife están dominadas por corales del género Pocillopora mientras que los flancos y hacia el borde expuesto al mar, se presentan otras formas, generalmente masivas.

Entre los organismos corallívoros de Gorgona, hay que destacar a los “tamboreros” y a un gasterópodo de la familia Ovulidae. De los corallívoros conocidos en otros lugares, tenemos que notar en el bajo número de cangrejos ermitaños corallívoros, lo mismo que del erizo Euclidaris, el cual se encontró en la isla, pero no comiendo corales. Los daños causados por un pez de la familia Pomacentridae en los corales masivos son considerables y hacen que sobre las zonas afectadas se fijen algas bentónicas, las cuales afectan considerablemente el desarrollo de los corales, especialmente hacia las zonas poco profundas del arrecife.
Al comparar la estructura arrecifal de Gorgona, con arrecifes de Panamá afectados por Acanthaster, se encontró que en zonas libres de esta estrella, las colonias coralíneas diferentes de Pocillopora, como Porites, Pavona, Gardineroceris y Pocillopora (las preferidas por este coralívore), son mucho más abundantes.

SUMMARY

This study offers an overview of the distribution and structure of coral reefs and coral communities at Gorgona Island, off the Pacific coast of Colombia. Biotic interactions, mainly the effects of coralivores, are examined and compared with coral communities elsewhere in the eastern Pacific in order to provide a basis for understanding regional differences in community structure.

Located at the south end of the Panamá Bight and ca. 30 km offshore, Gorgona is largely removed from the influence of upwelling and freshwater dilution. The key coralivore Acanthaster, which is widely distributed in the tropical eastern Pacific, is absent from Gorgona, probably a result of unfavorable physical conditions (low temperatures and low salinites) for larval development in the Panamá Bight area. True fringing coral reefs are present at Gorgona and are best developed on the eastern or leeward side, but they also occur in one area on the western and exposed side of the island. The La Azufraida reef, the largest of the fringing reefs, was about 1 km long and 150 m wide, had a minimum thickness of 8 m and supported live corals to a depth of 15 m. Pocilloporid corals predominated on the reef crest and upper to mid forereef slope, and massive and small species increased in relative abundance in the deep forereef and sand plain zones.

A coralivorous pufferfish and ovulid gastropod were abundant, but other known coralivores (e.g., Acanthaster, hermit crabs and Eucidaria) were either absent, un-common or not feeding on live coral. Damage inflicted on live massive colonies by a damselfish, in order to "farm" algae, could play an important role in altering the relative abundances of corals in shallow reef zones. A comparison of coral reefs at Gorgona and Panamá, in areas with and without Acanthaster, show that nonpocilloporid corals, which are preferred prey items, have a higher relative abundance on reefs where the predatory sea star is absent.

INTRODUCTION

Information on the nature of coral reef communities at Gorgona Island is of interest because this area lies near the southernmost limit of coral reef development in the eastern Pacific region. Gorgona’s geographic position (Fig. 1), at the south end of the Panamá Bight, places the island (including Gorgonilla Islet and associated rocks) beyond the influence of the strong upwelling system in the Gulf of Panamá (ABBOTT, 1966; FORSBERGH, 1969; GLYNN, 1974). Gorgona Island is also far enough north and east to avoid the cool coastal Perú Current system which moves away (in a westerly direction) from continental South América in the vicinity of Cabo Blanco (ca. 4°S), Perú. Thus, although the Gorgona area lies within the tropical Panamic Province, it is to some extent bounded north and south by marginally tropical conditions.

While the coral communities of Gorgona are diverse and relatively mature compared with other eastern Pacific areas (PRAHL et al., 1979), some species present elsewhere are notably absent from Gorgona (GLYNN et al., 1972). One of these, a key coralivore, is the crown-of-thorns sea star Acanthaster planci (Linnaeus). This study focuses on the ecology
Figure 1. Location of Gorgona Island off the SW Colombian coast and in relation to the Panamá Bight area. From chart number 22050, Cabo Corrientes to Isla Gorgona, 2nd ed., April 7, 1979, Defense Mapping Agency, Washington, D.C.
Figure 2. Distribution of coral reefs at Gorgona Island. Base map courtesy Instituto Geográfico “Agustín Codazzi”, Bogotá (1959), scale 1: 7,700. El Viudo and some rocks and shoals present on the base map but not confirmed in our survey were omitted. Coral communities illustrated in Prahl et al. (1979), are also shown here in relation to coral framework development.
of the Gorgona coral formations, especially that aspect dealing with the effects of corallivores on coral community structure and reef growth. The field work was carried out under the auspices of the Sula III Expedition which permitted an intensive study of Gorgona over the period 18-23 May 1979.

Until the recent work of Prahl et al. (1979), the coral formations and reefs of Gorgona were only incompletely known (see Crossland, 1927; Murphy, 1939; Abbott & Evans, 1968; Cosel, 1977). Prahl and co-workers published the first detailed information on the distribution and structure of Gorgona reefs. They further considered the effects of thermal conditions, sedimentation, and corallivores on the distribution and growth of corals. The present study is an attempt to extend and amplify the latter work. Here we reexamine and slightly amend the distributional patterns of coral reefs at Gorgona. Reef morphology is examined and preliminary results of reef probing are presented as an indication of reef frame thickness. Coral zonation and community structure (relative abundance, live coral cover and diversity) are also considered and new sampling data are presented to assess the abundance of corallivore populations. These results will serve as a basis for comparing Gorgona coral communities with other areas in the eastern Pacific region. A comparison that will receive special attention involves coral communities free of Acanthaster (Gorgona and the Gulf of Panamá) with reefs where the effects of Acanthaster have been monitored for several years (Gulf of Chiriquí, western Panamá).

MATERIALS AND METHODS

An aerial reconnaissance of the shallow shelves of Gorgona and Gorgonilla islands was carried out on 28 March 1975 between 1030-1130 aboard a light, fixed-wing aircraft. Color photographs taken at an angle of approximately 45°, employing a polaroid filter to reduce glare, were obtained of the entire island shores at an elevation of 760 m. The flight was timed to coincide with the dry season (cloud cover was about 10%) and an extreme low stand of the tide. Coral reef formations were sketched on a large-scale map (Fig. 2) of the Gorgona Island group based on the aerial photographs and information obtained from in situ inspection.

Coral abundance was measured with a chain transect 10 m in length and containing 78 links per meter (Porter, 1972; Glynn, 1976). The location of the first sampling site at Gorgona (on the La Azufrada fringing reef) was selected blindly from the surface along the deep reef edge. Additional sites were measured at 8 m intervals toward the lee or shoreward side of the reef. The chain was laid out in a straight line, parallel with the isobath, so as to conform with the bottom irregularities, that is, with all links in contact with the substrate. Sampling in Panamá was carried out on a fringing reef (here named Secas-W) located on the south side of the largest, SW-most island in the Secas group, Gulf of Chiriquí (see Glynn et al., 1972, Fig. 1, p. 490 for
exact location) on 16 January 1980. Here two transects were obtained at each of five sites, from near shore (3.7 m) to the deep reef edge (10.7 m). Sampling sites were spaced at 30 m intervals, beginning about 10 m seaward from the inshore edge of the reef frame. Coral species diversity ($H'$) was calculated from the Shannon-Wiener measure of mean diversity per individual (PIELOU, 1969) with each chain link contact enumerated as a datum. The table of functions in Lloyd et al. (1968), with conversion to logarithms to base 2, was used for ease of calculation. Species evenness $J'$ or relative diversity was calculated from PIELOU's (1969) measure $H'/H'_\text{max}$. LOYA (1972) has offered empirical justification for use of the $H'$ diversity measure in coral communities.

Sections of iron pipe were driven into the reef frame (see GLYNN & MACINTYRE, 1977) in order to determine reef thickness.

Corallivorous fish were censused by swimming along measured transects running perpendicular to the reef face. The area and time period sampled were noted for each census. The abundances of invertebrate corallivores were sampled with 0.25 m$^2$ wire-frame quadrats. All coral inside each quadrat was inspected in situ and broken apart when necessary. The initial sampling site was selected blindly by dropping a quadrat from the surface above the deep reef base. Three zones, the reef base (5 quadrats), slope (7 quadrats) and reef flat (6 quadrats), were sampled. Subsequent quadrat sites within zones were selected by moving 2 m horizontally in the same direction along the reef. Sampling sites between zones were located by moving straight up the reef face from the last quadrat site in the deeper zone.

All coral species were collected (with the exception of Porites lobata) and voucher specimens deposited in the collections of the Departamento de Biología, Universidad de los Andes, Bogotá. The following are the scleractinian corals observed at Gorgona Island during this study. Detailed description of the species are presented by Von Prahl & Guhl (1981).

Pocillopora damicornis (Linnaeus), the variety often called caespitosa, i.e., P. damicornis var. caespitosa Dana, was also observed. Pocillopora capitata Verrill; P. danae Verrill; P. elegans Dana; P. eydouxi Milne-Edwards & Haime; Psammocora (Stephanaria) stellata Verrill; Porites panamensis Verrill; P. lobata Dana, large colonies were observed, but not collected, in the Banco del Horno area near Punta Coll. Pavona varians Verrill; P. clavus Dana; P. gigantea Verrill; Gardineroseris planulata (Dana); Cycloseris elegans (Verrill); only a single, beath-worn specimen was found, and Tubastrea coccinea Lesson, an ahermatypic species.

OCEANOGRAPHY OF THE GORGONA AREA

Three oceanographic areas, Panamá Bight, equatorial front, and Perú Current, have been recognized in the coastal waters of the eastern
Figure 3. Aerial view of La Azufrada fringing reef (760 m, 28 March 1971). A small section of the south end of reef is not shown. Note clearing in forest near center top of photograph. Arrows indicate locations of probe holes 1-3 and crater-like depression.

Figure 4. Aerial view of Playa Blanca fringing reef (760 m, 28 March 1971). A small section of the south end of reef is not shown. The southern one-third of a smaller fringing reef is visible to the north of Playa Blanca. Note narrow zone of forest clearings above beach.
Pacific from Panamá south to Perú (Stevenson et al., 1970). The Panamá Bight area, characterized by warm surface water of low salinity, extends from the 81° W meridian east to the coast and from the entrance of the Gulf of Panamá (7.5° N) south to Punta Galera (1° N), Ecuador (Fig. 1). The strong upwelling system in the Gulf of Panamá, regarded here as an extension of the Panamá Bight, is centered between about 7.5° N and 9° N (Smyda, 1966). The equatorial front area, an abrupt transitional region between the tropical water of the bight and the cool saline water of the Perú Current system, lies between Punta Galera and Cabo Blanco (ca. 4° S), Perú. Thermal gradients of 5° C to 6° C per degree of latitude, and over short distances as much as 0.3° C per 1.6 km of latitude, have been observed in this area (Stevenson et al., 1970). The Perú Current area extends as far as 17° S. Gorgona Island (2° 58' N; 78° 11' W) is located in the southern half of the Panamá Bight area (Fig. 1). The Gorgona group is situated near the edge of the continental shelf and about 30 km off the mainland, a predominantly mangrove-fringed coast in this region (West, 1957). Gorgona Island, consisting chiefly of basic rock formations that are most likely late Upper Eocene in age (Gansser, 1950), is a relic of the Coastal Cordillera which extends north-south from the mainland of Cabo Corrientes, Colombia to near Esmeraldas, Ecuador (Gansser, 1950; Oppenheim, 1952).

Circulation of surface water within the bight is cyclonic, flowing counterclockwise (Forster, 1969; Stevenson et al., 1970). Water moving past Gorgona largely derives from the eastward branch of the bight circulation system and thus flows predominantly northward (NNE). Current velocities in the dry season (December to April) and also during mid to late wet season (August to November) are higher in this area (150 cm/sec. or 3 knots) than in the early wet season, from May to June (50 cm/sec. or 1 knot) (Stevenson et al., 1970). At times currents also move toward the west (Stevenson et al., 1970) or the east (Wyrck, 1965). [Murphy (1939) noted that Antonio de Alcedo, a historian, asserted that Gorgona was named after the character of the currents surrounding the island. Evidently the occasionally strong easterly set of currents, and calm spells, rendered passage very tedious; this condition was described at the time by the term engorgonarse, meaning to be engulfed]. From about May through December, the Equatorial Countercurrent flows east between 4° N and 11° N, thereby entering to some extent the circulation system of the bight (Wyrck, 1965). Also, the northerly flowing coastal current, the so-called Colombia Current (Wooster, 1959), eventually mixes with water in the Gulf of Panamá.

A thermal dome typically forms near the center of the Panamá Bight from January through March at the height of the dry season. Surface temperatures at this time are 25° C to 26° C, the lowest of the year. During the dry season in the Gulf of Panamá, however, surface temperatures are commonly 20° C to 24° C and occasionally drop to 16° C to 18° C locally (Glynn & Steward, 1973; Glynn, unpub-
lished observations). The cooler conditions associated with the upwelling system in the Gulf of Panamá do not appear to penetrate significantly into the Panamá Bight (Wooster, 1959).

Temperature observations over three dry seasons (1964 through 1966) showed 26°C, 27°C and 28°C surface isotherms surrounding Gorgona Island (Stevenson et al., 1970). Thus it does not appear that Gorgona experiences incursions of cool water from the north. It is possible that some water exchange occurs across the frontal boundary, but the amount involved and the extent of modification are presently unknown. Perhaps the 18.7°C temperature reported on the west coast of Gorgona (Prahl et al., 1979) was related to a narrow, northward-flowing coastal current that is sometimes observed in this area from April to June (Stevenson et al., 1970).

Salinities in the Panamá Bight often vary from 33.5‰ offshore to less than 20‰ near the Colombian coast (Forsbergh, 1969). Dry season surfacing of water in the central bight increases surface salinities slightly, to 34‰. Low coastal salinities are due to the influence of the Intertropical Convergence Zone in this region resulting in high annual rainfall, ranging between 4000 mm to more than 7500 mm (Forsbergh, 1969), and a large runoff. Salinities slightly offshore near Gorgona ranged between 31‰ and 33‰ from February 1964 to March 1966, differing little between seasons (Stevenson et al., 1970). Apparently the strong NNE currents at Gorgona, originating to a large extent offshore, are responsible for the stable salinity and usually clear

Figure 5. Aerial view of fringing reef (arrow) and linear ridges (lower left corner) immediately south of La Camaronera beach, west shore of Gorgona Island (760 m, 28 March 1975).
water close to the coast. Turbid water conditions resulting from run-off (producing suspended sediments and increased plankton productivity) seem to occur more frequently in the coral reef area of Chiriquí, Panamá (Dana, 1975) than at Gorgona.

Tides at Gorgona are of the semidiurnal type with the daily high and low waters varying little in height or duration of rise and fall (U.S. Dept. Comm., 1979). The maximum range is about 5 m. The extreme low water exposures (to - 0.64 m) occur during the dry season at midday, from January until about mid-April. The average monthly rainfall in the dry season, falling mainly in the afternoon (Prahl et al., 1979), ranges between 0.3 and 0.5 m. A second and somewhat less extreme set of midday tidal exposures (to - 0.55 m) occurs from August through December. This is during the height of the wet season when average monthly precipitation ranges between 0.6 and 0.9 m. The range and seasonal diel patterns of the tides at Gorgona are remarkably similar to those in Panamá, especially in the Gulf of Chiriquí. The large tracts of dead coral (principally Pocillopora) on the emergent sections of the reef flat suggest that tide-related mortality occurs at Gorgona as in Panamá (Glynn, 1976).

DISTRIBUTION OF CORAL REEFS

Our findings generally confirm the pattern of coral reef distribution presented in Prahl et al. (1979). Coral communities and pocilloporid reefs were present primarily along the east side of Gorgona and in the shallow channel between Gorgona and Gorgonilla (Fig. 2). The chief differences revealed by the aerial survey and in situ inspection involve three modifications to the earlier scheme. First, while coral communities were again observed from La Boca del Horno south to off the front of the prison, along the east side of Gorgona, no significant reef framework was found in this area. The Azufrada reef also proved to be slightly larger than the reef at Playa Blanca. The Azufrada reef was longer (ca. 1 km) and broader (ca. 150 m) than the Playa Blanca reef which measured approximately 0.8 km in length and 100 m in width (contrast Figs. 3 and 4). Finally, coral reefs and numerous incipient reef formations were observed on the rocky headland between the sand beach of La Camaronera and Puesto de Gorgonilla on the west coast of Gorgona. Reef development in this area was of two forms. The most coherent formations consisted of a closely packed intermeshing framework of Pocillopora spp., which appeared to rest on a basaltic base that abutted directly against the shore. According to Ganssler (1950) this section of the coast is a mountain slide lying adjacent to an inland and predominantly undifferentiated diabase-gabbro rock formation. These reefs were present at shallow depths (1 to 4 m) in the zone of strongest wave action (Fig. 5). Inspection of the fringing reefs at low water showed incipient reef-frame development in tide pools and basins receiving adequate circulation. Linear pocilloporid buildups or spurs and hillocks of various sizes were also present 100 to 200 m seaward of the fringing reefs (Fig. 5). The linear ridges were oriented parallel (or nearly so) to the prevail-