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Coral Reefs of Dominica (Lesser Antilles)

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Abstract

Systematic investigations on corals reefs of Dominica began in 1999 with the establishment of the Institute for Tropical Marine Ecology on the island. Taking into account the geological and oceanographically traits of this volcanic island, and its history of marine investigation, this report summarizes data on the distribution and morphology of reefs and coral assemblages, based on studies carried out between 1999 and 2013. It is an island-encompassing account, describing 31 coral reefs and 27 coral assemblages, including 46 species of stony corals (Scelarctinia, Anthozoa) and 4 species of hydrocorals (Anthothecata, Hydrozoa). The present condition of Dominica's reefs is discussed in view of historic resource uses and the current exposure to

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sediment inputs, solid waste, effluents, fisheries and tourism. Perpetuated misconceptions on the location and size of the island's reefs are depicted and guidelines for their preservation are outlined.

Keywords: coral reefs, Dominica, Sclecartinia, Anthothecata, Caribbean

Zusammenfassung

Die systematische Erforschung der Korallenriffe von Dominica begann 1999 mit der Gründung des Instituts für Tropische Meeresökologie auf der Insel. Unter Berücksichtigung geologischer und ozeanographischer Eigenheiten dieser Vulkaninsel und ihrer meeresbiologischen Erforschung, vereint dieser Bericht Daten über die Verbreitung und Morphologie der Riffe und Korallenvorkommen. Er bezieht sich dabei auf Studien die zwischen 1999 und 2013 ausgeführt wurden. Diese inselumfassende Beschreibung dokumentiert 31 Korallenriffe und 27 nicht-riffbildende Korallenvorkommen, welche 46 Steinkorallenarten (Scelarctinia, Anthozoa) und 4 Hydrokorallenarten (Anthothecata, Hydrozoa) enthalten. Der aktuelle Zustand der Riffe Dominicas wird im Rahmen ihrer historischen Nutzung besprochen, sowie der andauernden Einwirkung von Sedimentzufuhr, Müllablagerungen und Abwässern. Darüber hinaus werden die Folgen von Fischerei und Tourismus erörtert. Irrtümer über Lage und Größe der Riffe werden aufgezeigt und mögliche Richtlinien für deren Erhalt skizziert.

Introduction

Wai'tukubuli, meaning 'tall is her body', is the indigenous Kalinago name of the island that Christopher Columbus called Dominica on Sunday, November 3rd 1493. It was the first island sighted in the western Atlantic by the crew of the 17 vessels that embarked on Columbus's second voyage. One vessel sailed around the northern part of Dominica and into what is now called Prince Rupert's Bay, before rejoining the fleet, which anchored at neighboring Aichi (now Marie Galante). In reference to this excursion, the translator for accounts, Nicola Syllácio wrote, "Dominica is remarkable for the beauty of its mountains and the amenity of its verdure and must be seen to be believed." For those who have travelled and lived throughout the Caribbean, this description is still merited. Home to a variety of microclimates, distinct vegetation zones line the island's shores and drape its volcanoes, harboring a remarkable fauna and flora to this day.

The natural environments on land are fairly well documented, considering the historically difficult access to the rugged interior regions of this particularly mountainous island in the Lesser Antilles. To a certain extent, our understanding of Dominica's terrestrial habitats has become common knowledge on a local level and incorporated in environmental policies. In contrast, the island's marine habitats continue to be poorly understood, and misconceptions of its coral reefs are perpetuated amidst their rapid degradation. Contributing circumstances included the long absence of a marine research station and the challenging seas in most of the island's coastal waters; leaving Dominica's marine environments unmapped prior to the turn of the century. This situation changed in 1999 with the establishment of the Institute for Tropical Marine Ecology (ITME), bringing forth the largest wave of scientific studies on the island's sublittoral habitats to date, including coral reefs. Individual findings from these studies are scattered in journals, reports, public media records, and most of the marine environments are unknown or inaccessible to residents and visitors. Environmental awareness among Dominica's citizens and government representatives, regarding the island's coastal marine habitats, remains spotty and skewed at best, warranting a comprehensive overview of Dominica's coral reefs.

With the intent to narrow the existing information gaps, I merged studies on individual coral reefs and assemblages from 1999 to 2013, and built an island-wide composite picture of Dominica's coral resources with three principal objectives; (a) the systematic cataloguing of all known coral reefs, their location, size and condition, including the distribution of stony corals (Scleractinia) and hydrocorals (Anothoathecata), (b) the evaluation of Dominica's coral communities through a distinction between coral reefs and coral assemblages, and (c) the consideration of the natural and anthropogenic factors shaping these natural resources. Personal field notes and unpublished data from this period are an integral coalescent of the emerging big picture.

This document is put together as a site and island-specific instrument to facilitate the planning of future coral reef research projects, environmental impact assessments, and to set a baseline for resource conservation initiatives. It addresses naturalists, divers, and professionals in environmental sciences and policy, who are familiar with coral reefs and interested in their preservation in Dominica. It is not meant to review the biology and ecology of corals and reefs; information that is readily available in a multitude of books and internet resources.

Definition and delineation of coral reefs

The equivocal use of the term "coral reef" is a common obstacle in the attempt to consolidate the findings from records on the topic. Particularly in the case of Dominica, where the narrow, steep, and partly rocky sublittoral is conducive to the settlement of coral larvae, but also influenced by natural disturbance levels of terrestrial run-off and coastal surge hindering the growth of extensive coral reefs. Fuelled by the growing recreational diving industry, coral reefs have become popular and marketable environments, resulting in an unprecedented claim of concern for their conservation, and an ambiguous use of "coral reef"; referring to true coral reefs in the strictest sense, reef-like coral veneers, coral clusters or assemblages and isolated stony corals. Such equivocal terminology complicates the interpretation of national resource profiles (IRF/CCA 1991) and regional coral reef data summaries (BRUKE & MAIDENS 2004), and has led to substantial inaccuracies regarding Dominica's coral reefs.

Distinguishing between coral reefs and other types of stony coral communities may be a superfluous semantic exercise, since all these habitats have the potential for harboring and attracting organisms, which support fisheries and tourism interests. However, true coral reefs are three-dimensional structures that are built by organisms (bioherms), and marked by long-term development and growth. In Dominica they have been characterized by a greater coral diversity than other substrates bearing stony corals (STEINER 2003), yet 97.6 % of the island's coral reef area remains outside of the two marine protected areas. Although coral reefs, non-reef-building clusters of corals, and isolated coral colonies, simultaneously change under the influence of environmental stressors in the island's coastal waters, the equation of their degradation and loss is at the source of many misunderstandings.

Henceforth, the term "coral reef" refers to a structure built by calcareous organisms that are sessile (permanently attached to the ground), including colonial Scleractinia (stony corals) that are zooxanthellate (bearing endosymbiotic photoautotrophic dinoflagelates) and hermatypic (reef-building), and with visible signs of carbonate buildup. Substrates emerging from such a build-up are also referred to as biogenous hard substrates. The visible boundaries of biogenous hard substrates upon which living stony corals or their recognizable exoskeletal remains are found, render the herein reported size of each coral reef (Table 1, Fig. 19). Coral clusters that form structurally distinct surface qualities when compared to their surrounding benthos, including reef-like veneers, and without signs of reef accretion, are defined as coral assemblages (Table 2, Fig. 19). Isolated coral colonies are classified as such.

In the absence of a structural delineation of coral reefs from other habitats, the assessment of their surface area is impossible. Consequently, an evaluation of the condition of coral reefs on a scale, which is relevant to national or island-wide environmental policy, is further complicated.

Thanks to the growing recreational diving industry, SCUBA equipment has become readily obtainable and widely utilized in scientific field studies describing and quantifying coral reef resources. Ecological aspects of reef distribution, species composition and condition are commonly addressed, and rely heavily on qualitative and quantitative data. Numerous standardized methods were developed in recent decades to enhance the replicability of studies and ease the comparison of results. For regional comparisons of coral reef resources, various methods have been combined into survey protocols. The most frequently applied protocols in the Caribbean, follow the guidelines of AGRRA, the Atlantic and Gulf Rapid Reef Assessment (Kramer 2003) and CARICOMP, the Caribbean Coastal Marine Productivity Program (CARICOMP 2001, 2004). In both protocols and variations thereof, site-specific surveys are built on linear and spatial sampling units (e.g. 10 m transects and $\geq$1 m^2 quadrats) and sample sizes covering a few hundred square meters. The focus of AGRRA lies on the distribution and condition of live reef organisms (algae, invertebrates, fishes) and the benthos that they cover, while CARICOMP also assesses productivity and other communities (seagrasses, mangroves). Quantitative data are collected in a strategic manner so that dead reefs and reef tracts are avoided.

The strength of this approach lies in the characterization of reef types or zones, when geographic and oceanographic parameters (e.g. latitude, depth, currents, substrates and disturbance regimes) are taken into consideration, and for long-term monitoring purposes. However, where the surface areas of coral reefs are unknown, overestimations of benthic live coral cover are common, because neither the size of live reefs (based on the distribution limits of live colonies on carbonate substrates), nor the reefs' possible size maxima (based on visible carbonate reef boundaries) can be considered in qualifying their present condition. As a result it remains difficult to weigh the implications of quantitative results (e.g. live coral cover) on a national scale or in an island-wide evaluation of marine resources.

In order to provide a realistic outlook for the preservation of Dominica's coral reefs, this report builds on the surface areas of coral reefs, first ascertained in 2007 by Steiner & Willette (2010). The evaluation of size and condition of coral reefs among contiguous habitats, and in their exposure to disturbances are embedded in the geological and oceanographic setting, as well as past and current uses of Dominica's natural resources. I encourage the readers to keep this in mind as they explore coral reefs and assemblages along the island's coastal waters.

Geological and oceanographic setting

Dominica is a volcanic island on the eastern margin of the Caribbean Plate, where the alignment of the Lesser Antilles follows four major arcs along the fault lines from the Eocene to Oligocene, Miocene, Pliocene, and Quaternary. The three most recent have formed the island, starting with volcanic eruptions during the Miocene (BELLON 1988, SMITH et al. 1980, ROOBOL & SMITH 2005). Signs of this can be found on the island's eastern coast occupied by Miocene rocks (7–5.3 Millions of years ago: Ma). Coalesced volcanoes built up the main bulk of the island during the Pliocene (4–2 Ma). During the Pleistocene a number of volcanic centers were built over Pliocene rocks and are separated from them by an extensive saproliteratelite soil horizon caused by a long period of tropical weathering that formed about 2 Ma (ROOBOL & SMITH 2005). Raised, Pleistocene strata including sedimentary deposits, coral rubble, massive (*Montastraea* and *Orbicella*) as well as ramous (*Acropora*) corals in their natural growth positions can be seen at outcrops on the west coast at Morne Daniel and Gueule Lion, whereas raised beachfronts are visible in the upper parts of Roger (Fig. 1). Currently there are nine active subaerial volcanoes.

With an area of approximately 750 km^2 and several mountain peaks reaching over 1000 m altitude, the island is characterized by a high-relief terrestrial topography and a narrow sublittoral zone. The widest shelf is found along the northeast (Pliocene and younger Pleistocene, <1.8 Ma, Ignimbrite volcanic deposits). Considering the 50 m depth contour-line (isobath) to be the maximum potential depth limit of the majority of Dominica's modern euphotic coral reefs, regardless of other factors, sublittoral areas meeting this criterion extend up to 2.8 km off shore along the northeastern shore, between Wesley and Marigot. Only two other areas provide a moderately wide sublittoral; the southern half of Prince Rupert's Bay (Pliocene and younger Pleistocene, <1.8 Ma, Ignimbrite volcanic deposits) and the seafloor towards the west of Grande Savane (older Pleistocene, 2.0–1.8 Ma, aprons of block and ash flows including Andesite lavas, and younger Pleistocene, <1.8 Ma, Ignimbrite flows). In both cases, benthic environments in depths of 50 m or less extend up to 1.2 km from shore. Much narrower and steeper sublittoral areas characterize the rest of the island with close to vertical drop offs along some river cuts and coastal calderas. These topographic features, at tropical hurricane-prone latitudes, *dictate* the distribution and size of Dominica's sessile epibenthic communities that depend on stable substrate and light, as coral reefs do; a triviality that all too often is ignored. Mesophotic reefs with zooxanthellate corals occurring in over 100 m depth (Engelbert et al. 2014) have so far not been documented in Dominica.

The island's tidal amplitudes of less than one meter play a minor role in the distribution of its coral reefs. The only reefs partially exposed to air during spring tides are some of the fringing reefs between Anse Soldat and Woodford Hill (Fig. 2) where scattered patches of the back reefs and reef crests are affected. Oceanographic forces that significantly shape the distribution of the island's reefs include surface currents driven by the Trade Winds and impacts by storm-induced waves. The influence of the Trade Winds has led to a stark difference between the sessile communities of the eastern and southern (windward) and western (leeward) side of the island. Given the lack of a wide island shelf or wave energy dissipating structures such as barrier reefs, the windward side is marked by turbulent waters and receives the full force of Atlantic waves. With the exception of a few semi-sheltered bays, the sublittoral areas are characterized by rocky

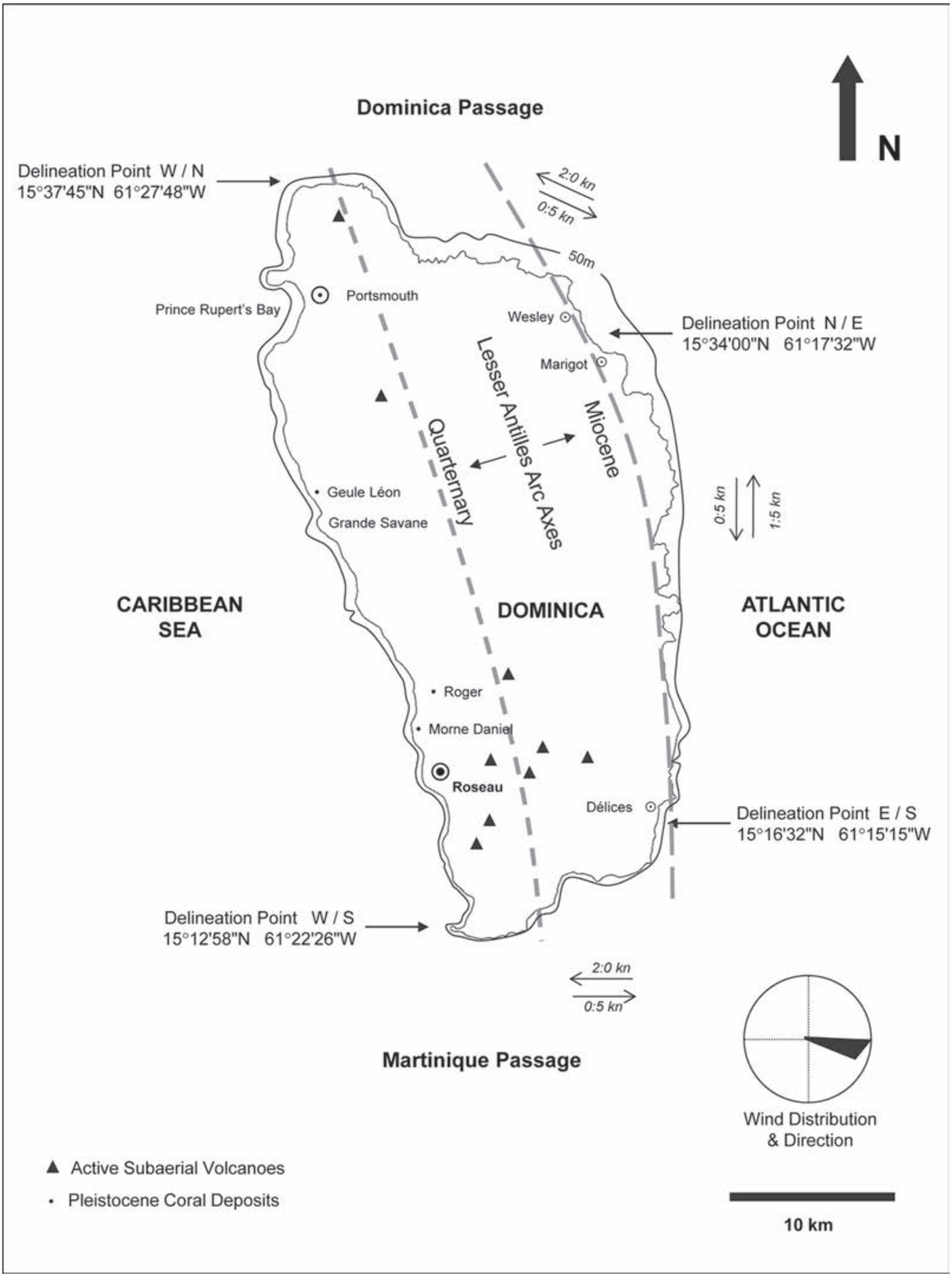

Fig. 1: Map of Dominica including the delineation points for defining the north, east, south and west coast. Dashed liens show the alignment of fault lines.

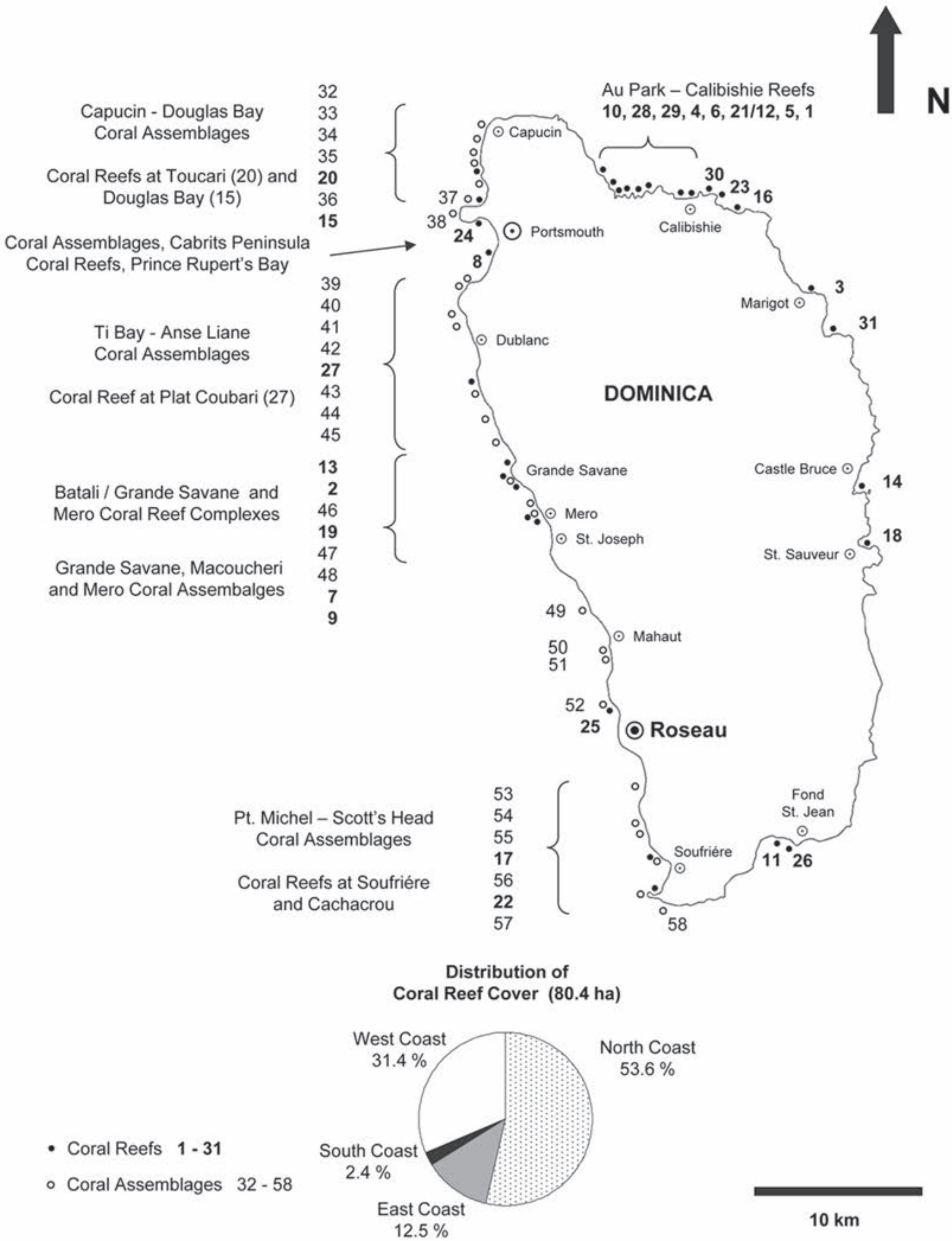

Fig. 2: Distribution of coral reefs, assemblages, and coral reef benthic cover in Dominica. Sites are numbered according to site listings in Tables 1 and 2.

substrates, lacking significant macroscopic sessile communities other than sheet-forming and encrusting organisms that include few Scelractnia and Anthothecata. At depths beyond 50 m this scenario may change and include mesphotic reefs, but such depths remain to be unexplored. In these waters, coral reefs are only found in a few small bays with north-facing sub-bays, which offer sufficient protection from the physical impact of the Atlantic. In contrast, the large reefs are established along the central regions of the calmer leeward side of Dominica, yet only in areas with the widest shelf areas, and in some of the bays along the north coast. The north coast is roughly parallel to the prevailing Trade Winds and thus has a tangential windward orientation. Reef-harboring bays face north towards the Guadeloupe Passage and are well protected from Atlantic surge.

Natural mechanic disturbances from storm-driven waves appear in distinct forms, depending on the trajectory of the storm in relation to the island. Tropical storms or hurricanes passing north of Dominica from East to West (e.g. Hurricanes Lenny in 1999, Dean in 2007 and Omar in 2008) often lead to extreme surge along the west coast. The destruction of corals then comes in the form of uprooting and breakage of colonies by the water itself or by debris, abrasion of coral tissue caused by debris and quick moving sediment-laden waters, and burial of reef sections by shifting sediments. During such events the sediments originate from resuspended materials already deposited in coastal waters, as well as new alluvial inputs affecting all shores. The latter affects the entire island. Small reefs and coral assemblages on narrow shelves are the most exposed during these events and in some cases do not recover from storm impacts other than providing the substrate for new colonization by reef organisms (Plate 2). Surges caused by storms passing south of Dominica affect primarily the east coast, while the ensuing terrestrial runoff affects the entire island. Assuming an east to west trajectory of a hurricane passing directly over the island, and given the island's size, the principal destructive force of a direct hit comes from the northeasterly winds in the hurricane's approach, southwesterly winds as it moves into the Caribbean Basin and terrestrial runoff throughout and beyond the duration of the hurricane.

Temporarily stable and slow moving high-pressure systems to the west of Dominica occasionally lead to pressure-gradient-driven westerly winds and a destructive surge along the west coast of Dominica. Such events have led to severe physical damage of corals, the resuspension and transport of sediments, and have resulted in the burial of near shore seagrasses and coral reefs. This is an example of a destructive natural disturbance that occurs on sunny days with no storms in sight.

The characteristically narrow and steep shelf provides a narrow euphotic zone and a restricted potential area for storm-produced coral fragments to survive and continue growing as long as they get stuck in areas sufficiently illuminated for the endosymbiotic zooxanthellae, as it occurs in fragments from some *Acropora* species (Lirman 2000, Tunnicliffe 1981). Given the aforementioned combination of chronic natural disturbances and the limited potential reef area, reef accretion in less than 50 m is also limited along most of the west coast.

The best in-reef temperature records exist for the depth of 16 m in the Salisbury Reef on the central west coast (Fig. 6B), and spans the time between July 2007 and May 2012. It shows yearly temperature oscillations between 25 and 30 °C with mean diurnal fluctuations of 0.2 °C. Storm and hurricane impacts are clearly visible as pronounced temperature drops, as are prolonged elevated temperatures that coincided with coral-bleaching events. Simultaneous measurements at 9 m and 3 m depth showed yearly temp oscillations of the same amplitude, but roughly one degree warmer (26.6 to 31 °C) in the shallow waters, and showed distinct mean diurnal variations of up to 0.5 °C. The significance of this relates to the 2005 coral-beaching event, during which more corals were bleached in shallow waters, but the resulting mortality was higher in deeper waters with lower diurnal temperature oscillations STEINER & KERR (2008). Since all coral reefs in Dominica are well-flushed, the stratification in water temperatures are among the parameters to be considered when gauging changes on the reefs' composition and cover over time.

Coral reef resource use

The first peoples that came to and lived in Dominica did so no later than 3100 BC and up to 400 BC (HONYCHURCH 1995). They have been named Ortoroid and were part of a series of migrations from the Orinoco Delta northward, along the Lesser Antilles. Among this first group and all the subsequent settlers (Arawakan speakers) up to the 15th century, areas near coral reefs were one of several settlement sites with distinct strategic benefits. Mollusks, crustaceans, echinoderms and fishes where collected and caught around these locations with an increasing number of techniques through time. The fishing pressure excreted by early settlers cannot be deduced from the archeological sites in Dominica. Signs of coral mining during that time frame have not been found.

Throughout the 16th century the "mountainous rainforest citadel" (HONYCHURCH 1995) that is Dominica, became a principal retreat for the Kalinago, the indigenous people from the Lesser Antilles at that time. However, European encroachment on the island intensified as of the mid 17th century, predominantly by French and British settlers and military units, which gained significant control of the island during the turbulent 18th century. The Kalinago and growing numbers of maroons escaping slavery, found shelter in the rugged interior of the island but lost virtually all access to coastal waters and their resources. Colonial fortifications, stone houses and many foundations of wooden houses were built with the use of mortar containing lime from burned corals. Large construction sites (e.g. Fort Shirley and the Cabrits Garrison on the Cabrits Peninsula, Fig. 20) and some estates (e.g. Hampstead, north coast) had their own coral kilns. This practice continued up to the 1950s when cement became readily available and a more cost-effective material. There are no estimates of how much coral was extracted from Dominica's reefs and coral assemblages for the production of coral lime, yet considering the relatively small potential and actual reef area of Dominica (72 hectares documented in 2007, see STEINER & WILLETTE 2010), the structural loss may have been substantial in shallow areas with easy access. In northern Dominica, coral rubble was also used in the construction and maintenance of the first motorable road during the first half of the 20th century (NAPIER 2009)

Coral reef organisms have always been only one section of the artisanal near-shore fisheries of Dominica, yet the overall fishing pressure on coastal marine resources has been diverse in terms of techniques targeting demersal, pelagic and migratory organisms in all habitat types, including coral reefs, seagrass beds, rocky and sandy environments. Several techniques are indiscriminant (e.g. fish traps) and some also very destructive (dynamite). Despite a comparatively low human population that was still under 30,000 at the turn to the 20th century, peaked at close to 74,000 in the late 1970s and dropped to under 72,000 in 2011, fishing pressure has been historically significant, because most of the population lives in coastal zones and terrestrial wildlife was always modest. The demand for additional sources of protein prompted the imports of salted cod from New Foundland, which remained a main staple prior to the advent of personal refrigerators and the import of frozen meats. The overexploited status of reef fishes has been acknowledged by Dominica's Fisheries Division (Sebastian 2002) and is immediately evident to anyone who has seen adult reef fishes in their natural habitat and now snorkels or dives over Dominica's reefs.

Today's primary extractive and chronic use of reef resources is fishing. Hook and line, fish pots, spear guns and occasionally gill nets are used (Sebastian 2002). Dynamite is no longer used but the scars of this practice can be seen on north coast reefs. The collection of marine algae, primarily by women, for the production of agar used as a principal ingredient in a traditional beverage called sea-moss, is practiced along the north coast's fringing reefs. The island's modern, near-shore fisheries remain artisanal in terms of equipment and range, characteristically indiscriminant, and affect all littoral habitats including coral reefs. Most of the catch is sold and consumed locally, while some is used as bait in fish pots. Non-extractive uses of coral reefs and coral assemblages such as recreational SCUBA diving and snorkeling tours targeting a few areas, largely in the southeast, emerged in the 1980s.

Not directly affecting coral reefs are and were the artisanal long line, and line and hook, fisheries targeting deep water and migratory pelagic fishes in the Guadeloupe and Martinique Passages and east of Dominica, the newly emerging off-shore fisheries targeting revolving around anchored fish aggregating devices (FAD) targets the same species west of Dominica.

For the sake of completeness, it shall be noted that whaling was never part of Dominica's fisheries. Confusion in that regard may arise form terms such as "whaling station" which are used in descriptions of Portsmouth from the late 1800s to the early 1900s, by Napier (2009). Supply ships from New England did indeed exchange cargos in Portsmouth with whaling ships coming from the South Atlantic. The most famous whaling ship to use the harbor was the "Charles E. Morgan", making its last voyage out of Portsmouth in 1921 with a mainly Dominican crew (Honychurch 1983), and only in that sense where Dominicans' directly involved in whaling.

Investigation of the marine benthos

Dominica's coastline was for the first time accurately drawn in John Byre's map of Dominica from 1776. By 1872, surveys by the British Admiralty rendered detailed bathymetric charts of the islands near-shore waters up to depths of 82 m. In January 1879, five benthic trawls, in depths of 154 to 1111 m along the west coast, were performed from the Coast Steamer Blake (Pourtalès 1880, Cairns 1979). Based on the logged coordinates, three trawls were carried out between 7 and 2.5 km west of Pointe Ronde (south of Prince Rupert's Bay), and two between 3 and 2 km west of Goodwill (northern Roseau). The organisms collected included, deep sea Scleractinia in the families Oculinidae, Caryophillidae, Flabellidae, Dendrophyllidae, and Gardineriidae.

The earliest scientific publication on Dominica's euphotic, sublittoral marine environments appears to be a short list of marine algae by GRIEVE (1909). Almost six decades later the Bredin-Archbold-Smithsonian Biological Survey of Dominica brought forth the first wave of marine studies, which were carried out between 1964 and 1967; namely on burrowing sponges (RÜTZLER 1971), archiannelids (KIRSTEUER 1967), balanomorph cirripeds (ROSS 1968), decapods (MANNING 1970), echinoids (KIER 1966) and marine algae (TAYLOR & RHYNE 1970). For this endeavor Clark Hall (Layou Valley) served as temporary field station. In 1964, Kier covered the widest ground with 17 study sites along the west coast between Pointe Ronde and Scott's Head, and one at eastern Woodford Hill. Rützler and Kirsteuer primarily dove at Scott's Head using SCUBA tanks and a portable compressor, and also carried out an excursion to Panto Hole, east of Middle Bay, near Marigot during the same year. Rützler described a new species of coral-burrowing sponge, naming it after the collection site at Scott's Head, *Cliona cachacruensis,* now known as *Siphonodictyon cachacruensis*, and returned three years later for further sampling. Kirsteuer described a new species of marine archiannelid, *Saccocirrus archboldi*, which he found at Panto Hole, where he also collected the barnacles later examined by Ross. A new spider crab, *Mitharx commensalis*, was described by Manning, and the holotype was collected at Tarou Point (Rodney's Rock). Tayler and Rhyne were not part of the Bredin-Archbold-Smithsonian Biological Survey team, but were invited to use the facilities at Clark Hall in 1967 when they collected and identified 130 species of marine algae. Nine of their 11 collection sites were along the west coast between Douglas Bay and Scott's Head, one was at Calibishi, north coast, and one at Rosalie, east coast.

Two more research vessels trawled Dominica's northeastern and eastern benthos, during the 1960s; RV Oregon II at five locations in 1966 and RV Pillsbury at two locations in 1969 (CAIRNS 1979). Three stations of RV Oregon II were between 7 and 20 km northwest of Marigot, in depths of 809 to 448 m, the fourth station was approximately 4 km from shore near Good Hope (north of Saint Sauveur) in 110 m depth and the fifth station was approximately 6 km from Pagua Bay in 357 m depth. The two stations of RV Pillsbury were between 7 and 5 km from shore near Bataka (depth 146–495 m) and Pagau Bay (depth 457–503 m) respectively.

Coral reefs had thus not yet been studied in detail, and during the following three decades only three reports on "coral reefs" emerged (SUMMERS 1985, JUDGE et al. 1987, WEYERMAN et al. 1996) that made no or weakly defined distinctions between coral reefs sensu stricto and coral assemblages. JUDGE (1978) and WEYERMAN (1996) also provided sketched maps of some areas. In most instances, however, neither the reefs nor their location are identifiable by persons who do not already know the island's sublittoral in much detail. Similarly, "coral reefs" encompassing coral assemblages were mentioned in the regional comparisons of reef condition in SMITH et al. (1997) as well as in the national surface area estimates of coral reefs presented by BRUKE & MAIDENS (2003). Several data and conclusions from these reports could not be supported by subsequent studies.

The second wave of investigations took off in 1999 with the founding of ITME. Initial field operations were based in Morne Daniel and Springfield before ITME secured a facility in Mahaut in late 2001. The first series of surveys on the distribution of stony corals, carried out between 1999 and 2002, included species composition of coral reefs and assemblages along the west, north and east coast (STEINER 2003). Covering most of Dominica's coral reefs, these surveys laid the foundation for subsequent studies on coral reefs and their associated fauna and flora. Borger (2004, 2005), and Borger & Steiner (2005) examined the progression of coral diseases, as well as the species and range extension of afflictions between 2000 and 2002. The comparatively high abundance of the echinoid *Diadema antillarum*, in contrast to Caribbean locations where mass mortalities in the mid 1980s were reported (Lessios et al. 1984, Lessios 1995), triggered the establishment of permanent monitoring sites in 2001. A long-term study rendering insights into temporal abundance and size class distribution dynamics of *D. antillarum* followed (Steiner & Williams 2005a, 2005b). Coral bleaching events of varying intensity affected Dominica in three consecutive years as of 2003. Steiner & Kerr (2008) gauged the changes in coral community structure following the 2005 coral bleaching events, based on surveys from 2005 and 2006. Some of these results were also contributed to a regional assessment of the 2005 bleaching episode by Eakin et al. (2010). In 2008 ITME contributed samples of *Orbicella faveolata* to a Caribbean–wide evaluation of genetic connectivity of this species (Foster et al. 2012). The samples from Dominica came from the Salisbury Reef and showed similarities with samples from Barbados and Tobago.

At the core of the present report is the single largest field survey of Dominica's coastal marine environments to date, which was carried out between September and December 2007, led by Steiner and Willette. With the objective of examining previously unexplored areas and mapping the island's marine habitats, and by combining the resulting data with additional surveys in 2008, they assessed 1,814.7 ha of benthos along 157.0 km of coastline (Steiner & Willette 2010). These efforts resulted in a composite picture and a drastically improved understanding of the island's near shore benthic marine habitats. Initial results were translated into a publicly accessible information platform, http://www.itme.org/mhdm in 2007 and subsequently updated. For the first time, the size of individual coral reefs could be considered in gauging the overall condition of Dominica's reef resources. Among other key results was the fact that seagrass beds were far more extensive and better developed than previously known, and that they were an integral part of regions with the largest and best-developed coral reefs. This insight spawned subsequent examinations on the distribution of the five seagrass species identified in Dominica; the Cymodoceaceae *Syringodium filiforme* and *Halodule wrightii*, and the Hyrocharitaceae *Thalassia testudinum*, *Halophila decipiens* and *H. stipulacea* (Steiner et al. 2010). The latter is an invasive species and in 2007 Willette, who first identified it, examined its successful distribution dynamics (Willette & Ambrose 2009, Willette & Ambrose 2012). *H. stipulacea*'s cataclysmic expansion between 2008 and 2013 and the displacement of native seagrassess were documented by Steiner & Willette (2013).

During the second wave of investigations, thirty five additional studies were presented in technical reports, some within multi-author compilations, on the distribution and abundance of reef corals and fishes, from the west (Lucas et al. 2001, Diamond 2002, Green 2003, Knuth 2003, McDonald 2003) and north coast, (Ishikawa et al. 2004, Byrd et al. 2005, Davis et al. 2006), the distribution of *D. antillarum*, in relation to benthic algal cover, and the abundance of herbivorous and predatory fishes (Williams et al. 2001, Smith et al. 2002), the distribution of marine habitats (Macfarlane & Price 2007) and the occurrence of algae, sponges, crustaceans, mollusks and echinoderms (Claremont et al. 2008). In collaboration with R. Armstrong and Y. Detrés from the University of

Puerto Rico, ITME set up an air sampler in Castle Bruce, East Coast (Fig. 2) in April 2002, and operated it for five months to collect Sahara dust aerosols. Analyses of the samples rendered the identification of fungi in five genera (R. Armstrong pers. com.). Dominica's windward location within the Lesser Antilles proved to be an ideal sampling site for these studies. Although not directly related to benthic studies, some of the identified fungi are linked to Aspergillosis in Caribbean gorgonians and may thus also be one source of such afflictions in Dominica's sea fans. Source reports and articles by ITME are available at http://www.itme.org/reports.html

Distribution and description of coral reefs

Benthic surveys carried out by STEINER & WILLETTE (2010) encompassed areas extending 75.0 to 300.0 m from shore, covering 1,814.7 ha, along 157.0 km of coastline. Eight sections of shoreline, predominantly located along the north coast and adding up to 17.7 km, remained unsurveyed at the time. A few coral reefs were thus partially or completely outside of the survey area. Since then, an additional 142.6 ha (10.3 km shoreline) were assessed. Except for Blenheim Bay and the stretch between Point La Soie and Walkers Rest (5.7 km), waters adjacent to Dominica's entire coast are being considered here and they include a total coral reef area of 80.4 ha (4.5 % of the surveyed benthos), distributed among the 31 reefs cataloged in Table 1.

The north coast harbors 54 % of the island's coral reef area, while the west, south and east coasts harbor 31 %, 13 % and 2 % respectively (Fig. 2). Coral reefs around Dominica are comparatively isolated, as broad tracts of contiguous reefs have not developed. The largest reef complexes are within the areas between Anse Soldat and Calibishie in the north (Fig. 3) and between Batali and Mero along the central west coast (Fig. 4B). Together they make up 74 % of the island's documented coral reef area. The largest reef is at Calibishie, yet the reefs with the highest species richness, live coral cover and architectural diversity lie between Batali and Mero.

In general terms and in reference to stony corals, reefs in good condition are commonly considered to have a high benthic live coral cover in a large number of species, and with few signs of recent mortality and overgrowth by algae or invertebrates. Aside from anthropogenic disturbances, these attributes and the reefs' associated fauna and flora are shaped by the site-specific and regional environmental parameters. Healthy reefs located near the physiological distribution limits of their coral species (e.g. temperature, light, turbulence, or dissolved nutrient levels) therefore do not meet the abovementioned criteria. The condition of a reef is thus best outlined within a local context. At the root of the natural limitations for Dominica's reefs are the narrow shelf, their proximity to land influences and the turbulent east coast as previously described.

Dominica's modern north and east coast reefs (windward) differ greatly in structure and condition from west coast reefs (leeward). They are shallow water fringing reefs (0.5–10 m depth), in which the ramose *Acropora palmata* is the primary scleractinian structural framework component. Characteristic for these reefs now, is a live coral cover under 5 % of the reef's total surface area and extensive "old" coral mortality, meaning that the skeletal remains of corals can visually no longer be linked to a species and that these conditions date back many decades. Forests of *A. palmata* have long disappeared and the species is an insignificant component among the remaining live corals. Turf and

Table 1: Coral reefs of Dominica, ranked by surface area. Site numbers as used in Figs. 2–17. Total area surveyed 1954.0305 ha. Clusters of contiguous reef patches surrounded by non-reef environments are recorded as single reef. Large sandy areas within reefs clusters and reef complexes inadequate for coral settlement (e.g. tidal channels, sand chutes, or unstable substrates) are excluded from reef area values. Coordinates are from the center of each reef.

No.	Name	Coast	Reef Type	Depth (m)	Area (ha)	Condition	Coordinates
1	Calibishie	North	Fringing	0-8	22.5166	critical	15°35'40.71"N 61°20'56.96"W
2	Grande Savane	West	Fringing	8-40	10.7884	good / poor	15°26'22.89"N 61°27'07.36"W
3	Marigot	East	Fringing	1-5	7.6750	critical	15°32'32.45"N 61°17'01.51"W
4	Anse Soldat	North	Fringing	0-8	5.0250	critical	15°35'41.40"N 61°22'57.17"W
5	Porte La Fin	North	Fringing	1-8	4.9780	dead	15°35'41.80"N 61°21'19.76"W
6	Anse de Mé	North	Fringing	0-8	4.4750	critical	15°35'43.51"N 61°22'45.40"W
7	Mero W	West	Fringing	10-25	2.7300	poor	15°25'04.66"N 61°26'05.22"W
8	Lemoines	West	Patch	3-8	2.5600	dead	15°33'03.82"N 61°28'05.12"W
9	Mero S	West	Banks, Fringing	8-35	2.5400	good / poor	15°25'51.79"N 61°25'52.55"W
10	Au Parc	North	Fringing	2-5	2.0400	dead	15°36'30.94"N 61° 2352.66"W
11	Dubuc	South	Patch1	2-9	1.9050	dead	15°14'41.11"N 61°18'06.65"W
12	Batibou Bay	North	Fringing	1-8	1.7938	critical	15°35'53.91"N 61°22.06.00"W
13	Batali	West	Spurs	10-30	1.6850	poor	15°26'54.08"N 61°27'01.45"W
14	Anse Quaneri	East	Fringing	0-9	1.5000	ceritical	15°25'59.29"N 61°15'03.47"W
15	Douglas Bay	West	Fringing	8-18	1.2200	critical	15°35'36.10"N 61°27'59.54"W
16	Woodford Hill	North	Fringing	1-10	1.1500	critical	15°35'13.78"N 61°19'17.75"W
17	Soufriére N	West	Fringing	10-40	0.9900	critical	15°14'13.88"N 61°22'18.25"W
18	Saint Sauveur	East	Fringing	0-9	0.9200	dead	15°24'11.30"N 61°15'05.49"W
19	Salisbury	West	Fringing	7-28	0.9025	good / poor	15°26'16.99"N 61°26'44.69"W
20	Toucari	West	Fringing	0-6	0.7860	critical	15°36'28.38"N 61°27'55.88"W
21	Bense Bay	North	Fringing	1-7	0.6480	dead	15°35'43.76"N 61°22'28.74"W
22	Cachacrou SH	West	Fringing	6-30	0.6275	poor	15°12'51.06"N 61°22'14.27"W

No.	Name	Coast	Reef Type	Depth (m)	Area (ha)	Condition	Coordinates
23	Hodges	North	Fringing	1-7	0.5225	poor	15°35'32.83"N 61°19'53.83"W
24	Cabrits South	West	Patch	5-8	0.2760	critical	15°34'56.42"N 61°28'05.89"W
25	Fond Colet	West	Patch	5-8	0.1250	critical	15°19'07.83"N 61°23'38.44"W
26	Roche Cassé	South	Patch	2-7	0.0400	dead	15°14'31.79"N 611°7'31.20"W
27	Plat Coubari	West	Patch	2-9	0.0270	poor	15°30'04.98"N 61°28'08.44"W
28	Thibaut	North	Patch	2-7	0.0035	dead	15°36'06.75"N 61°23'41.55"W
29	Blenh./Torite	North	Fringing	no data	no data	no data	15°35'46.56"N 61°23'15.80"W
30	Pointe Baptiste	North	Fringing	no data	no data	no data	15°35'53.36"N 61°20'15.93"W
31	Pagua Bay	East	Fringing	no data	no data	no data	15°31'08.32"N 61°16'04.42"W
	Total Reef Area				80.4498		

Additional Notes to Table 1. Field surveys that rendered the area estimates are described in Steiner and Willette (2010). The current condition of each reef is classified as follows: **good** (live coral cover ≥15% of the reef's total surface area, at least 20 species are present, except in *M. mirabilis* banks, large colonies of living framework-building species are common and there is little or stable algal growth), **poor** (live coral cover 10-14% with pronounced chronic algal growth and recent mortality), **critical** (live coral cover 2-9%, approx. 10 scelarctinian species, few live framework builders, algal growth, and recent mortality abound.), **dead** (coral cover is under 2%, stony corals no longer shape the topography of the reef, algal and invertebrate overgrowth abound. Many locations have multiple official and colloquial names. Site names used here are based on the names published in maps by the British Government's Ministry of Overseas Development, series E803, edition 4 DOS 1978, scale 1:25000.

calcareous algae, encrusting sponges, soft corals and zoanthids have overgrown large portions of the reefs. The state of windward reefs is a result of local disturbances (e.g. enhanced alluvial sediment outputs), in combination with the decline of live *A. palmata* colonies throughout the Caribbean. With the demise of a principal framework building species, such as *A. palmata* along Dominica's north coast, and chronic mortality in other coral species, comes a loss of structural habitat heterogeneity and a cascade of collateral reductions in species richness and live coral cover. In fact, coral-specific architectural (e.g. reef crest) or biological zones (e.g. *palmata* zone) typical in shallow Caribbean windward fringing reefs are no longer discernible along the north coast, and some reefs are devoid of live corals.

West coast reefs are also fringing reefs and with few exceptions located in deeper waters (5–40 m depth). They are in a better condition than their windward counter parts, but suffer from progressing reductions of live cover, the impact of which has been most acute

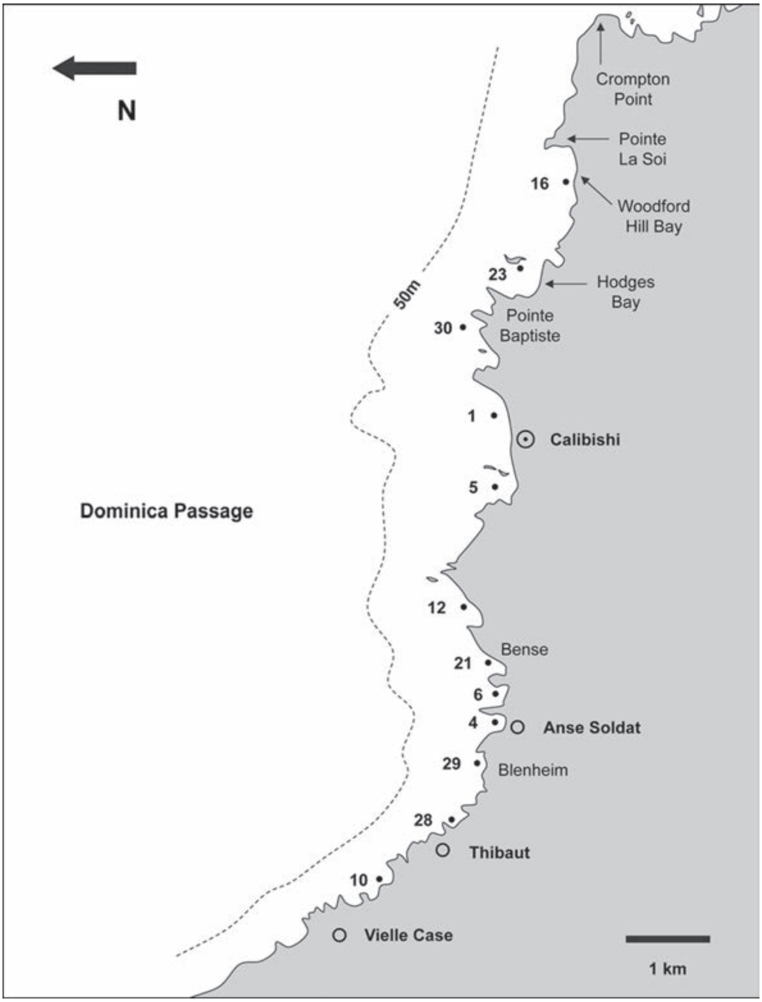

Fig. 3: Distribution of coral reefs between Vielle Case and Pointe La Soie, north coast.

in the reef sections below 12 m depth. Architectural characteristics include aggregations of mushroom and plate-like colonies of *Orbicella faveolata* in 15–30 m (e.g. Grande Savane) covering close to 100 % of the benthos and exceeding it with multiple overlapping tiers (Soufriére N). Shallower reef portions, the upper boundaries of forereef slopes, and the margins of sand chutes are commonly lined by aggregations of the massive columnar colonies of *Orbicella annularis* (e.g. Salisbury), which also form a solid coral cover in combination with thickets of the branching coral *Madracis mirabilis* (e.g. Mero W). However, both *Orbicella* species have undergone a catastrophic loss of live tissue in the last 15 years, in particular as of the 2005 massive coral bleaching event. Reef portions dominated by these species, which contribute the greatest structural rugosity and skeletal cover, are now dead. The same holds true for the majority of colonies from species that make up substantial portions of the deeper reef sections such as *Diploria strigosa*, *Agaricia* spp., and *Mycetophyllia* spp.

Shallower reefs or reef sections (2–15 m) are dominated by weedy species, with dome-shaped colonies that are less that 0.5 m in diameter. Here too, skeletal remains that can be attributed to a species and recent disturbance abound, indicating an ongoing deterioration. Coral reefs that span a wide depth range thus have moribund deep sections and shallow sections where weedy species are comparatively common in numbers, but cover no more than 15 % of the benthos.

Since early records on the condition of the island's coral reefs do not exist, a baseline can only be drawn from recent observations. Five scenarios in the reefs' condition are currently evident in different locations in Dominica as follows:

1) Isolated bank reefs that are built and dominated by *M. mirabilis*, and with the highest live coral cover (≥ 70 %) among Dominica's reefs. Few other species are part of these formations and species richness is not a measure of condition. However, the banks' resistance to coral bleaching and the overgrowth by algae and invertebrates are. Where these attributes exist, banks are considered to be in good condition. So far, direct physical destruction of entire banks has only been observed in the vicinity of Soufriére and Scott's Head (Scott's Head Soufriére Marine Reserve).

2) At least 20 species of stony corals are present, live colonies of framework-building species, exceeding 1 m in diameter, are common, live corals cover ≥ 15 % of the reef's total surface area, and there is little or stable algal overgrowth. This stands in stark contrast to the healthy banks of *M. mirabilis*, but it describes the best condition of a Dominican reef that is not a bank reef. Unfortunately, even this second scenario is now rare because of the previously described deterioration in deeper reef sections, which fit the third scenario.

3) Recent mortality has reduced live coral cover to 10–14 %, while close to 20 coral species can still be found.

4) Lower live coral cover (2–9 %), with approximately 10 coral species and few live framework builders, pronounce algal growth, and recent mortality make up the fourth scenario.

5) Stony corals no longer shape the topography of the reef because skeletal ruins are eroded (old mortality), live corals are absent or cover less than 2 % of the reef area, and algae and invertebrates make up the sessile benthic community.

In 2012, only a few sections of larger reefs fit scenarios one and two, and are classified as being in **good** condition. Coral reefs with scenarios three, four and five, are classified as **poor**, **critical**, and **dead** respectively (Table 1). When healthy *M. mirabilis* clusters or banks are located within reefs composed of other species in worse condition, they upgrade the overall classification of the reef. It shall be reiterated that these classifications are solely based on and intended for local comparisons. In view of the given environmental circumstances in Dominica, and the poor recruitment rates in many of the above-mentioned framework-building species, an increasing coral cover on reefs appears unlikely.

While the west coast also has dead coral reefs and most in poor and critical condition, its largest and most diverse reef tract, between Batali and Mero, is the "healthiest" and most diverse in Dominica. Therefore the following regional descriptions address the west coast first, followed by the north, east and south coasts. Scleractinian species whose names have been revised during the time frame addressed here are identified, to facilitate comparisons of this and previous reports from Dominica.

West Coast

West coast coral reefs (13) are heterogeneous in their architecture and include all reef forms occurring in Dominica; fringing reefs, spur and groove formations, oligospecific reefs or banks and patch reefs. Shallow reefs, in no more than 10 m depth, are located within bays or on the northern side of peninsulas or rocky outcrops (e.g. Douglas Bay). Deeper reefs (> 10 m) are within a wider range of settings, yet always in areas furthest away from large rivers.

The reefs along the northern west coast (Fig. 5), between Capucin and the southern shores of Douglas Bay, are dead (Lemoines) or close to it (Toucari, Douglas Bay, and Cabrits South). Toucari is the only shallow-water fringing reef of the west coast and its principal scleractinian framework builders are *Orbicella annnularis*, *O. faveolata*, *Siderastrea siderea*, *Diploria strigosa*, *D. clivosa,* and *Colpophyllia natans.* Physical destruction and algal overgrowth are among the evident signs of reef deterioration. The reef at Douglas Bay is rich in species and growth forms, making it structurally remarkably complex, but also marked by high recent mortality in that the species of a large part of the dead corals are identifiable.

To its south is an area of approximately 400 m^2 with disturbed *Acropora cervicornis* rubble deposits. Live colonies of *A. cervicornis* have not been documented and the species can be considered to be extinct in Dominica.

Large *O. annularis* complexes, with single colonies of 8 m in diameter as well as *S. siderea* colonies larger than 1 m in diameter, are an important structural component of the patch reefs south of the Cabrits Peninsula. The reefs are in depths between 2 and 8 m and also include patches of *M. mirabilis* with intermittently occurring *P. astreoides.* The isthmus connecting Cabrits to the mainland, as seen today, is man-made (18^{th} century) and is among the early human alterations influencing the reefs in its vicinity. In the 17^{th} century, what is the point of the peninsula today was an island and both the Douglas Bay reefs and the Cabrits patch reefs were under direct influence of different tidal-current regimes. The arrangement of the patch reefs and their separating sand channels at Cabrits, aligns with the historic passage between Cabrits and the mainland.

The only other reef within Prince Rupert's Bay is near Lemoines (Fig. 5), however, it too is dead. South of it lies the second of two areas in Dominica where deposits of *A. cervicornis* rubble have been found. In both instances, the areas are very much comparable to "typical" shallow water *A. cervicornis* habitats from other regions; well-illuminated areas, with bright, calcareous sediments (in this case originating from neighboring reefs), reflecting light, under moderate turbulence regimes. It is plausible that *A. cervicornis* thickets grew at these locations in the past.

Between Prince Rupert's Bay and Coulibistri (Fig. 4A) a cluster of six small linear patch reefs is near Plat Coubari, in less than 6 m depth. The reefs lie parallel to each other and roughly perpendicular to shore. Massive colonies of *O. annularis* and *O. faveolata* and dense stands of the ramose *M. mirabilis* are the main constructional scleractinian components. With an area of only 270 m^2 all together, and being dominated by live colonies of

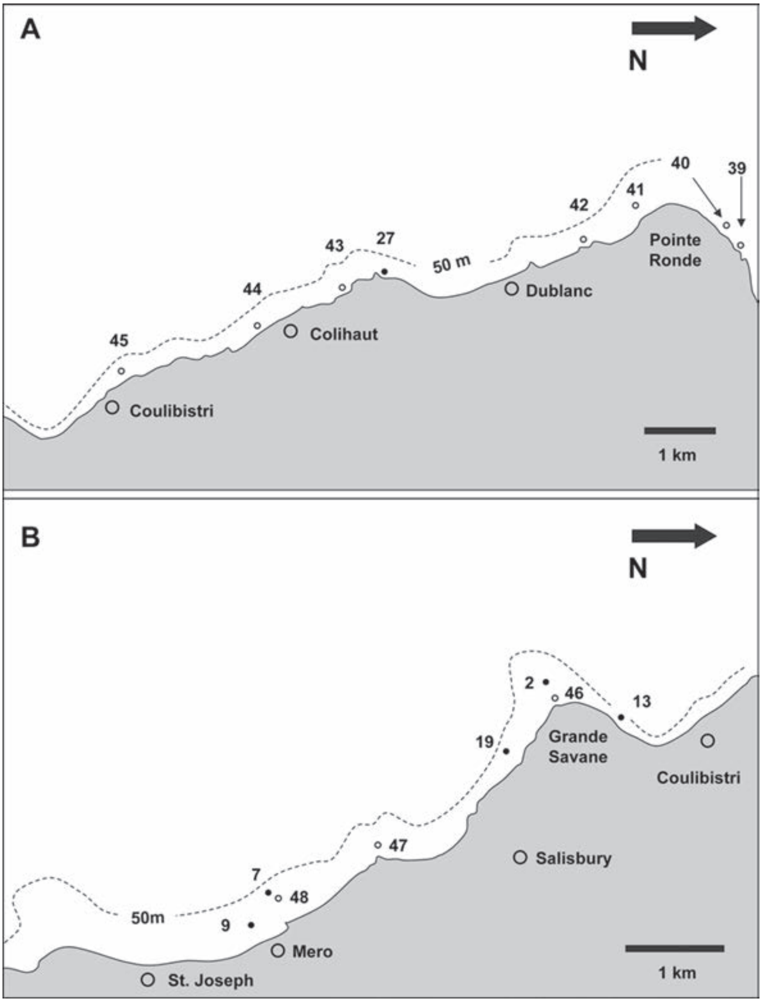

Fig. 4: Distribution of coral reefs and assemblages along the central west coast, between Pointe Ronde and Coulibistri (A), and between Coulibistri and St. Joseph (B).

Orbicella and thickets of *Madracis mirabilis* this reef is in exceptionally good condition, albeit not species rich, and a rarity in Dominica.

Coral reefs of the central portion of the west coast, between Batali and St. Joseph, include the most diverse reefs and the ones in the comparatively best condition. From north to south these include the reefs Batali, Grande Savane, Salisbury, Mero West, and Mero South (Fig. 4B). Batali Reef is composed of nine roughly linear reefs, aligned perpendicular to the shoreline in depths between 10 and 20 m. Sand chutes of no more than 50 m width, evenly separate the reefs, which results in a spur-and-grove formation (Fig. 6A). The first two and the last reef, from north to south, are compact with little sand accumulation between individual colonies. Corals in the other reefs are more scattered. Large monospecific clusters of massive species are absent. However, extensive stands of

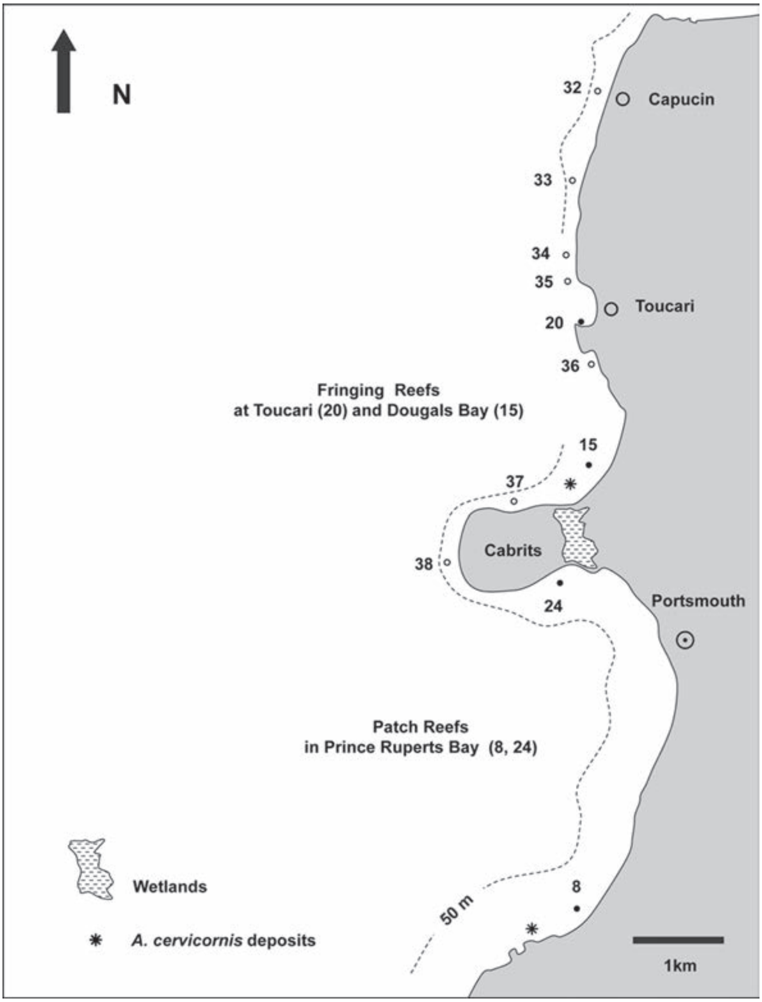

Fig. 5: Distribution of coral reefs, assemblages, and *A. cervicornis* deposits along the northern west coast, between Capucin and Pointe Ronde.

M. mirabilis (Fig. 21) mark the northernmost reef, and smaller clusters are found throughout the reefs. Massive colonies of *O. faveolata D. strigosa*, and *C. natan*s are framework components. The fact that this formation lies close to shore on steep and otherwise sandy terrain is unusual for Dominica. No other location exhibits this scenario, which may be linked to the wide shelf and extensive reef development south of Batali (Fig. 7). As the west coast alongshore currents predominantly flow towards the north, coral habitats on the northern side outcrops or peninsulas are subject to eddies and are characterized by higher coral cover and diversity, indicating a pronounced larval settlement at such locations. The Grande Savane shelf and reef complex may be beneficial to coral recruitment at Batali in terms of providing a source for coral planulae and a current-pattern-induced concentration.

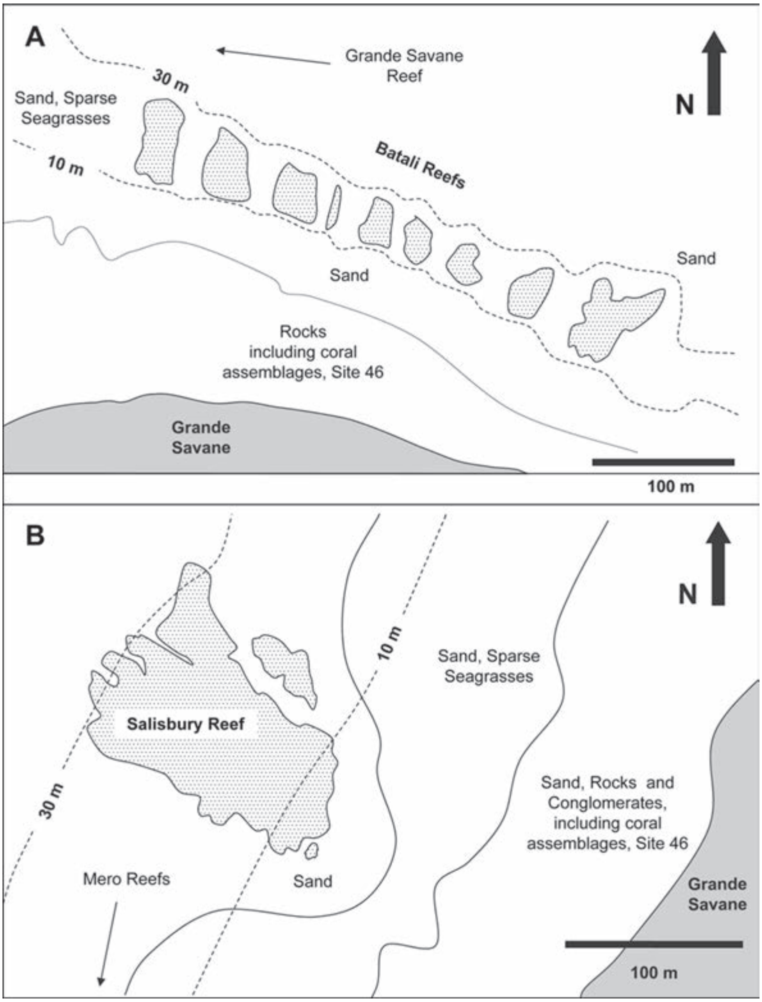

Fig. 6: Coral reefs at Batali (A, Site 13) and Salisbury (B, Site 19), west coast.

Grande Savane Reef (Fig. 7) is the largest reef along the west coast with 10.79 ha, in depths between 8 and 40 m (Table 1). Its northern margins lay 550 m, in southeasterly direction of the southern margins of Batali Reef. It has the farthest off-shore limit at approximately 800 m. Aside from its leeward location, its protrusion into the along-shore currents and the absence of large rivers in its immediate vicinity are features that make this site conducive to reef development. It also harbors the greatest structural variation within a single reef. Given its size, the comparatively high species richness (> 40) and a live coral cover close to 20 % (along the deep reef flat and upper forereef) it is like no other reef in Dominica, and possibly the largest local source of coral planulae. A distinctive sand channel, perpendicular to shore, splits the reef into a smaller northwestern and a larger southeastern portion, and is a useful feature for orientation under water. The forereef escarpment starts at around 20 m depth and its topography is strongly shaped

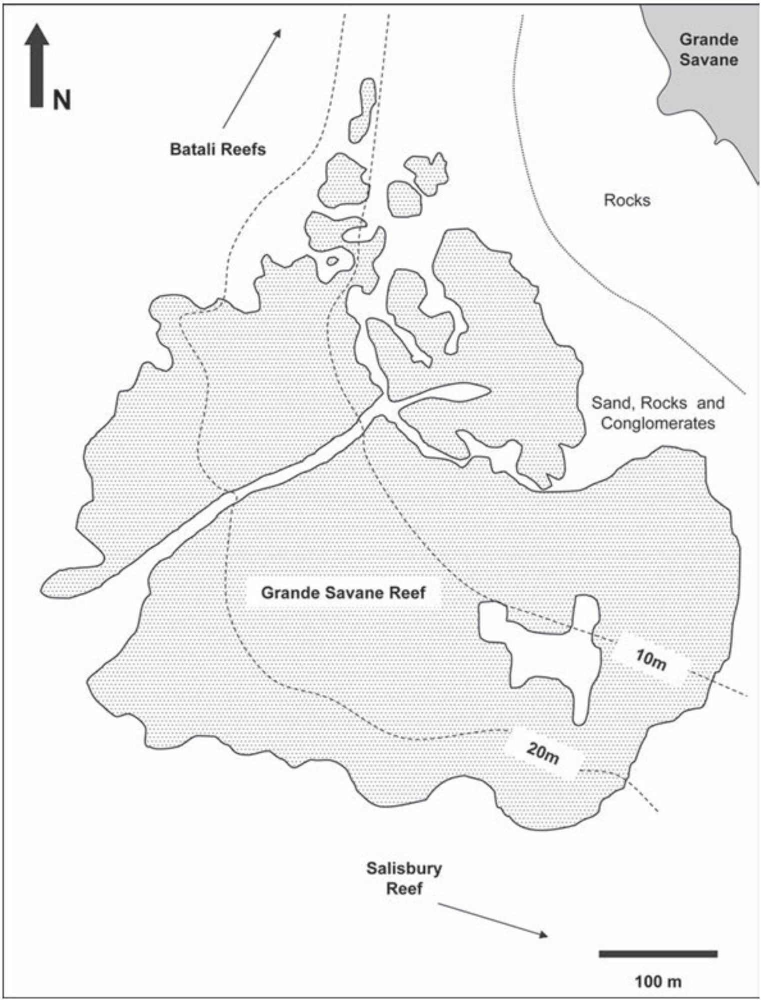

Fig. 7: Grande Savane Reef (Site 2), west coast.

by massive and foliose coral species that drape the rugose calcareous substrate with overhangs near the transition to the reef flat. Along the southeastern portion of the reef, the escarpment is steeper and far more extensive than along the northwestern portion of the reef. Dense gorgonian forests mark the northwestern transition between the reef flat and the forereef up to depths of 25 m. The northern margin of the reef flat is characterized by a pronounced drop (≤ 4 m) down to sandy environments and includes erosional features such as caves and mushroom-shaped reef patches. In contrast, the southern reef flat gradually transitions into sandy environments without any drops.

Salisbury Reef (Fig. 6B) is situated approximately 250 m, in a southeasterly direction, from the Grande Savane Reef. It was among the healthier reefs in Dominica up to 2005, and the reef where a single colony of *Solenastrea bournoni* (Fig. 24), is the only evidence of this species in Dominica. Topographically, there is no distinct margin between the forereef, which drops to 28 m depth, and the reef flat, which starts at 7 m depth. Hard calcareous substrates with dome shaped massive species under 0.5 m in diameter characterize the reef flat. Sand accumulation in the few solution holes is minimal. Below 14 m the forereef is ridged, and sand accumulation is more pronounced between individual ridges, along the northwesterly reef margins, below depths of 12 m, extensive, ridge-forming clusters of *O. annularis* are the largest coral frameworks on Salisbury Reef. Severe tissue loss due to predation by corallivorous fishes and herbivorous fishes that create and maintain algal-patches on the apical portions of *O. annularis* used to be the most evident causes of deterioration. The bleaching episodes of 2003, 2004 and more severely 2005, have exacerbated the degradation of these coral ridges, which no longer bear live coral tissue. *Madracis mirabilis* stands, similar to those found in Batali, also form large patches, flanked by now moribund *O. annularis* along a small northerly portion of reef separated from the main reef by a sand channel (Fig. 6B).

Two architecturally diverse reefs are in the vicinity of the village of Mero (Fig. 8). Mero West is a complex two-tier coral reef in depths of 10 to 32 m. It lies on the seaward contour of the submerged remnant of an eroded coastal spit that harbors coral assemblages discussed in the next section. The shallower part of Mero West (7–18 m) is characterized by *O. annularis*, often in conjunction with *M. mirabilis* stands, and by *O. faveolata*, *D. strigosa*, *S. siderea* and *C. natans* being the other important framework builders. The *O. annularis* - *M. mirabilis* patches are most extensive in the northeastern part of the reef's southern section, which is also the widest with close to a 100 m. The reef's width is tapered towards the north. Live coral cover of no more than 5% and a year-round and pronounced cover of macroalgae (e.g. *Lobophora, Dictyota* spp.) have been characteristic for this reef in the time frame considered here. Mero West's deeper (18–32 m) section is located at its foot, and it is composed of 10 patch reefs each ranging from approximately 50 to 200 m^2 in area and rising up to 4 m from the sandy sublittoral. Dome-shaped massive species characterize the coral community and the otherwise scarce *Porites porites* is common. Macroalgal cover is less prominent than in shallower reef portions.

The second reef near Mero (Mero South) includes Dominica's best-developed coral banks that are aligned in a spur-and-groove formation. *Madracis mirabilis,* is the dominating constructional species of this formation, which encompasses seven individual banks with elevations of up to 6 m, and range from 80 to 2,500 m^2. Within the areas lacking scars of physical impacts, only the branching *P. porites* and *P. furcata* sparsely co-occur. Live colonies of both *Porites* species virtually disappeared from all reefs, including the *M. mirabilis* banks at Mero, following the 2005 coral-bleaching episode (STEINER & KERR 2008). The resistance of *M. mirabilis* to bleaching during this particular event that triggered catastrophic mortality in most coral species in Dominica and its overall height live cover within its banks and thickets make it the island's most successful scleractinian reef-builder and maintainer at this time. Its delicate, branching colony morphology enhances the fall out of sediment in a process that is analogous to the "race" between sedimentation and the growth rates in seagrasses that lead to the formation of new rhizome layers (OTT 1988). Sediments accumulate between the branches of *M. mirabilis* assemblages, enhance the structural solidification and anchorage of the bioherm, and favor the vertical growth of large banks as long as sedimentation rates do not exceed the coral's growth rates. Similar to Mero N, Mero S also has a second, deeper

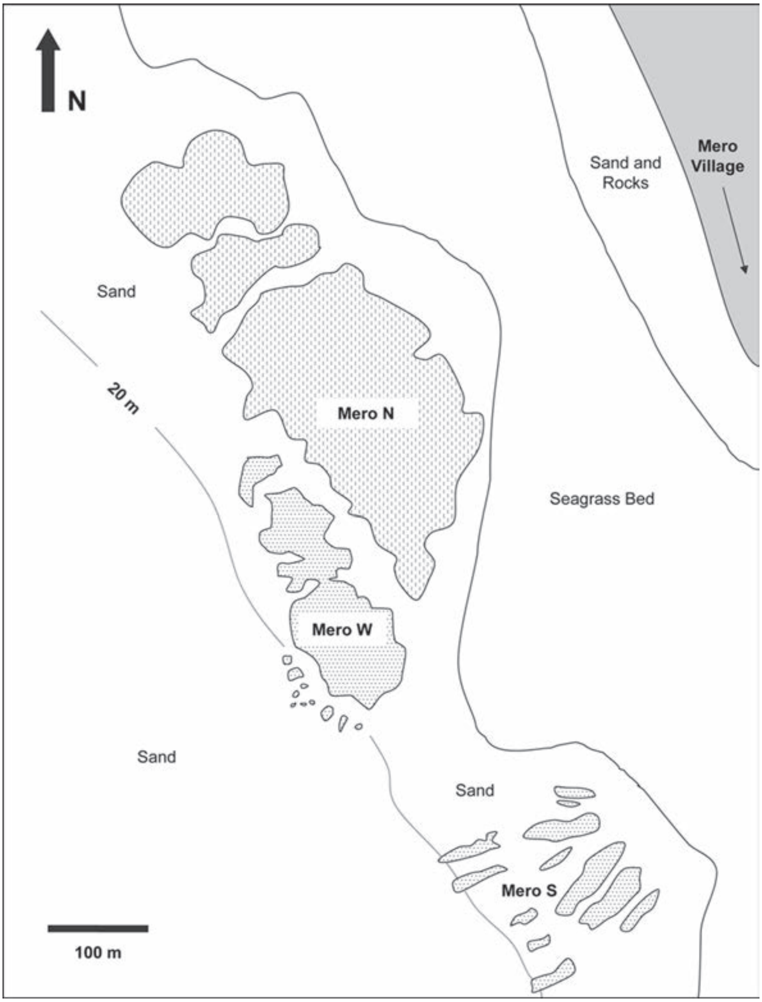

Fig. 8: Mero Reef W (Site 7) and Mero Reef S (Site 9), west coast. Mero N is a distinct rocky hard substrate with coral assemblages (Site 48), portions of which were classified as coral reef, Mero E, of in Steiner & Willete (2010). Seagrass beds have grown and changed in composition since 2009.

tier (25–35 m). It is a spur and groove formation, but unlike the shallower *M. mirabilis* banks, with massive species (e.g. *O. faveolata*) characterizing the architecture. Approximately 1.1 ha of the 2.5 ha of Mero S, are in the lower tier.

The southern portion of the west coast harbors only three coral reefs sensu stricto, a patch reef at Fond Colet, north of Roseau and the fringing reefs to the north of the village of Soufriére (Soufriére N) and Cachacrou on the northern side of the Scott's Head Peninsula (Fig. 2). Fond Colet is adjacent to the shipping lane, towards the Fond Colet deep-sea harbor, Dominica's main entry point for goods. This location is also exposed to urban effluents and severe sediment run-off from the Fond Colet River during the rainy season and storms. The environmental conditions are among the worst for coral reefs on

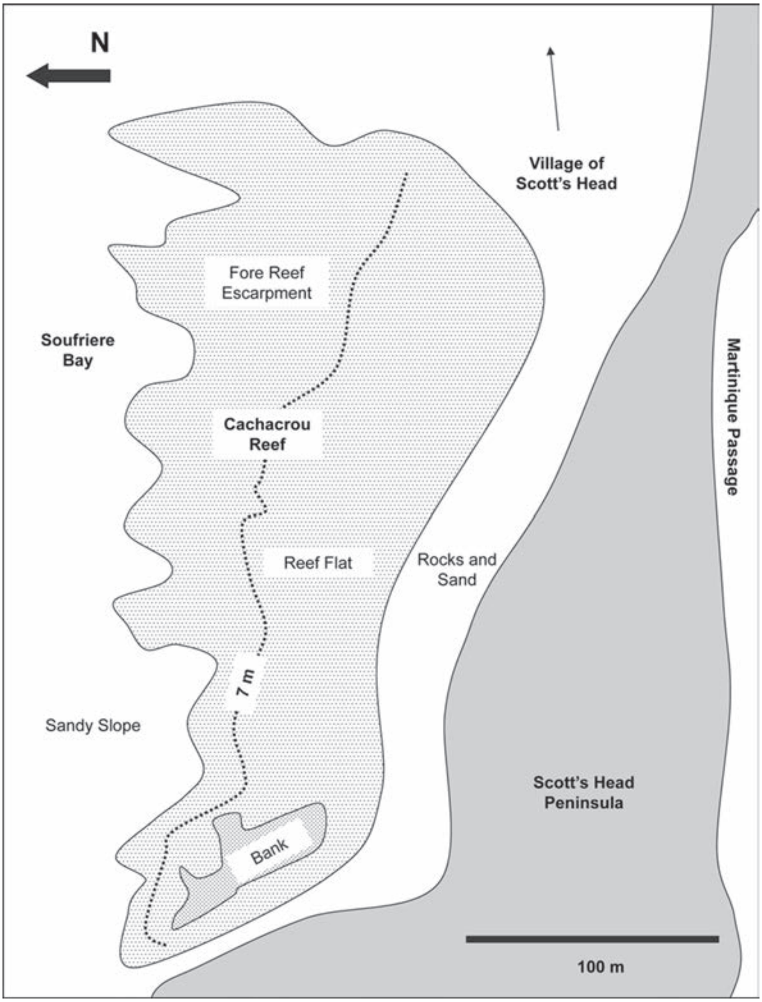

Fig. 9: Cachacrou Reef (Site 22), southern west coast.

the island. And indeed this reef is virtually dead, with the exception of numerous large *S. siderea* colonies on the northwestern portions of the reef, including the islands largest specimens recorded to date. With diameters of up to 5 m (Fig. 22), and considering the comparatively low growth rates of 5–8 mm a^{-1} of this species (GUZMÁN & TUDHOPE 1998), the colonies at Fond Colet are several hundred years old and have demonstrated their resistance to multiple chronic disturbances, making them living monuments of Dominica. Western margins of this reef harbor a few massive *O. annularis* and *O. faveolata* colonies and *M. mirabilis* thickets. The eastern margins show a series of parallel rocky conglomerates, oriented perpendicularly to shore, that appear to be the underlying foundation of what is left of this reef.

Five rocky outcrops mark the otherwise steep sublittoral areas between Point Guingard and Soufriére. The first is the largest one, with waters no deeper than 18 m extending approximately 300 m from shore. Along the southern slopes of this formation, coral assemblages transition into a coral reef whose mushroom and plate-like colonies of *O. faveolata* have formed multiple overlapping stories that cover an area exceeding the benthic cover of the reef. The reefs' listed sizes in Table 1 are approximations as it is difficult to delineate the shallow margins of the reef from the adjacent non-reef-building coral assemblages. Unfortunately most framework building coral colonies in this architecturally magnificent reef are dead.

The reef at Cachacrou (Fig. 9) has a distinct reef flat with an acute drop at its seaward edge in 6 to 8 m depth, separating it from the forereef escarpment. A *M. mirabilis* bank of approximately 1400 m^2 dominates the western portion of the reef flat. However, only few live colony fragments are left. Scattered reef patches with *O. annularis*, *O. faveolata*, *S. siderea,* and small *M. mirabilis* patches as the principal scleractinian constructional components mark the central and eastern portions of the reef flat. The reef edge is lined and topographically strongly shaped by the large colonies *O. annularis*, *O. faveolata*, and *S. siderea*. Overhangs and corals with flattened (e.g. *O. faveolata, O. cavernosa)* or foliose (*Agaricia* spp. and *Mycetophyllia* spp.) morphs structurally dominate the escarpment with increasing depth up to 30 m. Similar to the western reef at Mero, a year-round and pronounced cover of macroalgae such as the phaeophyte *Lobophora* has been characteristic for this reef. Hurricane David's (1978) impact on this reef included shifting sediment from the Scott's Head isthmus onto the reef. Cachacrou lies next to Scott's Head, one of Dominica's largest fishing communities. Fishing is geared towards targeting pelagic species in the Martinique Passage. Nonetheless, the ample structural damage on the reef can in large part be attributed to complementary in-shore fishing practices including fish pots, lines, and occasionally also gill nets. The reef also lies within the Scott's Head and Soufriere Marine Reserve (SSMR). Fishing directly on the reef has been curtailed, primarily by the tourism industry, which also uses this site and brings in other disturbances via inexperienced and careless divers.

North Coast

Coral reefs in the region are fringing reefs, distinguished by *A. palmata* frameworks along its reef crest and upper forereef escarpment. With the exception of the reefs near Au Parc (south of Vielle Case) and Thibaut, the reefs at Blenheim, Anse Soldat, Anse de Mé, Bense, Batibou, Porte La Fin, Calibishie, Hodges Bay, and Woodford Hill are located in north-facing bays (Fig. 3). All reefs in this area are either dead or close to it. Only skeletal ruins are left of the coral reefs near Au Parc and Thibaut, but *A. palmata* is recognizable as a previous framework component.

At Anse Soldat (Fig. 10) the principal reef tract lines the southwestern and southern portions of the bay. From shore and in depths of 0.2–1 m, the main reef extends 50 to 85 m towards the reef crest, from where the forereef drops to 10 m depth at approximately 130 m from shore. The forereef is structurally characterized by encrusting growth forms of *D. clivosa* and *D. strigosa,* sheet-like growth forms of the latter, as well as massive colonies of *S. siderea, O. faveolata,* and *D. strigosa* within extensive skeletal frameworks of the ramous *A. palmata.* Only a few live *A. palmata* colonies, all with clear signs of chronic breakage, remain in the bay. The reef crest is lined by the colonies of the hydrocoral *Millepora complanata* and gradually transitions into coral rubble, overgrown by members in the family Corallinacea and filamentous alga on the seaward side

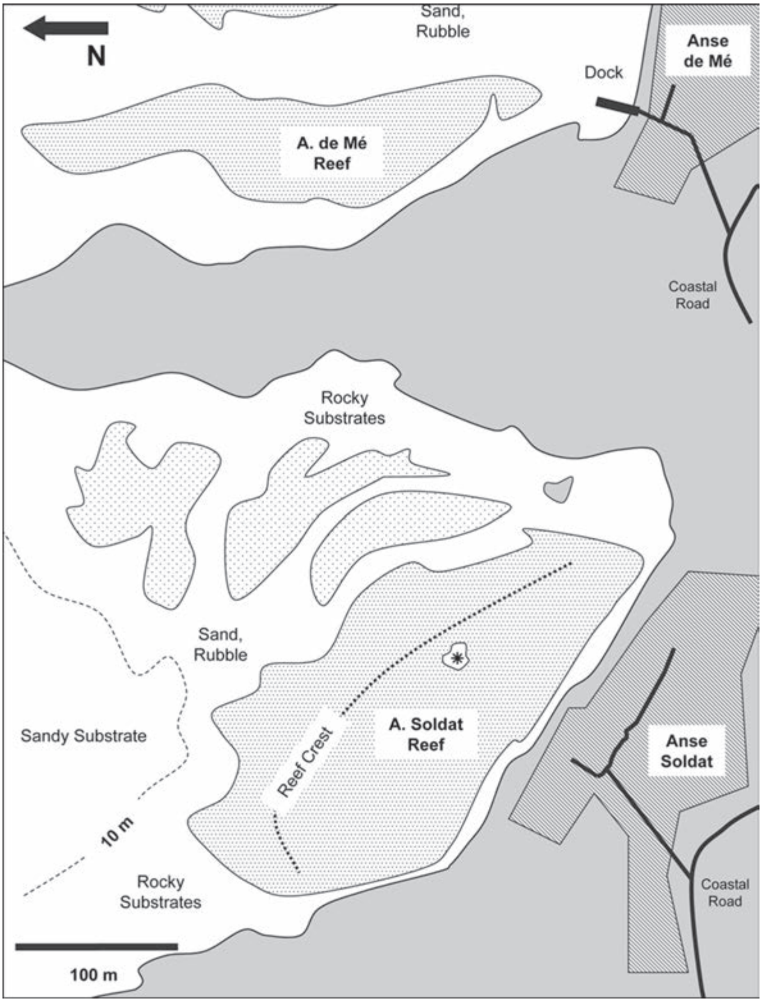

Fig. 10: Coral Reefs in Anse Soldat (Site 4) and the southern section of Anse de Mé (Site 6), west coast. Smaller reef patches in front of the A. Soldat's main reef are rubble ruins. ✱ Scar from dynamite fishing.

of the reef flat. The northwestern portion of the reef flat is the one of two north coast locations where *Porites branneri* has been identified. Towards land, calm and shallow waters provide suitable conditions for the seagrasses *Thalassia testudinum, Syringodium filiforme* and *Halodule wrightii* that are well established within the landward half of the reef flat (STEINER et al. 2010). *Thalassia testudinum,* is dominant within the first 15 m from shore. The corals *P. astreoides*, *P. divaricata*, *F. fragum, S. siderea* and *S. radians* also grow in this zone. Additional *A. palmata* frameworks and reef patches without associated seagrasses are located along the eastern portion of the bay. Live coral cover is most pronounced in scattered patches of up to 10 % along the forereef, but considering the entire reef it drops to under 2 %.

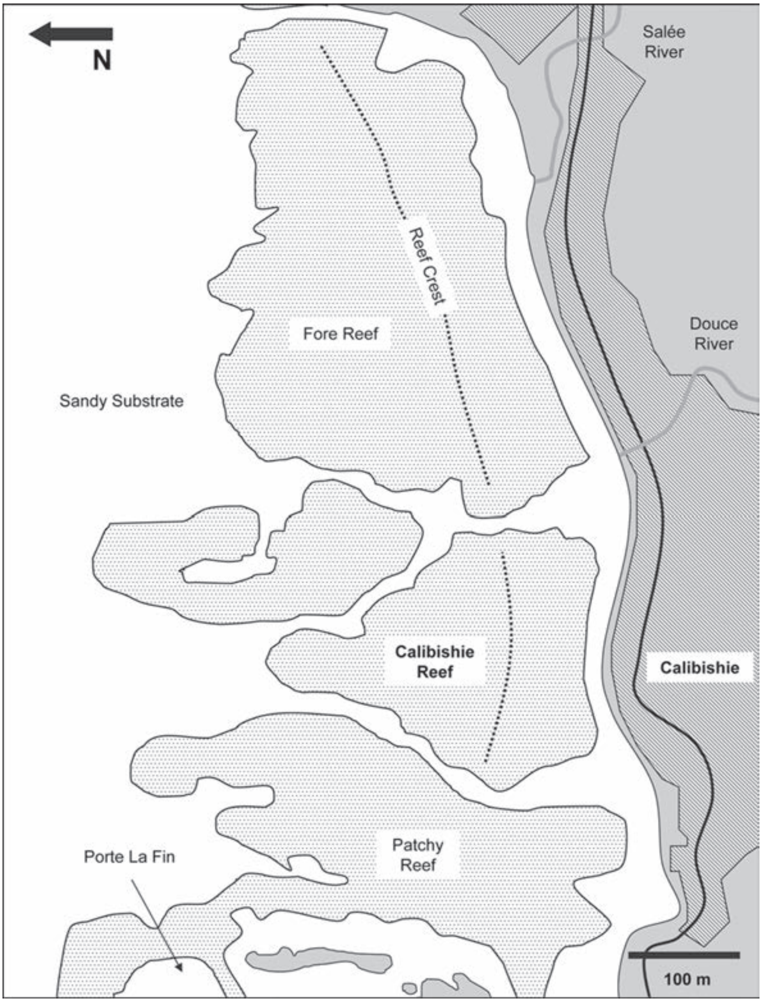

Fig. 11: Calibishie Reef (Site 1), north coast.

The reef at Anse de Mé, lines the western and eastern sides of the bay. It is unclear how much of reef used to exist between these two sides. Although tiny, Anse de Mé has been one of four official ports of entry, and has undergone multiple excavations. Its offshore margins and the remaining reef flats are similar to those at Anse Soldat in their structural coral composition and in their epibenthic communities. Reefs at Bense and Batibou have a coral species composition along their seaward margins that is similar to that of Anse Soldat, yet no seagrasses associated to the rear reef. The reef at Porte La Fin is dead.

The Calibishie reef is the largest reef in Dominica, extending up to 500 m from shore in depths of 0.3 to 5 m (Fig. 11). Live coral cover peaks in some forereef areas at under 10 % and is all but absent in other reef zones so that live corals no longer characterize the reef surface structure. The forereef framework is recognizably composed of *A. palmata* and *O. faveolata*, *D. strigosa* and *C. natans,* each with few live colonies. Pillow-like assemblages of live *M. mirabilis* and *P. porites* were present in late 2005 along the shallow northern reef margins. The reef crest is structured by eroded limestone covered with filamentous algae, and encrusting calcareous algae and sponges. Similar to Anse Soldat and Anse de Mé, the reef flats and back reef areas provide the necessary habitat for the north coast seagrass beds, composed of *T. testudinum, S. filiforme* and *H. wrightii.* Within these seagrass communities, *P. astreoides*, *P. furcata*, *F. fragum, S. siderea* and *S. radians* can be found. The latter also occur in the form of free living spherical and ovoid rollers as described by (WELLS 1988).

Between the bays of Calibishie and Hodges, lie the bays of Grande Baptiste and Petite Bapiste. The coast around Pointe Batiste is rugged, with a highly notched contour and numerous emergent rocks. Hard substrates possibly including carbonate deposits and coral reefs line the shore and extending up to 800 m from shore (Grand Baptiste Bay). No information on size, makeup or condition is available for the patch reefs in Grande Baptiste Bay. The listed coordinates in Table 1 are from an approximate central location of the entire complex.

The reef at Hodges Bay (Fig. 12) is on the leeward side of an islet that lies on the northeastern side of the bay. *Acropora palmata* frameworks constitute the main structure of the reef, with a few live colonies still remaining on its western margins and within the northern half of the reef flat, where *D. clivosa*, *D. strigosa* and *Porites* spp. are the distinguishing coral species. Massive colonies of *S. siderea* and *O. faveolata* characterize the southern margins of the reef. White calcareous sands that transition to volcanic sands within the bay characterize the eastern surroundings of the reef. The substrates on the windward side of the islets are littered in *A. palmata* skeletons, partially cemented together by crustose coralline algae, indicating that extensive stands of live *A. palmata* were previously present in this area. No live colonies of *A. palmata* have been found within the immediate windward surroundings (50 m) of the islet.

Three patch reefs make up the most noticeable reefs at Woodford Hill and lie in depths of 1 to 10 m. Portions of the reef closest to shore, are emergent during spring tides. It is the structurally most complex reef in this area. Rising up to 8 m on its deep end, it is broken up by caves and deep fissures. The reef top is densely covered in hydrocoral, zoanthids, gorgonians and filamentous algae. *Acropora palmata* constitutes one of the principal framework builders in all reefs together with *O. faveolata, S. siderea*, *D. strigosa* and *D. clivosa.* Large colonies of each are still alive but do not add much to the low live coral cover now typical of north coast reefs.

The area west of Woodford Hill, between Pointe La Soie and Crompton Point has hard substrates extending up to 600 m from shore but is unexplored. Only the immediate western vicinity of Pointe La Soie was examined in 2000, and the seafloor was littered in *A. palmata* skeletons, similar to the windward side of the islets at Hodges Bay. Satellite imagery from 2011, shows clusters of patch reefs between Pointe La Soie and Crompton Point. *Acropora palmata* stands might thus have characterized the area, and massive species may be alive on the deeper forereefs, as in Calibishie, but there are no good arguments why this area should not be as deteriorated as other north coast reefs. The beaches at Thibaut, Anse Soldat, Anse de Mé, Bense, Batibou, Porte La Fin, Calibishie, Woodford Hill, and the east coast beach at Marigot's Middle Bay are the only white calcareous sandy beaches in Dominica, with sands originating from the adjoining fringing

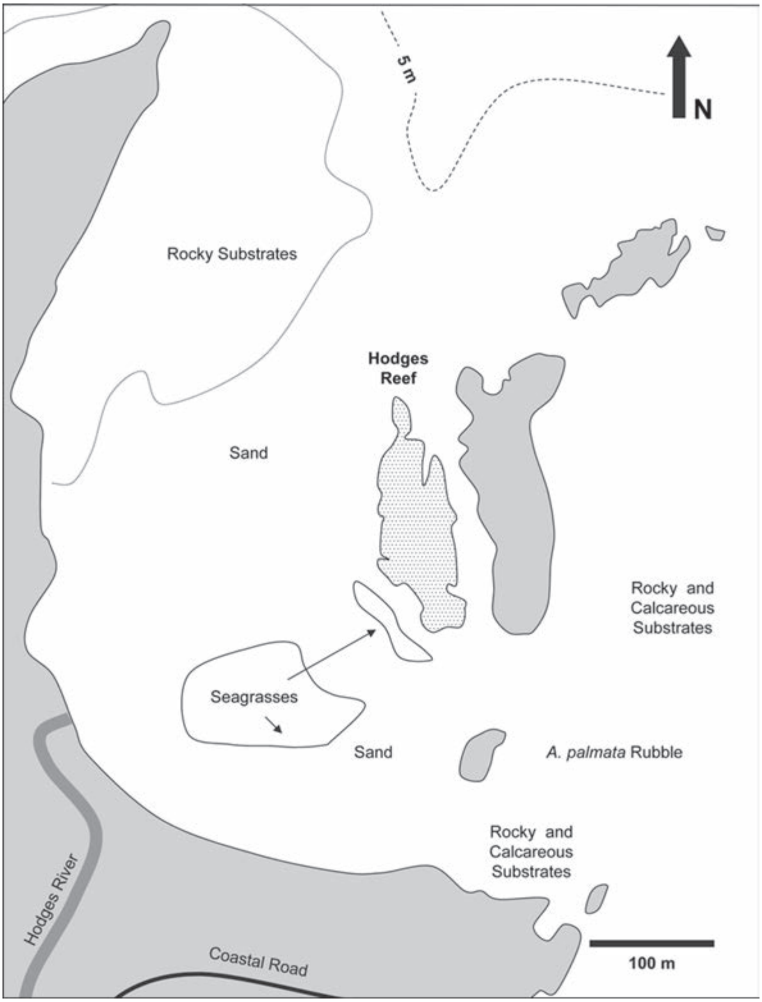

Fig. 12: Hodges Reef (Site 23), Hodges Bay, north coast.

reefs. Herein lays a visible example of how coral reefs have influenced the appearance of northern bays. Stony corals are not the only organisms involved in the construction of reefs, nor the only source of calcareous sediments, but their growth, together with that of other calcareous organisms, counteracts the continuous erosion of reefs. Their diverse skeletal growth forms contribute to the reefs' structural complexity, which in turn fosters a myriad of gradients in environmental parameters (e.g. light, water flow, oxygen levels), and opens physical and ecological niches for a diverse array of species; features that are lost with declining live coral cover and diversity

East and South Coast

East coast reefs are shallow fringing reefs and they are located in north-facing bays at Marigot and long the southern margins of east-facing bays in Pagua Bay, Anse Quaneri

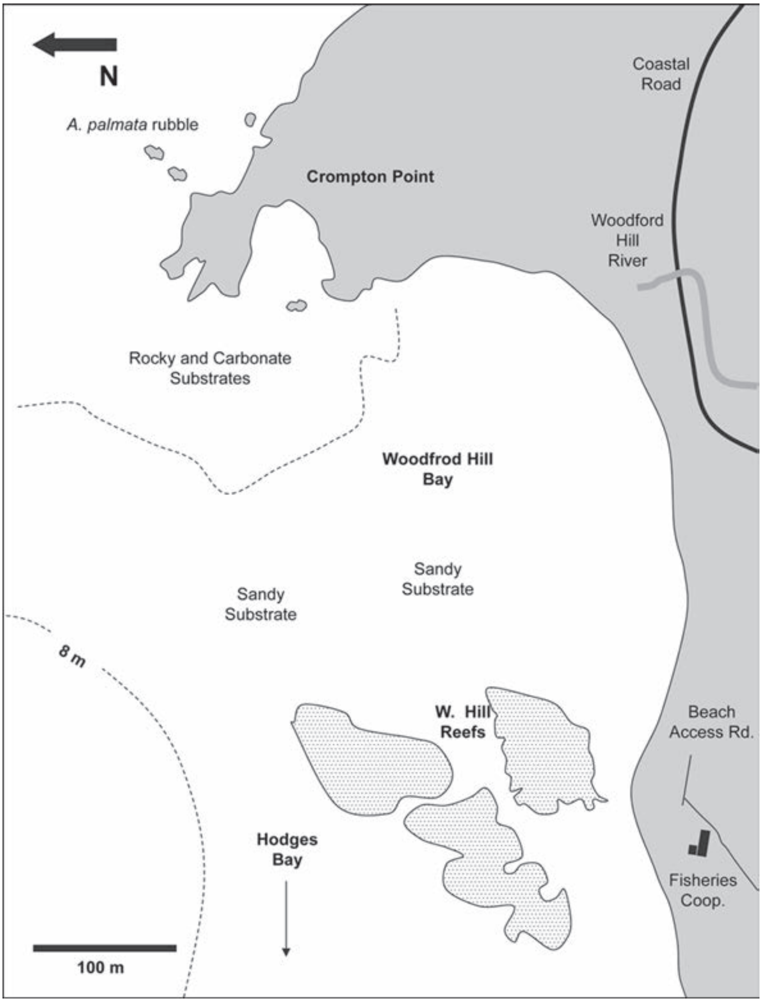

Fig. 13: Woodford Hill Reefs (Site 16), north coast.

and Saint Sauveur (Fig. 2). Pagua Bay remains unexplored. The reef at Marigot (Fig. 14), in depths of 1 to 5 m, is heavily overgrown by algae (*Sargassum* and *Dictyota* spp. stand out), along the northern half of the reef. *Diploria strigosa*, *D. clivosa*, *C. natans,* and *A. palmata* are the main live scleractinians shaping the topography of the reefs southern half. Towards the east, stands of the hydrocoral *M. complanata* characterize shallow portions of the reef, where incoming waves break. Only a few large *S. siderea* colonies are on this reef, however, dense clusters of *S. siderea* recruits (≤ 100 m^{-2}) have been observed in the back reef areas at this location. Within the sandy areas behind the back reef are Dominica's eastern-most occurring stands of *T. testudinum,* and *S. filiforme.*

At Anse Quaneri, also known as St. David's Bay (Fig. 15), two islets dissipate wave energy from Atlantic surge along its southeastern limit. The coral reef is sheltered from the direct impact of the Atlantic's surge. Three distinct bands are evident within the

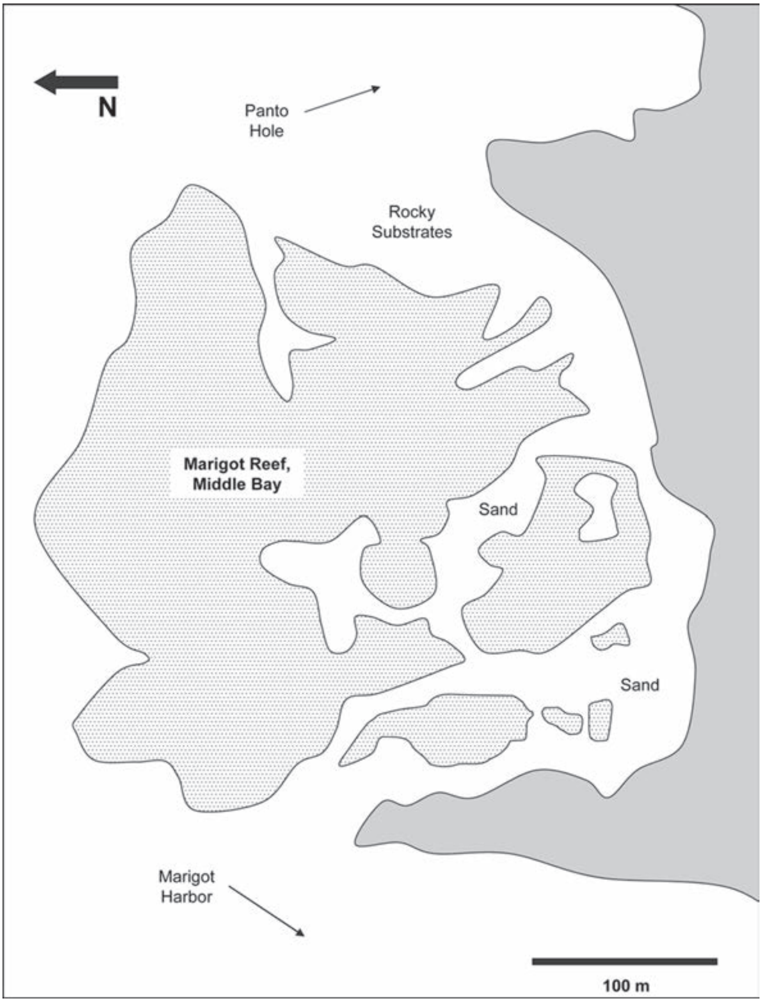

Fig. 14: Marigot Reef (Site 3) in Middle Bay, east coast. Depth does not exceed five meters.

epibenthic communities of the reef flat. From shore towards the reef's edge these are: a near shore zone dominated by extensive mats of zoanthids (*Zoanthus* spp.), followed by areas dominated by the encrusting gorgonian *Erythropodium caribaeorum*. Sea fans (*Gorgonia* spp.) dominate the seaward areas of the reef just before the reef's edge along which encrusting forms of *D. strigosa*, *D. clivosa*, *M. cavernosa*, and *S. siderea* are among the few live corals. Massive representatives of *S. siderea* line the northern reef edge, while *A. palmata* frameworks are best detectable along the eastern margins of the reef and include a few live colonies. *Porites branner*i was first recorded in Dominica at this reef in 2002 and was later also identified at Anse Soldat and Hodges Bay (north coast), and Marigot and St. Sauveur (east coast).

The reef at St. Sauveur is also positioned along the southern side of the bay. Eastern headlands offer protection from the Atlantic surge (Fig. 15). A manmade channel separates

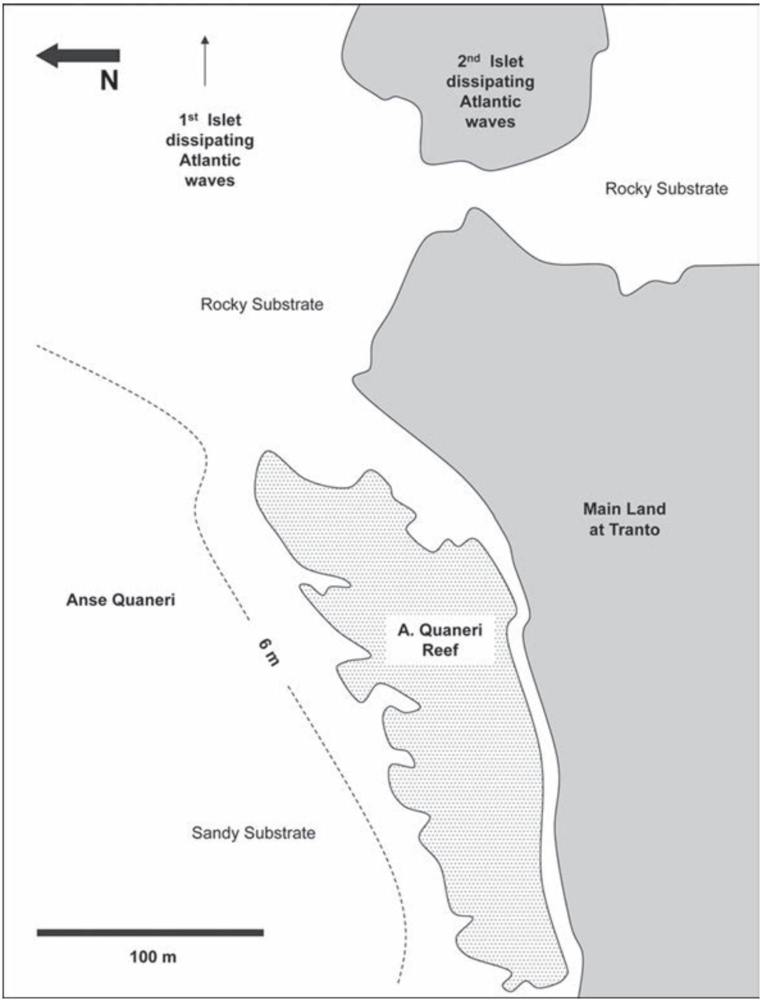

Fig. 15: Anse Quaneri Reef (Site 14), east coast.

the smaller western portion from the larger eastern portion of the reef. In 2006 a wave breaker was built on top of the reef and large sections of the reef flat were excavated. Prior to this disturbance, *D. strigosa* and *D. clivosa* were among the dominant living corals along the reef edge. A few live *S. siderea* up to 3 m in diameter and sheet-forming *O. faveolata* also characterized this part of the reef. Erosional channels within the limestone were diagonally aligned from southwest (reef flat) to northeast (forereef). *Acropora palmata* frameworks and a few live specimens lined these channels. The zoanthid – gorgonian communities on the reef flat were similar in composition and distribution than those at Anse Quaneri, yet far less dense, due to direct chronic human disturbances.

To the east of Fond St. Jean, a small patch reef near Roche Cassé (Fig. 2, Site 26) and the dead fringing reef at Dubuc (Fig. 2, Site 11) are the only coral reefs identified in this region. Given the turbulent waters of the south coast, it was somewhat surprising to find

M. mirabilis to be the principal scleractinian constructional component at Roche Cassé, as it has not been seen on any other southern or eastern reef. Compared to all other reefs along the eastern and southern shores, the live coral cover at Roche Cassé is high with 25 %, albeit not diverse. This patch reef contrasts the situation at Dubuc where a structurally well-developed fringing reef no longer bears live corals. *Acropora palmata* skeletons make up the principal branching frame works, and *O. faveolata* and *S. siderea* the massive ones.

Distribution and description of coral assemblages

Distinguishing coral reefs from coral assemblages in Dominica can be done with constructional variables such as the presence or absence of limestone substrates and skeletal frameworks. Delineating the area of each reef is thus an equally straightforward and replicable process. However, distinguishing a coral assemblage from sparsely occurring scleractinian colonies and defining their boundaries is far less clear-cut, because corals grow throughout the spectrum between these two extremes. Dominica's coral assemblages are exposed to natural environmental parameters that are close-to-adequate for reef building on one end of the spectrum and inadequate on the other end. Anthropogenic disturbances can further change the coral composition in such habitats.

To define coral assemblages, the co-occurrence of three features is used. The first two are an indication of potential moderate longevity of an assemblage (≥100 years); the presence of stable hard substrates for the settlement of corals and the presence of what are considered large colonies based on known species-specific size ranges. The third feature is a benthic live coral cover of no less than 5 % within the assemblage, and it is based on an island-wide comparison of non-reef coral growth areas. Twenty-seven sites meet the criteria, twenty-six of them are located along the west coast and one is on the south coast (Table 2). Another assemblage met the criteria up to 2003 (Marigot Bay). It was in surprisingly good condition, despite the heavy inputs of sediments, agrochemicals and solid waste, but was removed during the construction of a new port (2003–2004), and is not listed.

The surface area covered by coral assemblages has not been ascertained. In order to provide an indication of the size of individual assemblages and to allow persons to locate and explore them, the following references have been complied in Table 2. The central point of an assemblage was selected and its coordinates recorded. From this point, assemblages spread across the listed depth range within the given distance (radius). Obviously this approach bares much subjectivity and serves as rough estimate for local comparisons. Dominica's coral assemblages are thus sorted by their location from north to south, rather than by size. In the cases of Grande Savane (Fig. 17) and Soufriére N (Fig. 18, Site 17) assemblages of varying sizes are close to each other along the shore between Batali and Salisbury, and between Pt. Guignard and Soufriére, respectively. Each of these areas is presented as single site.

Dominica's coral assemblages are the result of chronic disturbances at levels that allow for repeated larval settlement, but not a prolonged accretion of carbonate substrates. In evaluating the condition of a west coast assemblages, depth and substrate type need to be considered. Colonies on smooth rounded rocks, in shallow waters up to 5 m depth along the west coast, are detached and removed more easily under direct physical impacts

Table 2: Coral assemblages of Dominica, North to South. Except for Scott's Head (S), all locations are on the west coast. Substrate types are classified as follows: **Rocks**, [1]rounded or [2]jagged; **Bedrock**, [1]lava or [2]ash; **Conglomerates**, [1]rounded or [2]jagged allochtone rock inclusions, or [3]solidified autochtone beach fronts. Radius refers to the distance (m) from the central point (coordinates), within the given depth range, to the outer limits of a particular assemblage.

No.	Name	Type of substrate	Depth (m)	Radius	Coordinates of Central Point
32	Capucin	Rocks	1–5	50	15°37'48.00"N 61°27'48.40"W
33	Clifton	Rocks and Conglomerates[1,2]	1–5	60	15°37'20,92"N 61°27'58.54"W
34	Cottage	Rocks	1–5	70	15°36'49.39"N 61°28'00.31"W
35	Toucari (N)	Rocks and Conglomerates[2,3]	1–5	150	15°36'40.27"N 61°27'59.58"W
36	Douglas (N)	Rocks	1–5	200	15°36'13.51"N 61°27'53.17"W
37	Cabrits (N)	Rocks	3–10	80	15°35'26.29"N 61°28'21.12"W
38	Cabrits (W)	Rocks	3–30	700	15°35'03.11"N 61°28'47.20"W
39	Ti Bay (S)	Rocks	1–5	40	15°32'46.32"N 61°28'24.96"W
40	Pointe Ronde	Bedrock[1]	2–5	40	15°32'42.50"N 61°28'39.27"W
41	Espagnol Bay	Conglomerates[1]	2–5	50	15°31'55.47"N 61°28'40.81"W
42	Espagnol Cliff	Rocks	2–10	60	15°31'32.12"N 61°28'26.99"W
43	Anse Liane	Rocks	2–15	130	15°29'33.10"N 61°28'04.75"W
44	Anse Cola	Rocks	2–5	70	15°28'52.12"N 61°27'42.32"W
45	Gueule Lion	Rocks	2–5	30	15°27'46.45"N 61°27'18.75"W
46	Grande Savane	Rocks, Bedrock and Conglomerates[3]	2–10	1100	15°26'30.53"N 61°26'57.82"W
47	Macoucheri	Rocks and Conglomerates[1,2]	2–10	80	15°25'45.58"N 61°26'13.00"W
48	Mero (N)	Rocks and Conglomerates3	3–14	250	15°25'08.96"N 61°26'02.86"W
49	Tarou Point	Bedrock[2]	2–15	100	15°22'50.38"N 61°24'42.31"W
50	Les Pointes (N)	Rock and Bedrock[2]	1–6	50	15°21'25.94"N 61°23'46.14"W
51	Massacre	Rocks	2–6	50	15°21'03.33"N 61°23'29.45"W
52	Fond Colet	Rocks and Conglomerates[1,2]	0–6	120	15°19'13.11"N 61°23'42.29"W
53	Loubiere Falaise	Rock	3–10	130	15°16'12.12"N 61°22'32.46"W

No.	Name	Type of substrate	Depth (m)	Radius	Coordinates of Central Point
54	La Vigi	Conglomerates[2]	3–10	160	15°15'04.49"N 61°22'32.05"W
55	Pt. Guignard (N)	Bedrock[2] Conglomerates[2]	2–25	160	15°14'35.93"N 61°22'24.13"W
56	Sorcière/ Soufrière	Bedrock[2]	5–40	710	15°14'10.58"W 61°22'07.32"W
57	Scott's Head (W)	Bedrock[2]	5–40	260	15°12'53.56"N 61°12'53.56"W
58	Scott's Head (SE)	Bedrock[2]	6–30	170	15°12'28.08"N 61°21'45.56"W

(storms, debris), than colonies in deeper waters or on rough stony surfaces. This reduces live coral cover and the incidence of skeletal remains in the former. Shallow assemblages on high relief rounded rock substrates therefore often appear healthier, but less species rich and with a lower benthic cover, than those on rough surfaces, or in greater depths. At the only south coast assemblage this pattern is shifted to greater depths because of the turbulent conditions along the Martinique Passage.

Along the west coast, the distribution of coral assemblages roughly concurs with the availability of stable substrates in the form of rocky outcrops from lava or pyroclastic flows and consolidated beachfronts, and along boulder fields and rocky alluvial deposits. While coral assemblages do not cover all rocky areas, they do not occur on other types of substrate. Species rich assemblages with comparatively large-sized colonies grow best at localities furthest away from rivers with year-round outputs, and in areas that are well flushed by alongshore currents such as Cottage, the western portions of Cabrits (Fig. 5), the stretch between Morne Espagnol and Colihaut (Fig. 4A), Grande Savane (Fig. 4B) Mero (Fig. 8), and the rocky sublittoral between Pt. Michel and Soufrière (Fig. 2). An exception is Macoucheri where a species-rich coral assemblage with numerous colonies of more than 1 m in diameter, is situated next to the Macoucheri River mouth to its south and just 300 m from the Salisbury River.

Another outstanding coral assemblage is Mero North (Fig. 8). Corals grow on the submerged remnant of an eroded spit of the coastal headlands that is now located in depths of 7 to 15 m. It is a formation that topographically distinguishes itself from the seagrass beds to its north, east and south, and the reef to its west. Jagged rocks and the rounded rocks typically seen on rocky beaches and the adjoining sublittoral mark its substrate composition. Within the southern quarter of this assemblage, coral clusters including massive colonies, protrude above the surrounding rocky substrate and the scattered coral, and were defined as the Mero East Patch Reef in Steiner & Willette (2010). A closer look at the underlying substrate showed that it is comprised of well-sorted, marble-sized pebbles (typical for the rocky beach intertidal) that are cemented by calcareous algae, and not coral rubble deposits or other carbonate frameworks as originally presumed.

Where solid basalt constitutes the substrate, assemblages have in some cases formed patches of a reef-like coral veneer. A good example of this scenario is the coral assemblages adjacent to the Soufrière N Reef (Fig. 18); in depths between 8 and 18 m, they are diverse in species and structure, include *M. mirabilis* patches. At these and shallower

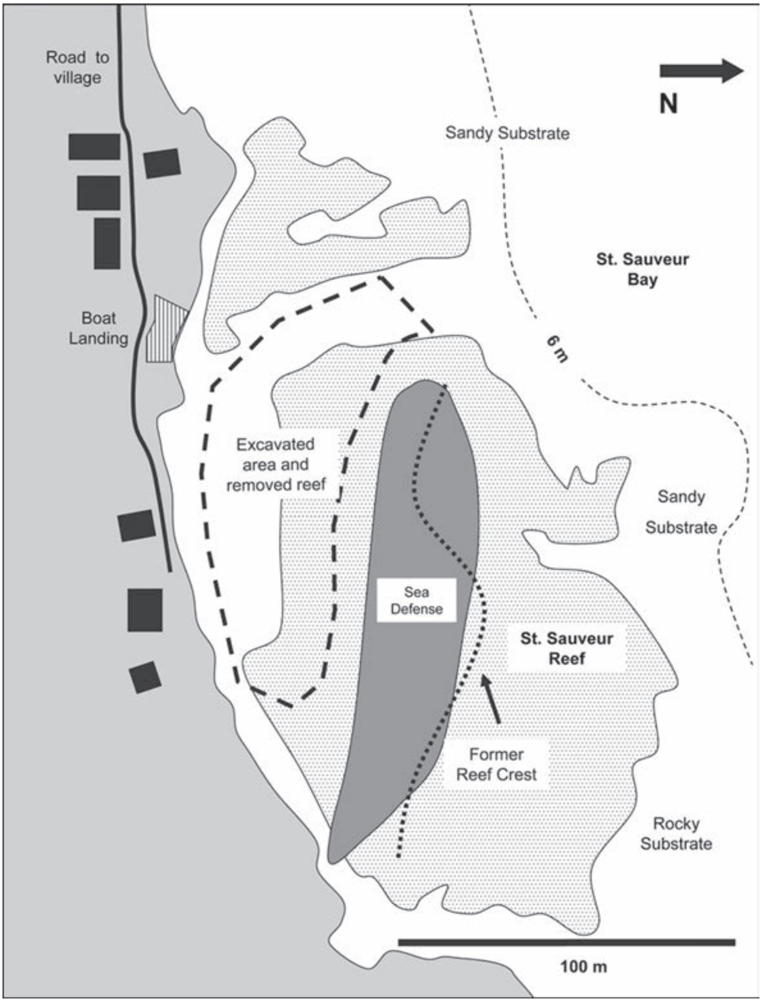

Fig. 16: Saint Sauveur Reef (Site18), east coast.

depths, the grazing urchin *Diadema antillarum*, common in Dominica, plays an important role in limiting controlling macroalgal growth. The widespread vertical drop offs where shading is a limiting factor for light-dependent communities do not harbor significant coral assemblages.

The northern sides of rocky outcrops and peninsulas, such as Tarou Point (Fig. 2, Site 49) and Cabrits (Fig. 5, Site 36), are influenced by eddies and are also prone to the establishment of coral clusters including massive specimens, primarily among *S. siderea*, *O. annularis*. *O. faveolata*, and *D. strigosa*. Submerged remnants of lava and pyroclastic flows at Pointe Ronde (Fig. 4A, Site 40), as well as patches of solidified rounded rocks and pebbles from old beachfronts at Espagnol Bay (Fig. 4A, Site 41) and Grande Savane (Fig. 17) and river mouths at Clifton (Fig. 5, Site 33) also harbor coral assemblages.

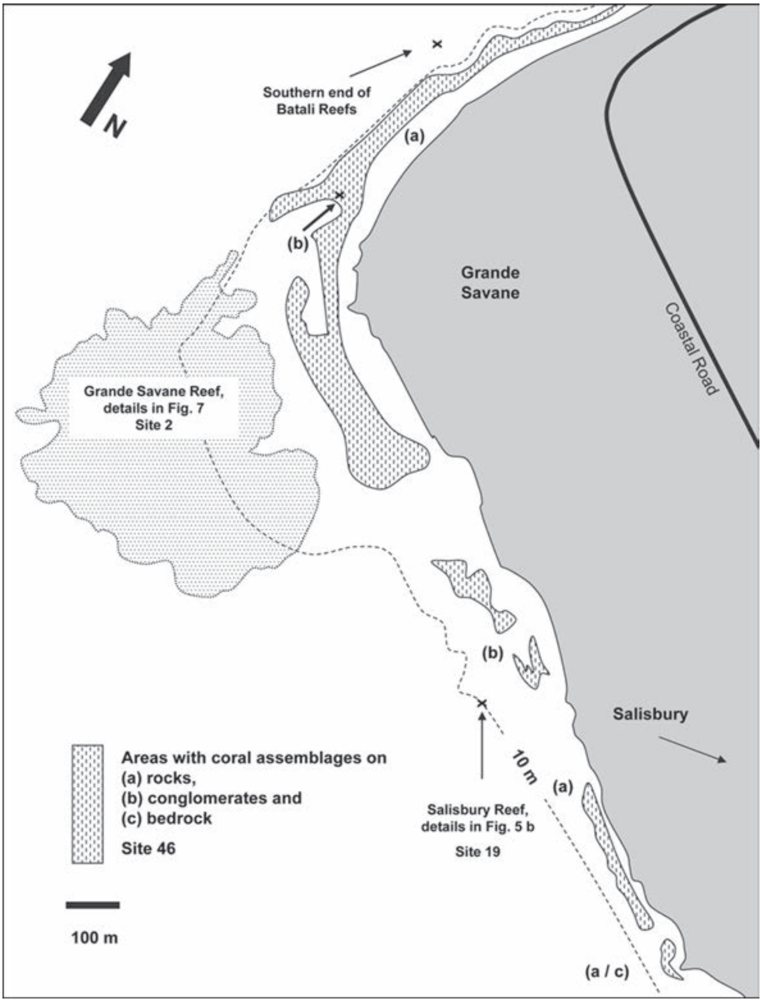

Fig. 17: Coral assemblages at and around Grande Savane (Site 46), west coast.

With the exception of Marigot, coral assemblages as described above have not been found along the north coast. Coral assemblages have also not been found along the east coast where bare rocks and extensive fields of rounded boulders characterize the sub-littoral at least up to 20 m depth. Rocky substrates along south coast are equally barren from Dèlices up to the vicinity of Scott's Head, where well-developed coral assemblages are located southwest of the village (Fig. 2, Site 57).

Distribution of Scleractinia and Anthothecata

In the absence of extensive contiguous reef tracts, the forty-six Scleractinia (stony corals), and the four Anthothecata (three fire corals, Milleporidae) and one lace coral (Stylasteridae) reported thus far, are distributed across reefs and rocky habitats; these

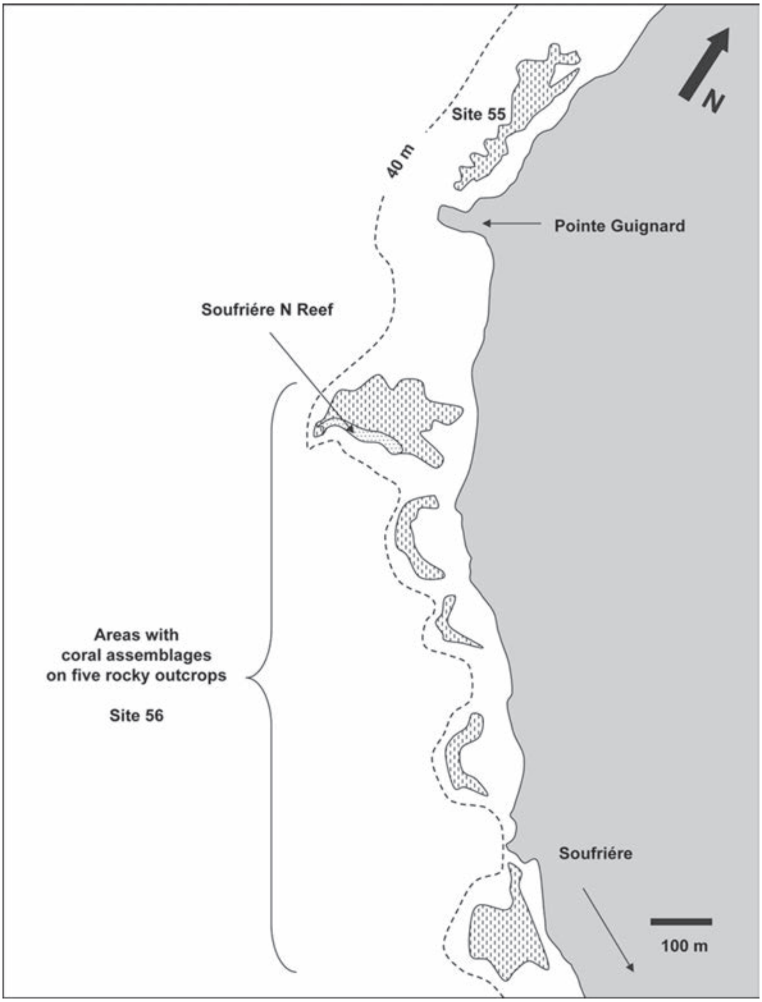

Fig. 18: Coral assemblages and Soufriére Reef N (Site 17), in the vicinity of Point Guignard, southern west coast.

are the windward and leeward shallow fringing and patch reefs extending to depths of up to 8 m, the deeper leeward reefs between 8 and 30 m depth, and the leeward rocky substrates. Given the specific parameters of each of these environments, the distribution of generalist (eurytopic) and specialist (stenoek) species shows no surprises. However, the multiple environmental stressors that are affecting Dominica's coral and discussed in detail in a separate section, have resulted in pronounced differences in species occurrence across the island's coral habitats.

The critical condition of north, east, and south coast fringing reefs is not only reflected in their low live coral cover, particularly among framework building species such as *A. palmata*, but also in their comparatively low species richness. The bulk of the species recorded for the east and south coast are in fact from just one reef (Marigot, Fig. 14) and

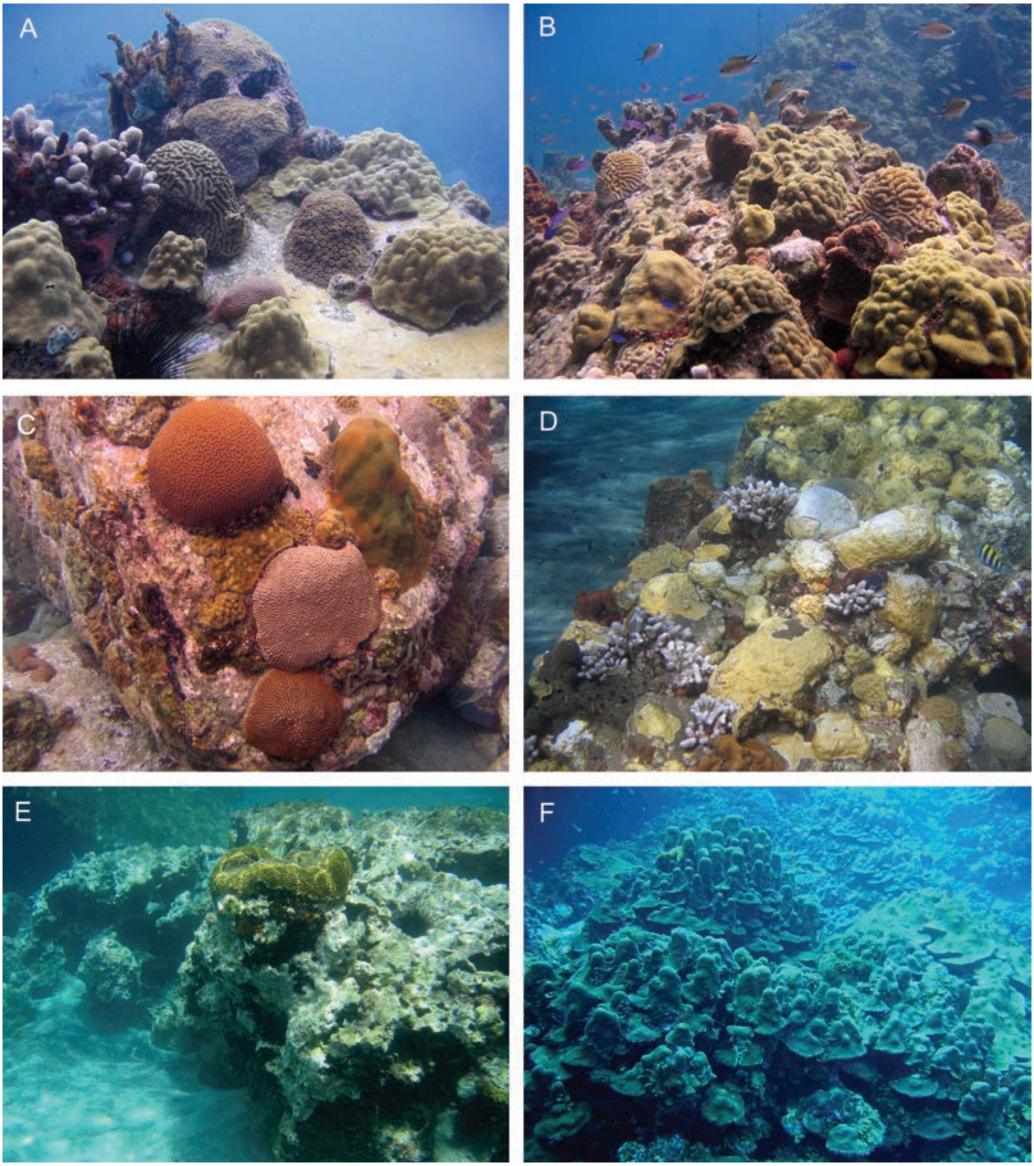

Fig. 19: A, Coral assemblage on boulders near Salisbury. B, Coral reef, spur and groove formation, spurs in foreground and background. C, Corals on a boulder at Batali with *Diploria labyrinthiformes* (spherical colony, top l.) *Orbicella faveolata* (top r.) *Porites astreoides* colonies below *D. labyrinthiformes*, and two *D. strigosa* colonies (lower half). D, Stony corals (*Porites furcata, P. astreoides, O. faveolata*) and encrusting fire corals (*Millepora* sp.) growing on consolidated rocks, Pointe Ronde. E, Margin of a coral reef with a single partially live colony, *D. strigosa*, Ti Bay. F, *O. faveolata* draping the forereef and Cachacrou in 2004. These colonies are now dead.

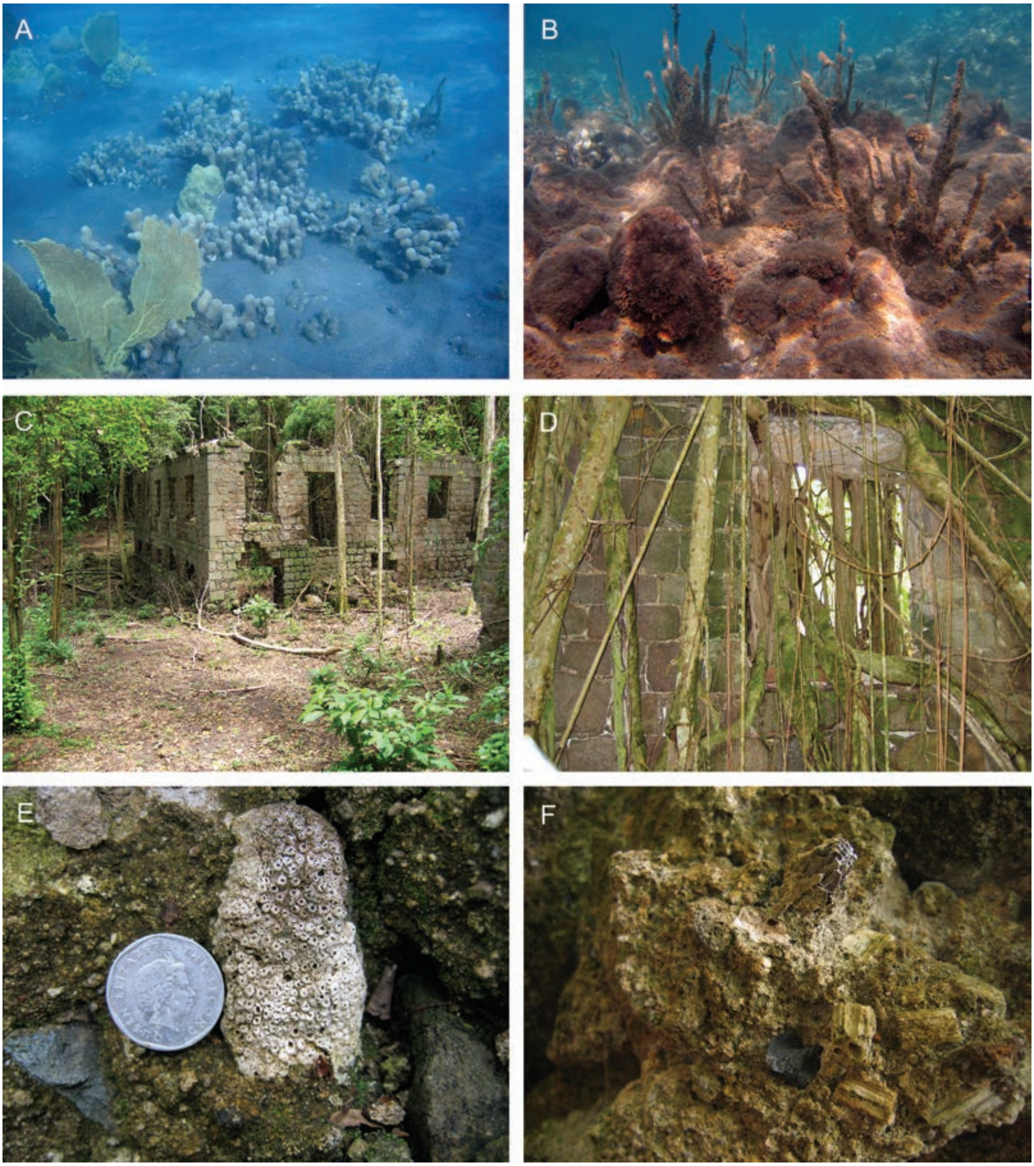

Fig. 20: A and B, Corals near Fond Colet, in March 2005. Most of the assemblage was completely covered by sediments, transported by uncommon south-westerly waves. It took 8 months of normal wave patters to remove the sediments. Filamentous turf algae, as seen in image B taken in 2007, colonized the dead coral assemblage. C and D, Ruins of Douglas Bay Battery, Fort Shirley (built between 1765 and the 1820s), Cabrits. E and F, Walls and foundations are built from blocks of volcanic rock, held together by mortar containing coral fragments and charcoal from coral kilns.

Table 3: Distribution of live Scleractinia and Anthothecata across Dominica's coral reefs and assemblages listed in Tables 1 and 2. Occurrence categories for each species: **abundant** (constitutes the dominant live coral cover), **common** (found at most locations without covering much ground), **occasional** (found at less than half of the locations in small numbers), **rare** (found at few locations in small numbers), ? (occurrence not specified), **–** (species not reported). Distribution patterns: **even**, **patchy**, **clustered**, **single location, single colony**. Additional qualifiers: [1] in the form of large banks, [2] status prior to acute change in occurrence and distribution due to high mortality following the 2005 coral-bleaching episode.

Scelarctinia

		West	North	East	South
	Astrocoeniidae				
1	*Stephanocoena intersepta*	common, even	-	-	-
	Pocilloporidae				
2	*Madracis mirabilis*	occasional, patchy [1]abundant, clustered	occasional, patchy	-	-
3	*Madracis decactis*	common, even	common, patchy	-	-
4	*Madracis formosa*	-	-	-	single location
	Acroporidae				
5	*Acropora palmata*	rare	occasional, patchy	rare	rare
	Siderastreidae				
6	*Siderastrea siderea*	common, even	common, even	occasional, patchy	occasional, patchy
7	*Siderastrea radians*	common, even	common, even	common, even	common, even
	Agariciidae				
8	*Agaricia agaricites*	occasional, patchy [2]abundant, even	occasional, patchy	-	rare
9	*Agaricia danae*	occasional, patchy	occasional, patchy	-	-
10	*Agaricia crassa*	rare	-	-	-
11	*Agaricia humilis*	occasional, patchy	-	-	-
12	*Aparicia pupurea*	rare	-	-	-
13	*Agaricia lamarcki*	occasional, even	occasional, patchy	-	-
14	*Leptoceris cucullata*	occasional, even	-	-	-
15	*Leptoseris cailleti*	-	-	-	?

Scelarctinia

		West	North	East	South
	Mussidae				
16	*Isophyllia sinuosa*	occasional, even	rare	rare	-
17	*Mussa angulosa*	occasional, even	-	-	-
18	*Scolymia cubensis*	rare, patchy	-	-	-
19	*Mycetophyllia danaana*	rare	-	-	-
20	*Mycetophyllia aliciae*	rare	-	-	-
21	*Mycetophyllia lamarckiana*	rare	-	-	-
22	*Mycetophyllia ferox*	rare	-	-	-
	Faviidae				
23	*Favia fragum*	common, patchy	common, patchy	occasional, patchy	occasional, patchy
24	*Solenastraea bournoni*	single colony	-	-	-
25	*Orbicella annularis*	occasional, even [2]common, patchy	occasional, patchy	rare	-
26	*Orbicella faveolata*	common, even	occasional, patchy	rare	occasional, patchy
27	*Orbicella franksi*	occasional, patchy	-	-	-
28	*Montastraea cavernosa*	common, even	occasional patchy	-	occasional, patchy
29	*Diploria strigosa*	common, even	occasional, patchy	occasional, even	-
30	*Diploria clivosa*	common, even	common, even	common, even	-
31	*Diploria clivosa morph1*	rare	-	-	-
31	*Diploria labyrithinformis*	common, even	-	-	-
32	*Colpophyllia natans*	occasional, patch	?	-	-
	Caryophyllidae				
33	*Eusmilia fastigiata*	occasional, patchy	-	-	-
	Meandrinidae				
34	*Meandrina meandrites*	common, even	occasional, patchy	-	occasional, patchy
35	*Meandrina jaksoni*	occasional, even	-	-	-
36	*Meandrina danae*	occasional, clustered	-	-	-
37	*Dendrogyra cylindrus*	rare	-	-	-
38	*Dichocoena stokesii*	common, even	rare	-	-

		West	North	East	South
	Scelarctinia				
	Poritidae				
40	*Porites porites*	occasional, even [2]abundant, patchy	rare	-	-
41	*Porites furcata*	occasional, even [2]abundant, patchy	occasional patchy	rare	-
42	*Porites divaricata*	rare	common, patchy	occasional, patchy	-
43	*Porites astreoides*	abundant, even	common, even	occasional, even	occasional, patchy
44	*Porites colonenis*	-	-	-	rare
45	*Porites branneri*	-	rare	occasional, even	-
	Dendrophyliidae				
46	*Tubastraea coccinea*	rare, clustered	-	-	-
	Anthoathecata				
	Milleporidae				
47	*Millepora complanata*	occasional, patchy	common, patchy	occasional, patchy	?
48	*Millepora squarrosa*	occasional, even	-	-	-
49	*Millepora alcicornis*	common, even	common, even	?	?
	Stylasteridae				
50	*Stylaster roseus*	occasional, even	-	-	?

one coral assemblage (Scott's Head SE, Fig. 2, Site 58). Characteristic windward coral communities are thus no longer discernable along the reef crests and forereefs, with the exception of *M. complanata* patches on a few reef crests in the north. Corals typical for a particular reef zone, are only conspicuous in the shallow reef flats and rear reef areas and include *P. divaricata* and *P. branneri*, and the unattached spherical colonies of *S. radians*.

Few shallow fringing reefs or reef portions exist on the leeward side (e.g. Toucari, *M. mirabilis* Bank at Cachacrou) and are in an equally poor state. Their structural complexity, however, does not stem from *A. palmata* frame-works but from the massive *O. annularis*, *O. faveolata*, *D. strigosa*, *C. natans*, and *S. siderea,* and the encrusting *D. clivosa*. On these reefs, the chronic reduction of species diversity and live coral cover has gone hand-in-hand with the loss of structural complexity.

Dominica's leeward reefs in 10–40 m depth are richer in scleractinian species, particularly those that span a wide depth range. The region between Batali and Mero, stands out with its diverse microhabitats at depths with intermediate disturbance levels *sensu* CONNEL (1978) with regards to light, sediment inputs and turbulence. Its reefs are among the largest on the island and close to each other so that comparatively large numbers of colonies occur within each species in that region. With the exception of typically windward species and species associated with shallow reef flats, the majority of Dominica's coral species are found within the Batali - Mero area. Weedy species dominate coral communities in colony numbers and coral cover in the shallow rocky environments. As in coral reefs, assemblages that are located under surface current eddies (e.g. Tarou, Cabrits) are richer in species than those without these features.

One azooxanthellate stony coral, *Tubastraea coccinea,* has so far been documented in Dominica's sublittoral habitats, although other species exist in shaded settings as the ceilings of caves. Further details on the distribution of individual coral species across Dominica are summarized as follows and in Table 3.

Order Scleractinia

Suborder Astrocoeniina

Family Astrocoeniidae (Fig. 21)

Stephanocoenia intersepta (ESPER, 1795) is evenly distributed along the west coast, on coral reefs and assemblages. Young colonies of 1-5 cm in diameter (recruits), as well as large colonies are common. Yellow and brown varieties are common, while the green varieties are rare.

Family Pocilloporidae (Fig. 21)

Madracis mirabilis (DUCHASSAING & MICHELOTTI, 1860) currently also referred to as *M. auretenra* by LOCKE, WEIL & COATES (2007) exhibits various distribution patterns. It is abundant where it has formed bank reefs, yet occurs occasionally elsewhere. Although several areas still harbor live banks or large thickets (Mero, Batali) most of those that are close to settlements and at frequently visited sites (Cachacrou) have been destroyed by direct physical impacts. *M. decactis* (LYMAN, 1858) is evenly distributed throughout the west coast, often growing near the edges of larger coral assemblages, especially overhangs and steep or vertical surfaces. Its occurrence in the north, east, and south is

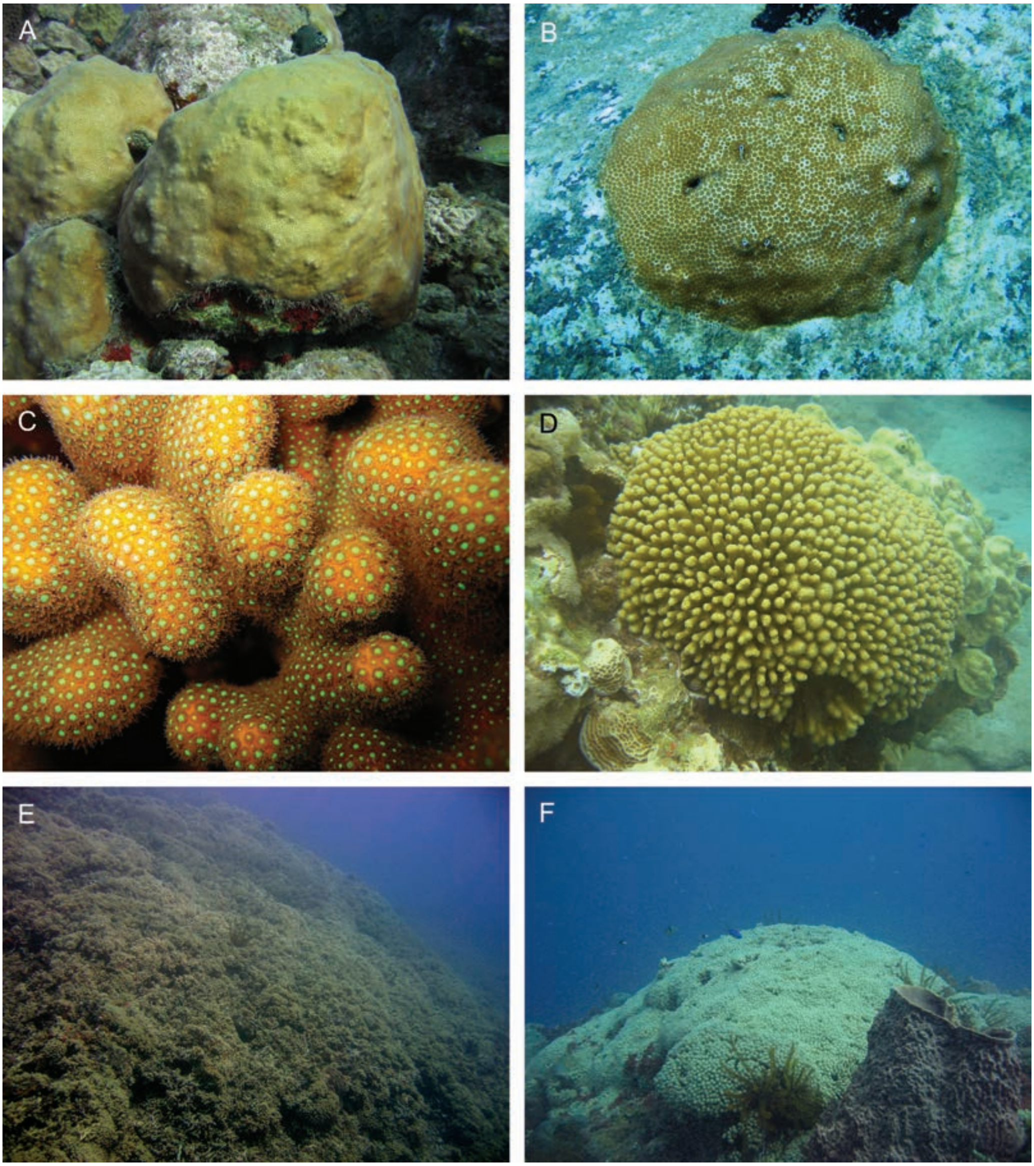

Fig. 21: A, *Stephanocoenia intersepta*, Salisbury. B, *S. intersepta*, Batali. C, *Madracis decactis*, Grande Savane. D, *Madracis mirabilis*, Toucari. E, *M. mirabilis* Bank Reef, Mero. F, *M. mirabilis*, Batali.

not well documented. *M. formosa* (WELLS, 1973) has only been reported from one coral assemblage along the south coast (Table 2, Site 58).

Family Acroporidae (Fig. 22)

Acropora palmata (LAMARCK, 1816) is the only living representative of this family in Dominica and the principal framework builder of the north and east coast fringing

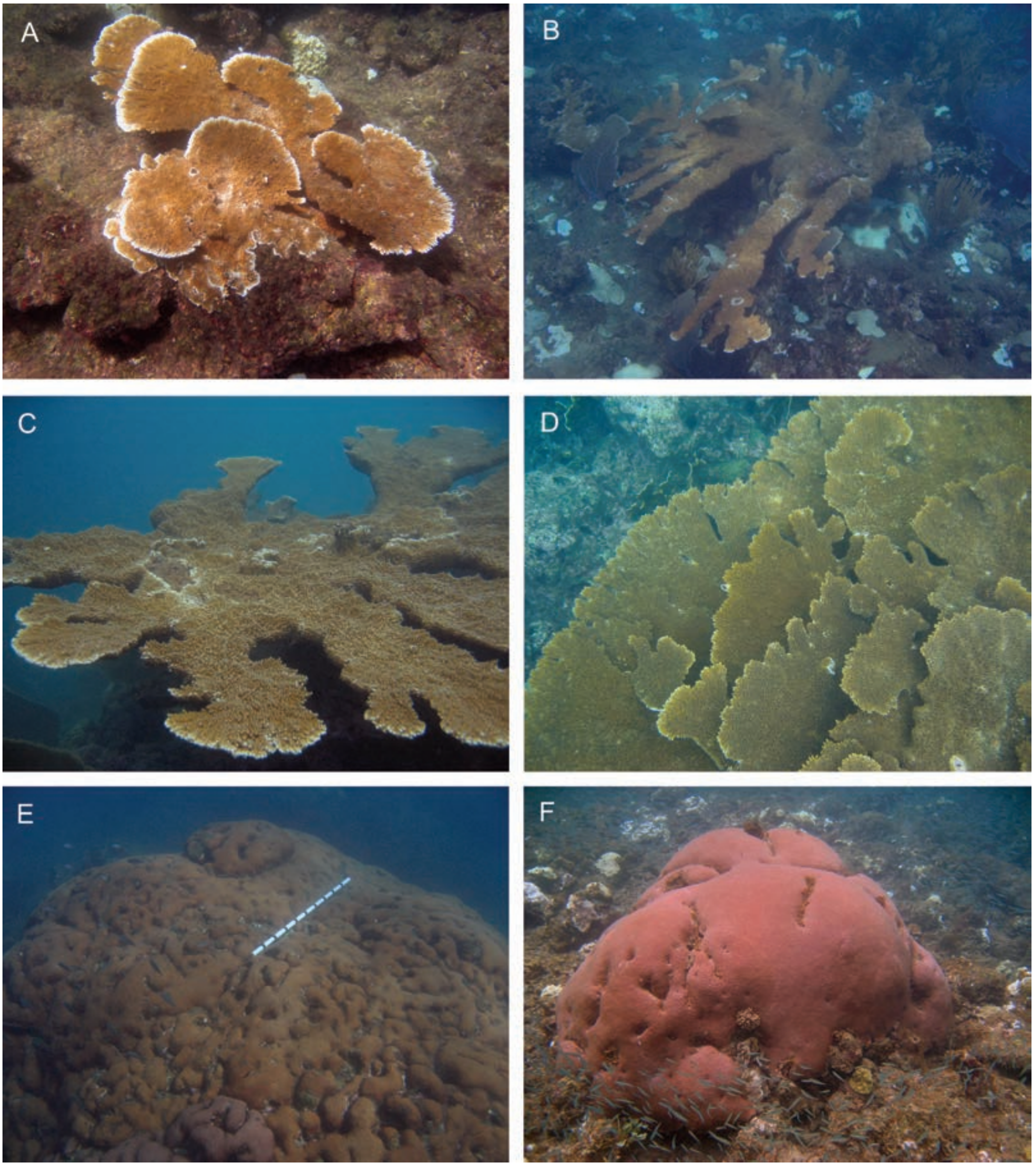

Fig. 22: A, *Acropora palmata* on *A. palmata* frameworks overgrown by filamentous algae, Calibishie. B, *A. palmata*, surrounded by bleached encrusting stony corals, Calibishie. C, *A. palmata,* Anse Soldat. D, *A. palmata*, Woodford Hill. E, *Siderastrea siderea* with 1 m reference pole, Fond Colet. F, *S. siderea*, Toucari.

reefs. However, few live colonies remain. *Acropora palmata* has suffered severe reductions throughout the Caribbean due to pathogen-induced mortality (PATTERSON et al. 2002, PRECHT et al. 2002). These factors may also have played a role in Dominica. In addition, a noticeable increase in terrestrial sediment run-off, commenced with the boom of the banana industry in the (1950s–1980s), and coincided with a drastic reduction of live coral cover along the north coast reefs (Lennox Honychurch, pers. comm.).

A few colonies of the *Acropora* morphotype referred to as *A. prolifera* (LAMARCK, 1816) by some authors, and confirmed to be a F_1 hybrid of *A. palmata* and *A. cervicornis* (VOLLMER & PALUMBI 2002), were documented in 2001, on the northeastern margins of the reef at Hodges Bay, north coast. *Acropora palmata* is and was rare along the west coast, and even more so colonies exceeding 2 m in diameter. When individual colonies do establish themselves, they are within few tens of meters from shore, mostly on rocky substrates. The only tabular colony ever recorded grew at Fond Colet, and toppled during Hurricane Lenny in 1999.

Acropora cervicornis (LAMARCK, 1816) has only been found in the form of skeletal fragments near the southern margins of Douglas Bay and Prince Rupert's Bay.

Suborder Fungiina

Family Siderastreidae (Figs. 22 and 23)

Siderastrea siderea (PALLAS, 1766) is among the most important species contibitung to massive frameworks, but has also formed many large isolated colonies in non-reefal habitats. Its evident longevity and resistance to multiple disturbances make it a key species in the structural survival of coral reefs in Dominica. On the steep slope of the Cachacrou Reef near Scott's Head, colonies with flat encrusting morphology were documented on steep slopes. Colonies with the "wide calyx morphology" were reported among coral assemblages north of Soufriére 20 m.

Siderastrea radians (ELLIS & SOLLANDER, 1786) is commonly found throughout all of Dominica's shallow habitats with stable substrates. Unattached spherical colonies were only found on the north coast backreefs.

Family Agariciidae (Figs. 23 and 24)

Quantitative records of *Agaricia agaricites* (LINNAEUS, 1758) in Dominica (Steiner 2003) encompass growth forms with thick vertical plates, also known as *A. danae* (VERRILL, 1901), the stubby branching forms referred to as *A. crassa* (VERRILL, 1901), and the rounded massive forms of *A. humilis* (VERRILL, 1901). The encrusting *A. humilis* is the least common of the four corals.

Aagaricia agaricites was an abundantly occurring species (STEINER 2003) up to late 2005 when AGRRA surveys were carried out amidst the onset of an extensive coral bleaching episode. One year later the survey was repeated at the same sixteen sites and no live colonies of *A. agaricites* (broadly defined) were found (STEINER & KERR 2008). Although new recruits were evident in late 2007, by 2013 this weedy species had not yet recovered to its 2005 status, illustrating the consequences of a single high-mortality event in less resilient species.

Agaricia purpurea (LESUEUR, 1820) and *A. fragilis* (DANA, 1846) are both rare in Dominica, and have only been observed along Dominica's west coast reefs. Among the agaricids that can form large plate-like colonies, *A. lamarcki* (MILNE EDWARDS & HAIME, 1851) is common. The distribution of *A. grahamae* (WELLS, 1973) is not clear. Both are

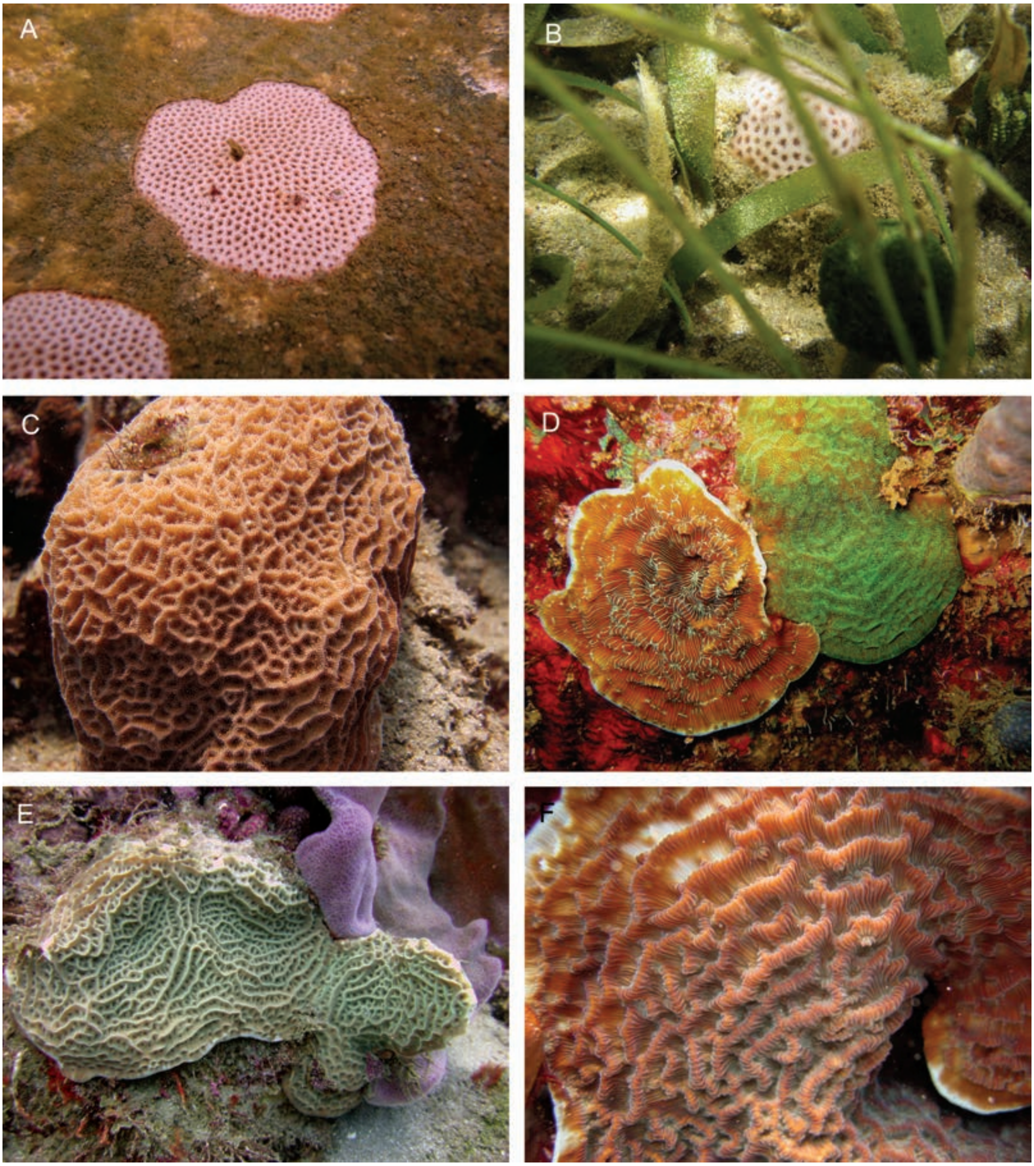

Fig. 23: A, *Siderastrea radians,* encrusting, Batali. B, *S. radians* on coral ruble within seagrass bed at Anse Soldat. C, *Agaricia humilis.* D, *Leptoseris cucullata* (le) *Agaricia* sp. (ri), Grande Savane. E, *Agaricia* sp., Mero. F, *L. cucullata*, Salisbury.

found along west coast reefs. So far, *A. lamarcki* is the only plate-like agaricid identified on north coast reefs.

Leptoseris cucullata (ELLIS & SOLANDER, 1786) is sparsely distributed along west coast reefs and coral assemblages. *Leptoseris* sp. with rougher surface than *L. cucullata* and with calices oriented in random directions has also been documented. *Leptoseris cailleti*

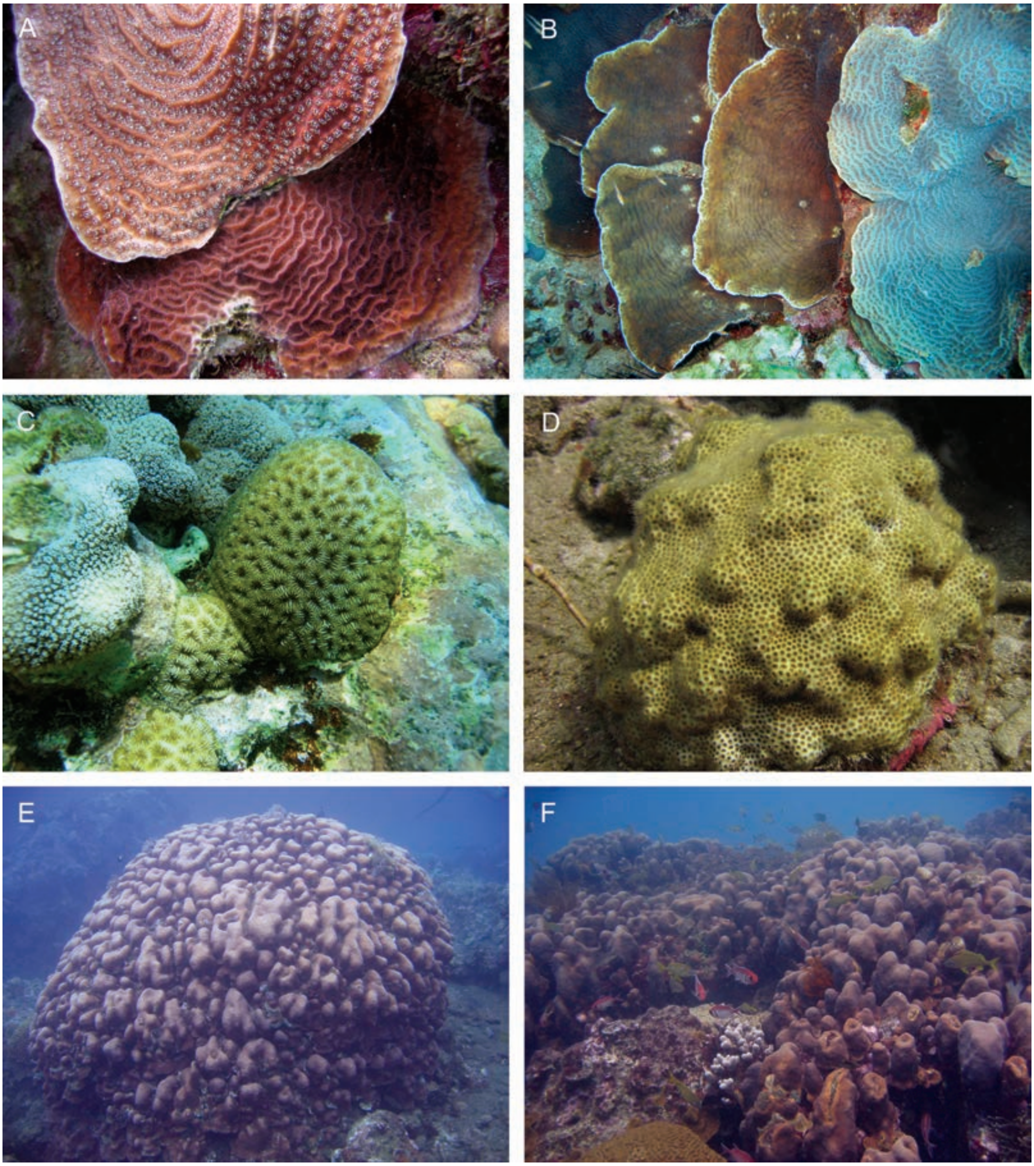

Fig. 24: A, *Agaricia lamarcki* (top) *Agaricia* sp. (*fragilis*, bottom), Batali. B, *Agaricia* spp. growing in sheets, Anse Soldat. C, *Favia fragum*, Ti Bay. D, *Solenastrea bournoni*, Salisbury. E, *Orbicella annularis*, Macoucheri. F, Extensive *O. annularis* colonies near Salisbury in 2005 (no longer alive)

(Duchassaing & Michelotti, 1864) occurs in waters deeper than 30 m and according to Cairns (1979) has been documented for depth range of 33 to 40 m "near Dominica" by Dinesen (1980). The coordinates of the sample material point at collection sites on the eastern sublittoral between Marigot and Pagua Bay.

Suborder Faviina

Family Faviidae (Figs. 24, 25, 26, 27 and 28)

Favia fragum (ESPER, 1793) is a weedy species, with golf-ball size colonies, and is commonly found along all west coast shallow habitats, but less abundant along other coasts where its shallow depth range is exposed to strong mechanical disturbances.

A single colony of *Solenastrea bournoni* (MILNE & EDWARDS, 1849) has been documented at the Salisbury Reef at a depth of 9 m.

Orbicella annulars (ELLIS & SOLANDER, 1786) is referred to as *Montastraea annularis* (LINNAEUS, 1767) It is among the key framework builders of west coast reefs, in the form of clusters of colonies (Scott's Head), and extensive old monospecific ridges that line the margins and erosional channels in some reefs (e.g. Salisbury). Individual *O. annularis* colonies do occur outside of coral reefs along the west coast. Recruits are extremely rare throughout Dominica (STEINER & KERR 2008) and the live cover of this species is continuously decreasing. Tissue loss following bleaching episodes is one evident causes of this process. Throughout the time frame considered here, the large *O. annularis* clusters in the Salisbury, Mero, and Grande Savane reefs were also heavily and increasingly scarred by corallivorous fishes, and the scared areas were colonized by filamentous algae.

Orbicella faveolata (ELLIS & SOLANDER, 1786) plays an important constructional part in west coast reefs. Its distribution is less clustered than that of *O. annularis*, but colonies within reefs tend to grow to larger sizes than outside of reefs. It occurs at locations with a wide range of environmental conditions. Its large colonies often make up a substantial portion of the overall coral cover. Based on genetic analysis of samples from Grande Savane and 15 sites across the Caribbean, Dominica's *O. faveolata* is in a group with those from Barbados and Tobago (FOSTER et al. 2012). Larval recruitment is thus at least partially sourced in the southern Lesser Antilles.

Orbicella franksi (GREGORY, 1895), is far less common than its cogeners and has so far only been documented along the west coast reefs. In previous records of the three aforementioned species from Dominica (STEINER 2003, STEINER & KERR 2008, STEINER & WILLETTE 2010) the genus name *Montastraea* was used.

Montastraea cavernosa (LINNAEUS, 1767) is common in reefs and rocky substrates along the west coast. The reddish-pink color variation of *M. cavernosa*, with characteristically large calices, has been identified along the west coast.

Among the meandroid favids, *Diploria strigosa* (DANA, 1846) is the most widely distributed in all coral habitats, and displays a variety of growth forms. Encrusting forms grow in shallow high energy locations (e.g. Anse Soldat), sheet-like forms are found along the deeper margins of reef drop offs (e.g. Batali), and intact spherical colonies with diameters of up to one meter, are still alive in shallow, well-flushed locations with little to no recreational use (e.g. Espagnol Cliffs, Anse Soldat, Grande Savane). Three variations have been observed in the external morphology of *D. strigosa*'s meandroid ridges and include sharp ridges, and rounded ridges similar to those of *D. clivosa*. The rounded ridge variety has only been observed in small colonies in the Batali - Mero region, but also in the Turks and Caicos Islands (pers. obs.). A third form, exhibits a ridge with a deep, apical groove. This aberrant morphology was only observed at Macoucheri (Fig. 4B, Site 47).

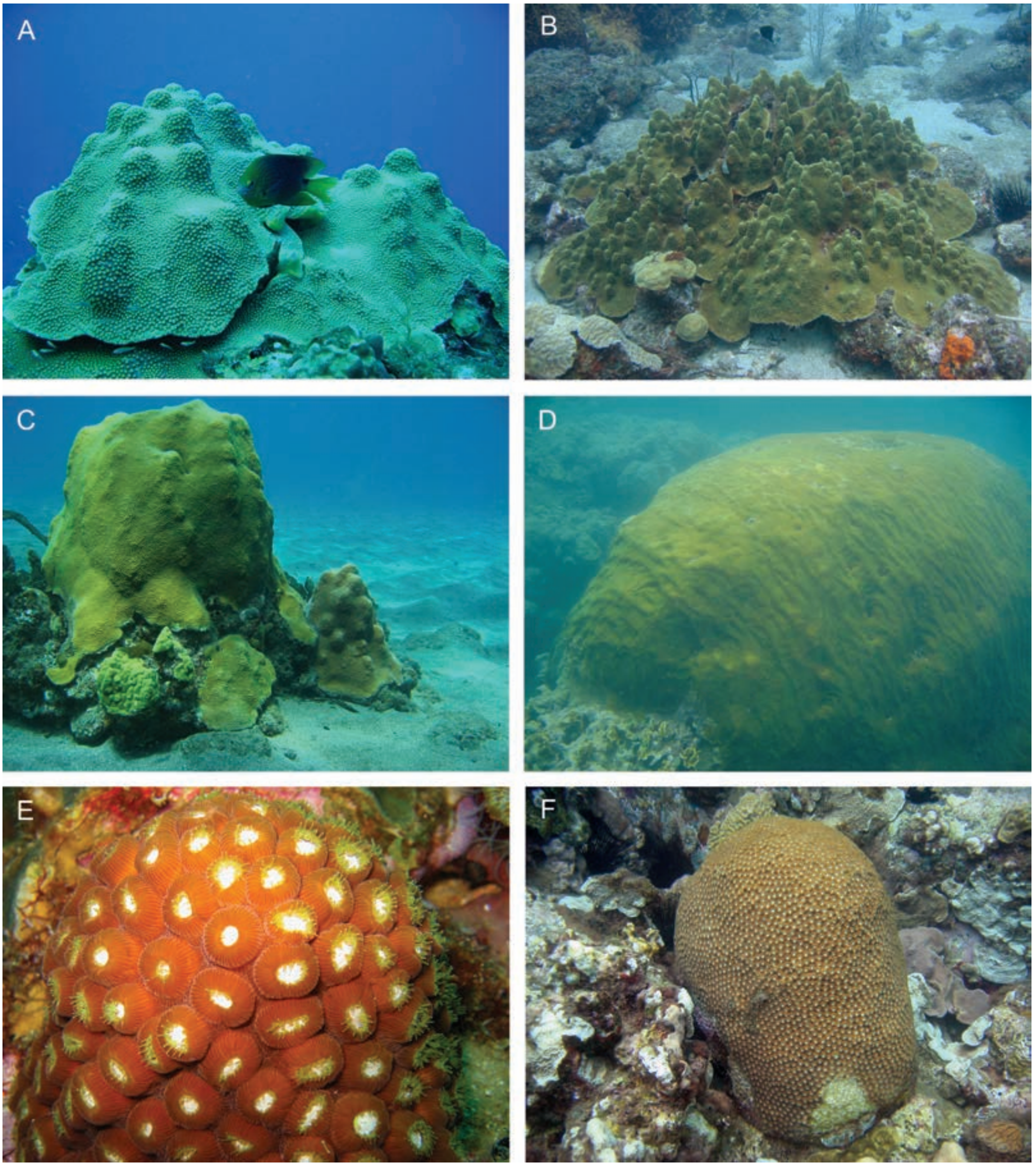

Fig. 25: A, *Orbicella faveolata*, Grande Savane. B, *O. faveolata*, Salisbury. C, *O. faveolata*, Ponte Ronde. D, *O. faveolata*, in waters with high turbulence at Anse Soldat. This colony shape has only been documented once in Dominica. E, *Montastraea cavernosa*, Grande Savane. F, *M. cavernosa*, Gueule Lion.

Diploria clivosa (Ellis & Solander, 1786) is known as shallow-water specialist, and in Dominica it is most important along the north coast, where it the main encrusting and cementing scleractinian species on the reef crests, forereefs, and erosional channels, besides *D. strigosa*. It also occurs in rocky habitats and shallow fringing reefs of the west coast, but plays no significant role in the formation or solidification of reefs. At

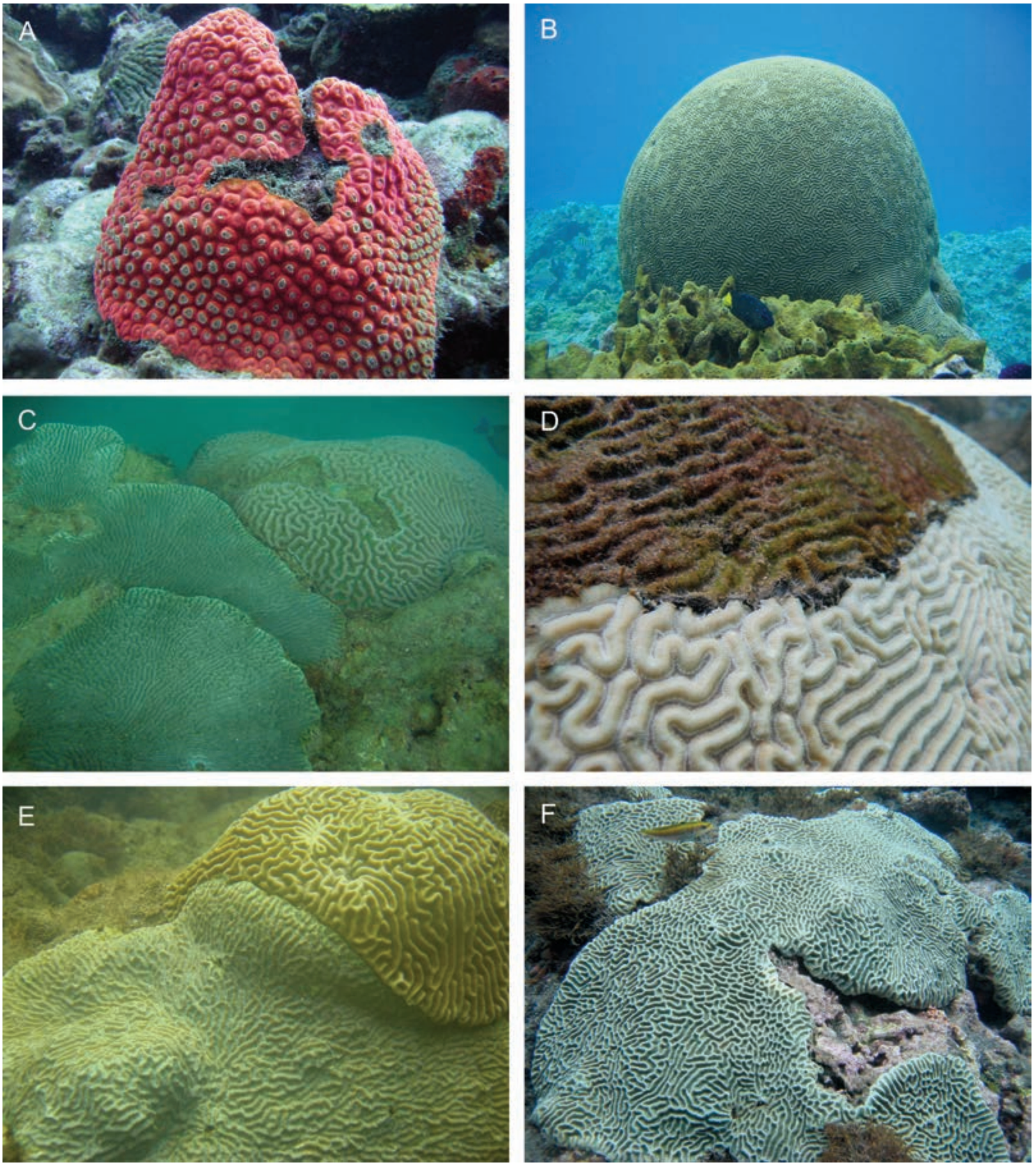

Fig. 26: A, *Montastraea cavernosa,* Grande Savane. B, *Diploria strigosa,* Salisbury. C, *D. strigosa* (three sheets, left) and *Colpophyllia natans* (top right), Anse Soldat. D, bleached colony of *D. strigosa* with dead upper portion overgrown by algae. Note the Black Band Disease at the margin of the bleached coral tissue. E, *D. strigosa* (top) and *D. clivosa* (bottom), reef flat, Anse Soldat. F, *D. clivosa* at with a breviserialis-type arrangement of calices in enclosed valleys, Ti Bay.

southern point of Ti Bay (Fig. 4A, Site 39), an aberrant colony morphology, here referred to as *D. clivosa* morph 1, was observed. Its valleys are very short with an overall appearance resembling *Agaricia purpurea*. The third *Diploria* in Dominica, *D. labyrinthiformis* (LINNAEUS, 1758) is a common coral on west coast reefs and rocky habitats.

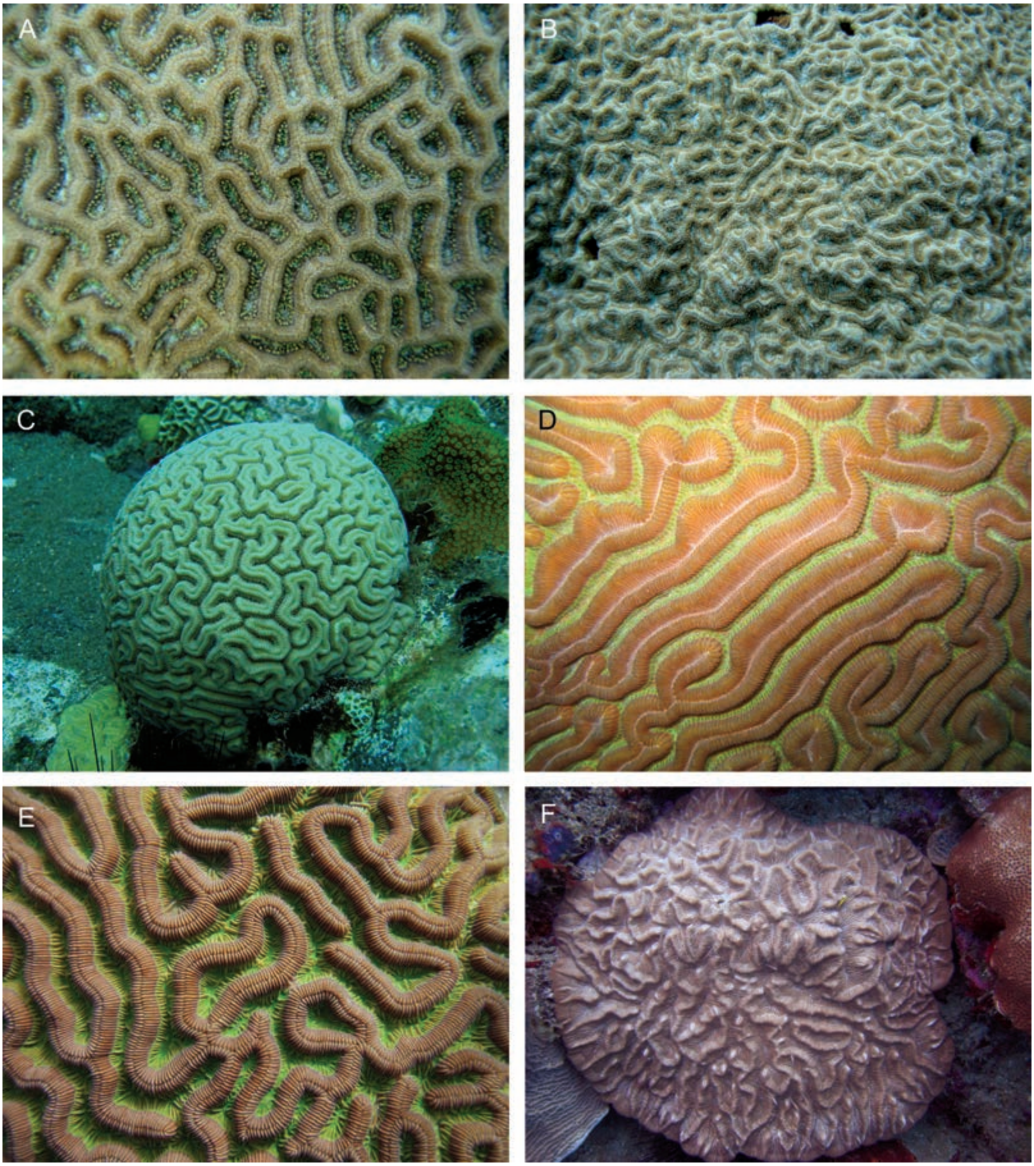

Fig. 27: A, *Diploria clivosa* with aberrant arrangement of calices; close up. Ti Bay. B, *D. clivosa* with aberrant arrangement of calices; close up. Ti Bay. C, *D. labyrinthiformis*, Grande Savane. D, *D. labyrinthiformis,* Grande Savane. E, *Colpophyllia natans*, variety with contrasting green valleys and brown ridges, Grande Savane. F, *C. natans*, monochrome variety with unusual shape and pattern of ridges, Mero.

Colpophyllia natans (Houttuyn, 1772) has two growth forms and color variations and in areas with differing environmental parameters. Along the north coast it occurs as encrusting form. Dome-shaped colonies are more commonly found along the west

Fig. 28: A, *Colpophyllia natans*, variety with contrasting green valleys and brown ridges, Grande Savane. B, *C. natans*, monochrome variety, Batali. C, *C. natans* growing around *Meandrina meandrites*. Neither species appears leisured by digestive enzymes of their neighbor. D, *C. natans*, Grande Savane. E, *C. natans* colonies with distinct color variations, Mero. F, *C. natans*, Lemoines.

coast. It has been very susceptible to coral bleaching, Black Band Disease and physical impacts, but recruits are still relatively common and its growth rates are among the faster ones.

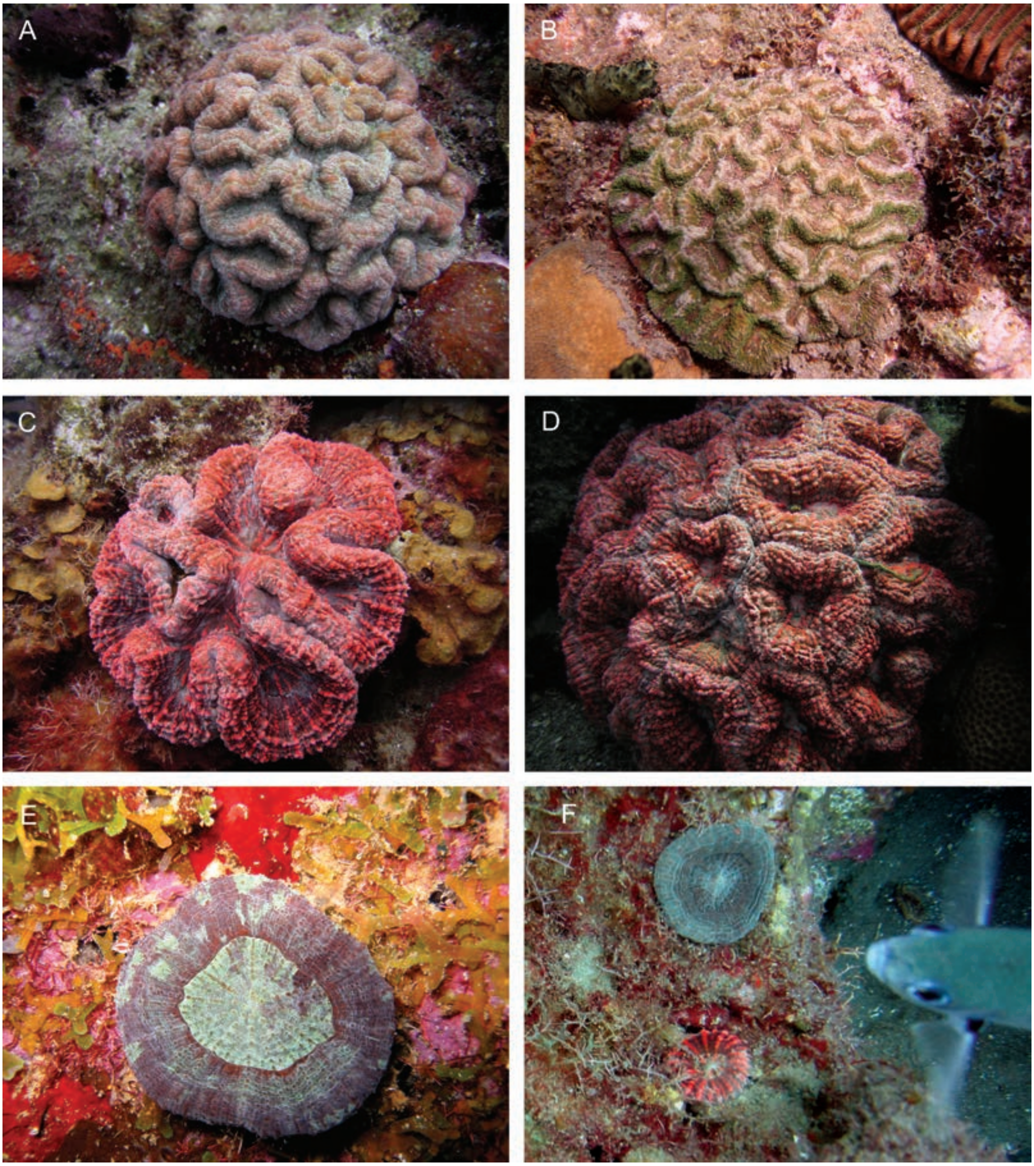

Fig. 29: A, *Isophyllia sinuosa*, Grande Savane. B, *I. sinuosa*, Salisbury. C, *Mussa angulosa* with incompletely budded calices (intra-tentacular budding), Cachacrou. D, *M. angulosa*, Batali. E, *Scolymia* sp., Cachacrou. F, *Scolymia* sp. (top) and single polyp of *M. angulosa* (bottom), Batali.

Family Mussidae (Figs. 29, 30, and 31)

The most common mussid is *Isophyllia sinuosa* (Ellis & Solander, 1786). So far it was reported for the west coast, primarily the northern half. It is found in reefs and rocky areas up to 15 m depth. *Mussa angulosa* (Pallas, 1766) is not common, but evenly

Fig. 30: A, *Mycetophyllia lamarckiana*, Grande Savane. B, *M. lamarckiana,* Mero. C, *M. lamarckiana*, Cachacrou. D, *Mycetophyllia* sp. (*danaana* ? hydmophorid morph), Cachacrou. E, *M. aliciae*, Grande Savane. F, *M. aliciae*, Grande Savane.

distributed along a wide depth range in coral reefs and shallow rocky habitats. Single polyped *Scolymia*, best fitting the descriptions of *S. cubensis* (Milne Edwards, 1849) are rare and have mostly been recorded in the Batali - Mero region.

Mycetophyllia lamarckiana (Milne Edwards & Haime, 1848) is the most commonly reported species in this genus in Dominica. However, in-field identifications based on

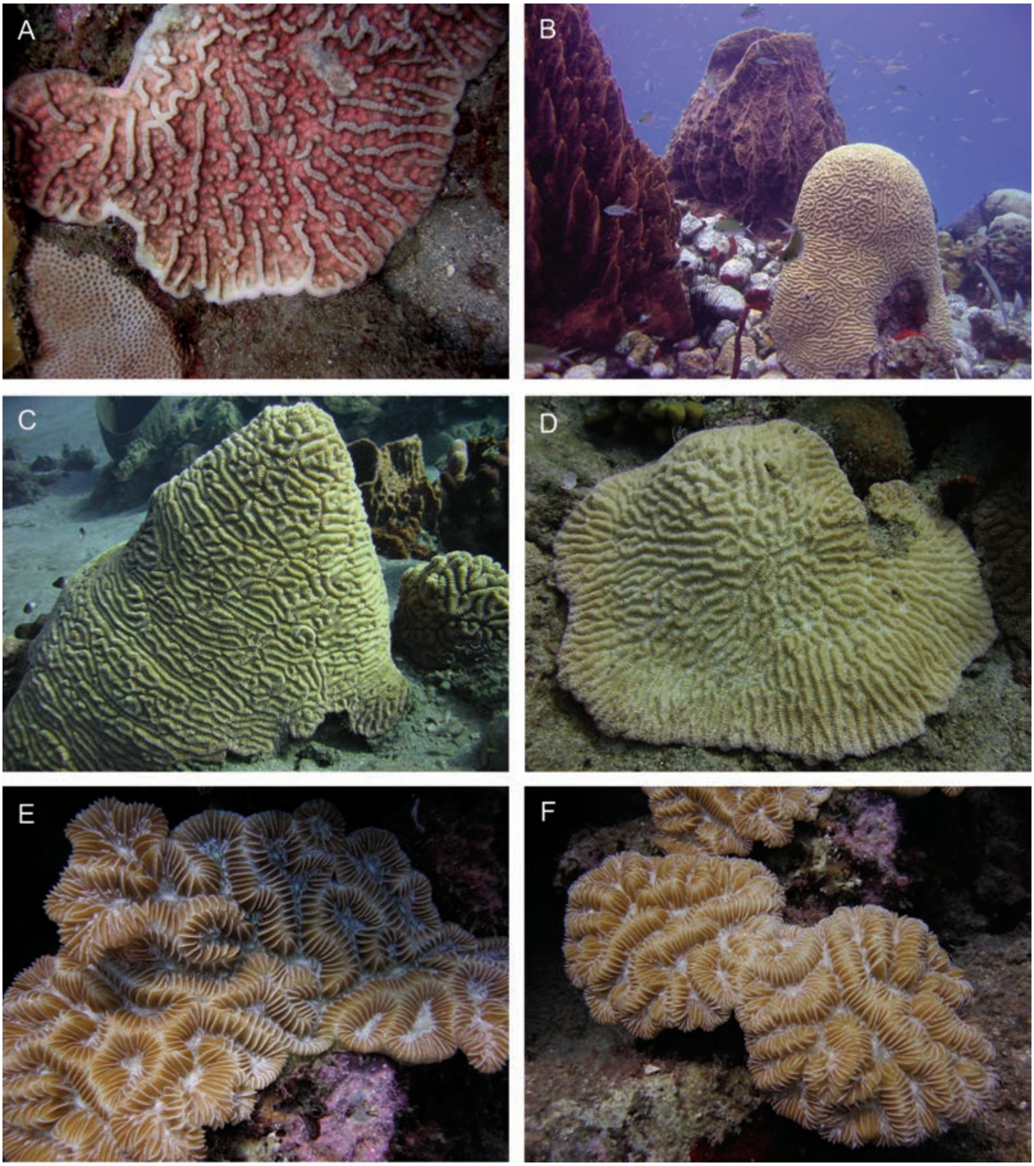

Fig. 31: A, *Mycetophyllia ferox* with on setting bleaching, Salisbury. B, *Meandrina meandrites*, Mero. C, *M. meandrites*, Salisbury. D, *M. jacksoni*, paling, Grande Savane. E, *M. meandrites*, with aberrant arrangement of calices, Mero. F, *M. meandrites*, Mero.

the overall colony appearance of some *Mycetophyllia* spp. are often inconclusive. Keeping this in mind, it appears as though *M. danaana* (Milne Edwards & Haime, 1849) and *M. aliciae* (Wells, 1973) also occur in Dominica but are less common. The more easily identifiable, *Mycetophyllia ferox* (Wells, 1973) is rare.

Suborder Caryophylliina

Family Caryphyllidae (Fig. 32)

Eusmilia fastigiata (PALLAS, 1766) is sparsely distributed along the west coast, both in coral reefs and rocky areas, but it is less common in the later and north of Batali. Fifteen caryophyllid deep-water species were reported for Dominica in POURTALÈS (1880), and CAIRNS (1979).

Suborder Meandriina

Family Meandrinidae (Figs. 31, 32, and 33)

Meandrina meandrites (LINNAEUS, 1758) is very common along the west coast, rare along the north coast and has not been identified elsewhere. Records of *M. meandrites* from Dominica encompass *M. jacksoni* (WEIL & PIZÓN, 2011). *Meandrina danae* (MILNE EDWARDS & HAIME, 1848) was first documented in 2003 as *M. brasiliensis*, with a limited and clustered occurrence in the sandy areas along the shallow margins of the Mero South reefs, and along the southern margins of rocky habitats between the Batali reefs and the northern end of the Grande Savane Reef.

Dendrogyra cylindrus (EHRENBERG, 1834) is rare and it has been identified in different reefal settings (e.g. Mero), but also in rocky areas with few tens of meters from shore (e.g. Scott's Head). Its pillar-shaped colonies show signs of chronic toppling.

Dichocoenia stokesii (LINNAEUS, 1758) is common. Varieties with a comparatively smooth surface arrangement of calices and others with strongly protruding individual calices have been reported.

Suborder Poritiina

Family Poritidae (Figs. 33 and 34)

Porites furcata (LAMARCK, 1816) was not distinguished from *P. porites* (PALLAS, 1766) in quantitative surveys to date. Based on qualitative observations, *P. furcata* is the most common ramous *Porites* species in Dominica. It grows in the form of isolated colonies, occasionally in mono-specific thickets of several square meters (e.g. norhern end of Site 53, Fig. 17), and commonly co-occurred in smaller, sparsely distributed clusters within *M. mirabilis* banks up to late 2005. Following the bleaching episode of that year, both *P. furcata* and *P. porites* suffered high mortality and live colonies were close to absent throughout Dominica (STEINER & KERR 2008). By 2007 colonies baring thumbnail portions of live tissue on *P. furcata* were still evident, but up to 2013 neither *P. furcata* nor *P. porites* have regained their former abundance. The third branching representative of this genus, *P. divaricata* (LESUEUR, 1821), is primarily found along the northern reefs, associated to backreef seagrasses and is uncommon along the west coast. It has not been reported from the east and south coast.

Porites branneri (RATHBUN, 1887) grows in few locations along north and east coast in shallow turbulent waters, with little to no cover of fleshy macroalgae. *Porites astreoides* (LAMARCK, 1816) is evenly distributed across all coral habitats and is by far the most abundant coral in terms of colony numbers and live coral cover of a single species (STEINER 2003).

Fig. 32: A, *Meandrina* (*jacksoni*), Mero. B, *M. meandrites*, Batali. C, *M. meandrites*, Salisbury. D, *M. danae*, Mero. E, *Eusmilia fastigiata*, Mero. F, *E. fastigiata*, Mero.

Suborder Dendrophyllina

Family Dendrophyllidae (Fig. 35)

Tubastraea coccinea (Lesson, 1829), an azooxanthellate scleractinian is regarded as an alienspecies in the Caribbean since the 1970s, with possible origins in the Indopacific or Eastern Pacific (Fenner 2001). It was documented for two locations in Dominica. One

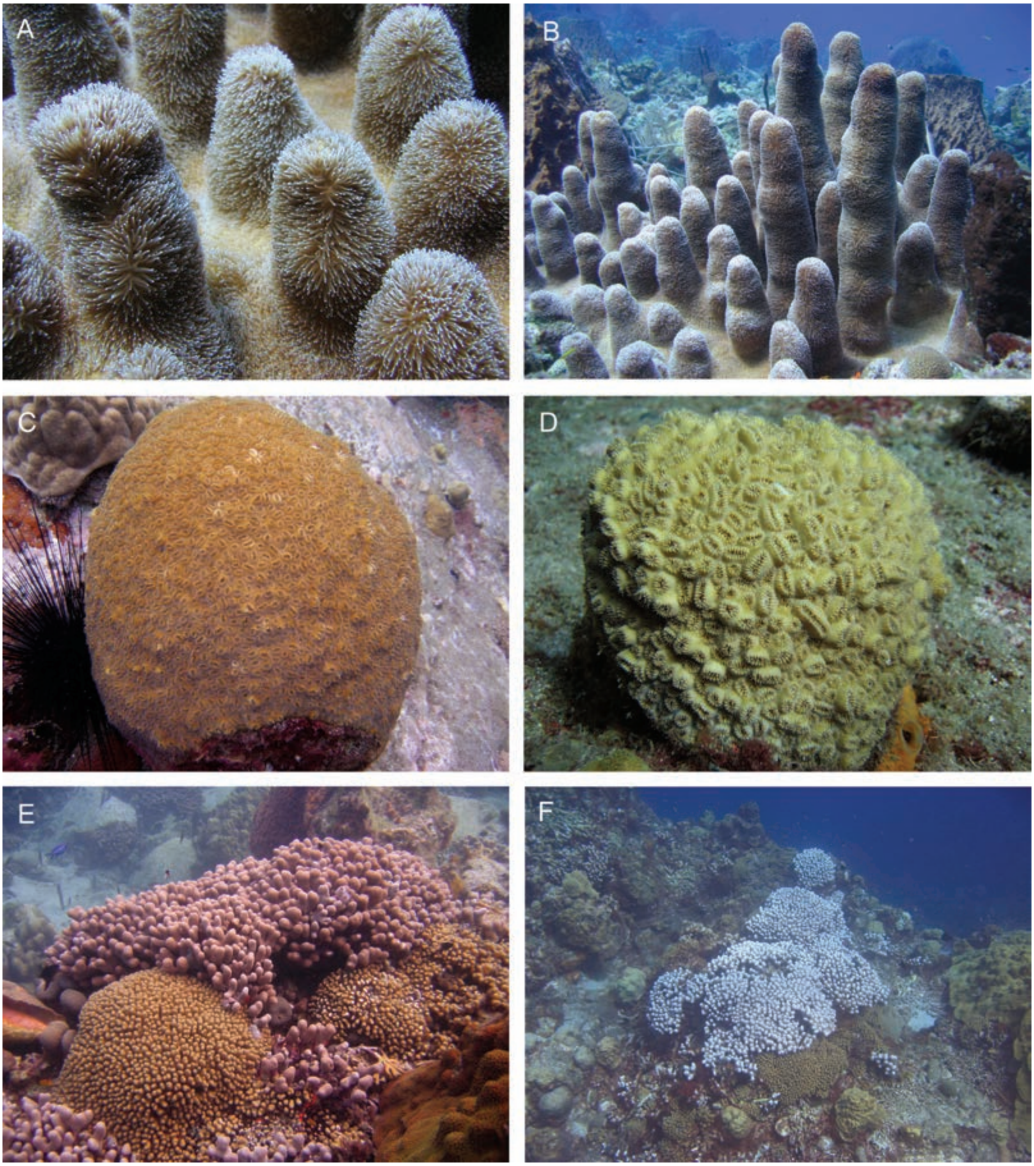

Fig 33: A, *Dendrogyra cylindrus*, Grande Savane. B, *D. cylindrus*, Grande Savane. C, *Dichocoenia stokesii*, Batali. D, *D. stokesii*, Salisbury. E, *Porites divaricata* (top); up to 2005 a common species in banks of *Madracis mirabilis* (bottom), Cabrits. F, *P. divaricata* during the onset of the 2005 coral bleaching episode, Cachacrou.

is north of Pointe Guignard, along the walls of rocky outcrops and submerged ledges within 2 m of the low tide mark (STEINER 2003). In 2005 the central point of this assemblage was within 40 meters of 15°14' 30.29"N, 61° 22' 22.58"W. The other location is north of Soufriére on the vertical wall in the vicinity of 15°14' 02.42"N, 61° 21' 53.86"W.

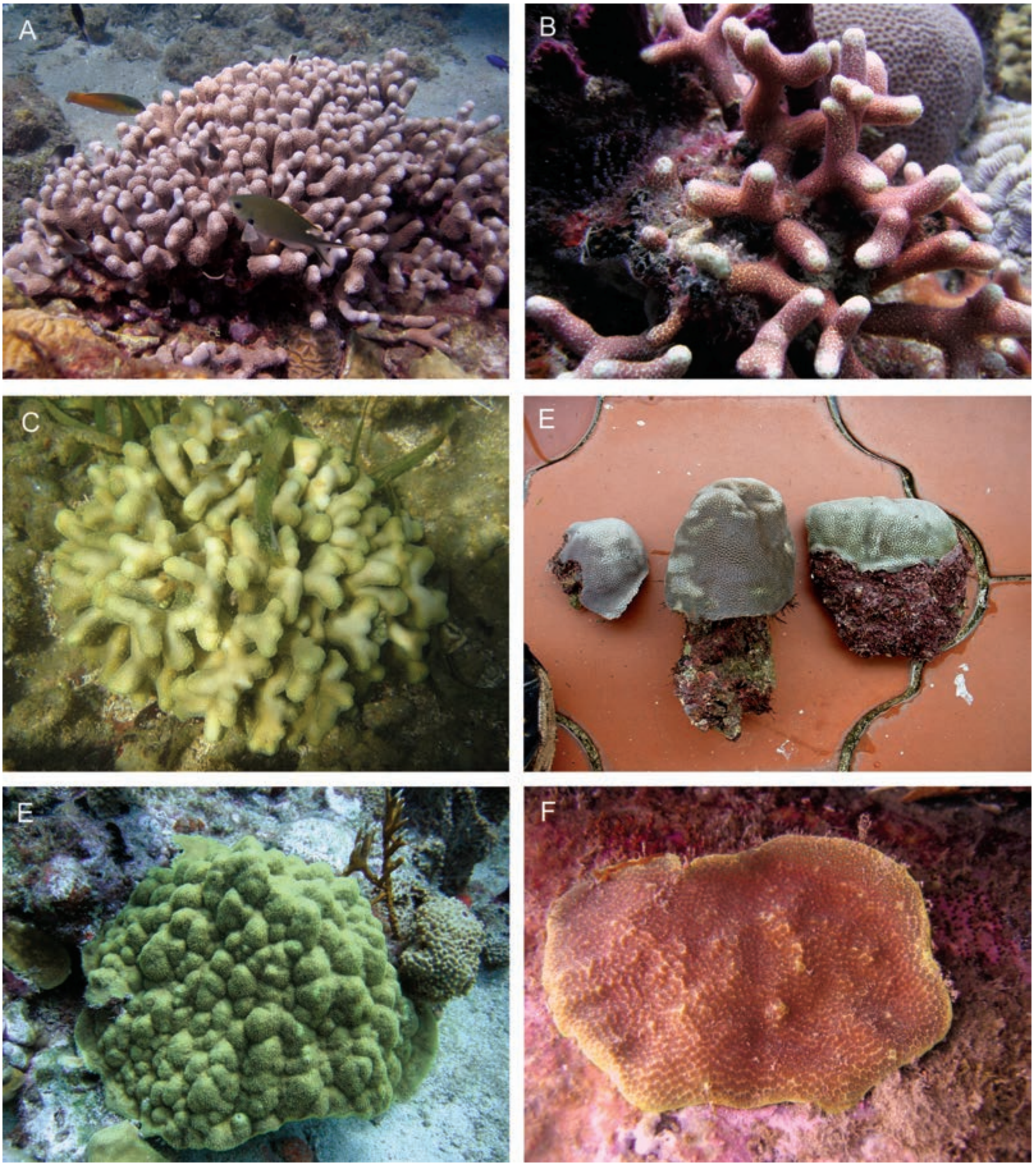

Fig. 34: A, *Porites furcata*, Salisbury. B, *P. divaricata*, Mero. C, *P. divaricata*, Anse Soldat. D, *P. branneri*, specimens from Anse Quaneri. E, *P. astreoides*, Grande Savane. F, Plate-like variety of *P. astreoides* or *P. colonensis* according to some authors, Macoucheri.

Order Anthoathecata

Family Milleporidae (Fig. 35)

The in-field identification of milleporids, based on colony morphology is hindered by chronic breakage in Dominica's shallow environments. While encrusting sheets of

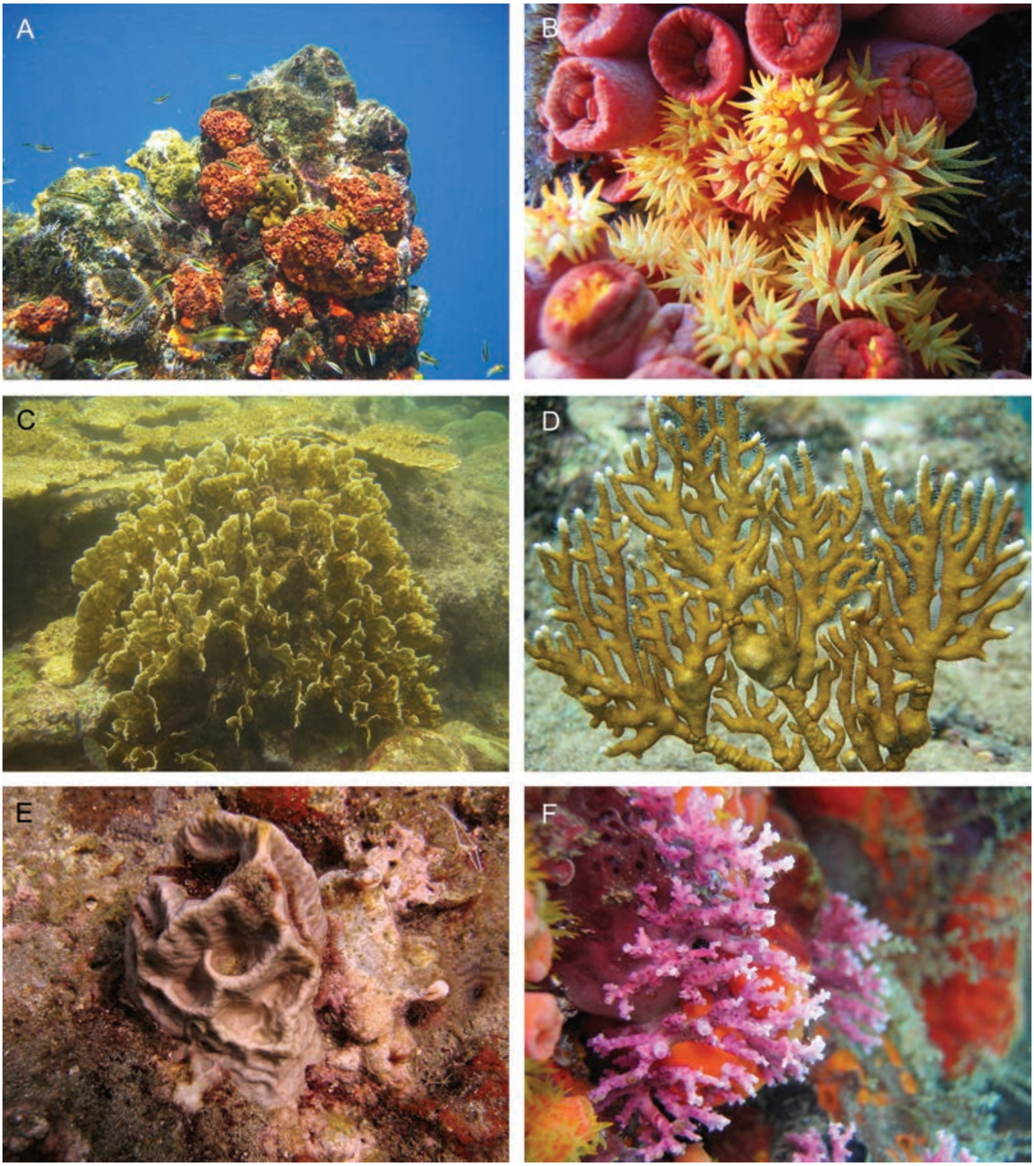

Fig. 35: A, *Tubastraea coccinea* (orange clusters), Pointe Guignard. B, *T. coccinea*, Pointe Guignard. C, *Millepora complanata,* Anse Soldat. D, *M. alcicornis*, Batali. E, *M. squarrosa*, Salisbury. F, *Stylaster roseus*, Pointe Guignard.

Millepora abound, erect growth forms are uncommon. The exception is *Millepora complanata* (LAMARCK, 1816) which is able to form its characteristic foliose thickets along the reef crest of a few northern (Anse Soldat) and eastern reefs (Marigot). In deeper reefs, the identification based on colony morphology is easier. On the leeward side of Dominica, *M. alcicornis* (LINNAEUS, 1758) is common, while *M. squarrosa* (LAMARCK, 1816) occurs occasionally.

Family Stylasteridae (Fig. 35)

Stylaster roseus (Pallas, 1766) occasionally occurs in reefs and rocky habitats with cryptic architecture.

Disturbances and conservation

Sediments, solid wastes and effluents

Multiple natural and anthropogenic disturbances are shaping Dominica's coral reefs and other light-dependent sessile communities. The primary natural disturbances originate in the seasonal oscillations of dry and the rainy seasons. Increased sediment run-off during the rainy season reduces light penetration in coastal waters, leads to salinity fluctuations, and introduces terrestrial debris and organic matter. Intensified coastal waves prolong the resuspension of sediments and debris in near shore benthic habitats, and reduced light levels, thus limiting photosynthesis in the coral's endosymbionts, the zooxanthellae. Since the island is well flushed by ocean surface currents, neither salinity fluctuations, nor eutrophication or anoxia scenarios are a concerning issue at a local scale. However, the prolonged mechanical impacts and the occasional burial of reefs from sediment and debris-laden waters do occur, depending on the intensity, duration and direction of storms. Human-induced and enhanced increases in terrestrial run-off are currently rooted in slow but steady coastal zone alterations and growing coastal quarries. The recently constructed seawall defenses to combat coastal erosion along many stretches of the west coast roads (e.g. Colihaut, Tarou, Pointe Michel, Soufrière,) also trap terrestrial debris and runoff. This side effect offers an opportunity for controlled disposal of debris and sediments after storms. Historically, deforestation facilitated sediment run-off and peaked in the early half of the 20th century. Because of the shrinking agricultural industry, many agricultural lands are now being overgrown.

Corals have no defenses against mechanical impacts or burial, with the exception of some free-living favid corals from Pacific that can dig themselves into and out of sands (Bongaerts et al. 2012). Nevertheless corals do actively rid themselves of sediments that gradually accumulate and adhere to the corals' mucus, which is then moved towards the periphery of the colony with the help of the tentacles and cilliary movements across the ectoderm. Energy allocation for this and other important physiological processes (e.g. growth, gametogenesis and the release of gametes etc.) can thus become a fundamental limitation, under single or multiple, prolonged or chronic, environmental stressors (Szmant 1991, Fabricius 2005). Increased susceptibility to pathogens and coral mortality are commonly observed in reefs exposed to multiple stressors (Weil 2004).

In addition to augmented sediment loads and organic materials, agrochemicals (e.g. pesticides, defoliants and fertilizers), solid wastes and untreated industrial and urban effluents are part of the cocktail pulses introduced into the coastal waters during storms and heavy rains. Input and contamination levels of agrochemicals and effluents have not been ascertained along Dominica's coastal waters. However, the incidence of solid waste increases with the proximity of settlements, which was noted in the habitats surveys 2007 by Steiner & Willette (2010). Many of the legal and illegal garbage dumping sites are close to or on shore where roads provide easy access. While beaches and shorelines are kept reasonably clean, much waste ends in the sea. The extent of this was also exemplified in 2004 when prolonged easterly surges (sourced in Hurricane Ivan's trajectory from Grenada, across the Caribbean Basin and towards Cuba) washed several tons of urban and industrial debris (tires, car parts, household electronics, scrap metal, plastics, etc) back onto the west coast shores.

Dominica's efforts to reduce this type of pollution include the reduction and elimination of uncontained coastal garbage dumps (e.g. at Jimmit), a centralized sewage collection and outfall facility for Roseau, the separation and recycling of materials (oils, acids, other toxic wastes) at the Fond Colet waste management plant, and more stringent building codes related to waste water treatment by the Ministry of Lands, Housing, Settlements and Water Resource Management. Insufficient compliance and enforcement are the main hindrances in these efforts.

The implementation and timing of large coastal infrastructure projects, or projects with long-term unsecured loose sediments (quarries), have also proven to enhance contaminating levels of sediment inputs. The most elaborate project of this nature in recent times (2006–2007) was the expansion of the international airport near Marigot. The seaward extension of the runway was one of its components. Filling material for this extension came from the removal of large amounts of soil excavated to reduce the height of hills on the landward end of the runway. This process lasted over a year, and was done without an initial securing of the outer seaward margins of the area to be filled. Consequently heavy sediment plumes were carried towards and on the north coast coral reefs by the prevailing surface currents. Coral reefs in this area were already in critical condition and the meager artisanal fisheries came to a halt putting several fishermen out of business.

Fisheries and tourism

Dominica's fisheries have remained artisanal in terms of scale and the gear applied, but they target a wide array of organisms, and have heavily impacted the coral reefs around the island (SEBASTIAN 2002). The use and accidental loss of seine nets, fish traps and to some extent gill nets has contributed to the overexploitation and physical destruction of coral reef fishes and coral reefs. Low numbers of coral reef fishes and continued habitat degradation are one consequence of the fishing practices to date. This has been recognized by the country's authorities and a variety of insightful efforts have been undertaken to mitigate such impacts. Besides continuous registration and monitoring of the fisheries in terms of the number of persons involved, the fishing gear used and landing data, regulations have been put in place to manage fishing gear, seasons, and quotas. In general terms, the strategy is to develop the offshore fisheries of pelagic species with the establishment of Moored Fish Aggregating Devices (FAD), and thus reduce or partly eliminate near shore fisheries, particularly on coral reefs. Such a move shall reduce one of the stresses on coral reefs, and hopefully fish numbers will increase over time, including herbivorous fishes that could control or reduce algae, which out-compete corals in growth rates and spatial expansion. Said efforts are facing obstacles beyond financial and technical constraints, as they represent a change of the local fisheries in terms of techniques and culture.

The new off-shore fisheries revolve around half day or day trips to a FAD where demersal, pelagic and migratory pelagic species (e.g. Tuna) are targeted with simple baited hooks. Caught fish, including large tunas of several hundred pounds, are pulled in by hand. Even in this simple set up, such fisheries are much more cost and gear intensive (boat and engine size, fuel requirements, and the need for mooring lines of 5 km and more) and therefore very few persons are able to get involved. The use of new technologies such as satellite based geographic positioning systems, needed to easily locate FADs, is not something older fishermen are likely to acquire. Furthermore the installation of a FAD is subject to the stipulations of United Nations Convention of the Law of the Sea, in that the persons making the investments in establishing FADs have no right of propriety. Few persons are thus in a position or willing to repeat the investment after gear loss through storms or ships, or when other fishermen also use the FADs without sharing the catch. Increasing financial wealth of Dominican's may lead to an expanding off shore fisheries and reduce the fishing pressure on coral reefs. Realistically though, soaring food prices, which will remain the rule in small island nations with a life-style relying on food imports, will continue to force some people to collect, catch and shoot what-ever they can along the islands near-shore habitats.

A significant component of the tourism industry, since the 1980s, has been recreational diving. Although it is not an extractive use of coral reefs, it also represents a source of physical impacts on coral reefs. The establishment of moorings as of the late 1990s has all but eliminated anchoring damage at dive sites. Another positive development is linked to dive sites that are within marine protected areas where fishing activities have been markedly reduced, primarily due to the pressure from dive operators. The chronic breakage of corals by unskilled divers does, however, remain a principal direct physical impact caused by humans at frequented dive sites which are mostly in 10-30 m depth.

Improvements in coral reef conservation

In Dominica, the protection and conservation of the island's remaining live coral reefs will rely on the acknowledgement of their distribution, size and condition, the importance of their contiguous habitats (e.g. seagrass beds), and a strong commitment towards locally manageable reductions in disturbances (e.g. sediments, coastal development, fishing pressure, recreational use of reefs). Attention should be given to the eight coral reefs still in good or poor condition (as identified in Table 1). All other reefs are in a critical condition or dead. Financial and technical resources must therefore be allocated accordingly. Where these are constrained, the ratification and implementation of policies addressing global developments such as rising sea surface temperatures or CO_2 sequestration measures should be a lesser priority for small island nations seeking tangible successes in natural resource conservation.

To date 97.6% of Dominica's coral reefs remain outside of the two existing marine protected areas. The marine protected area adjacent to the Cabrits National Park is a byproduct of the way the park's boundaries were delineated. No significant live reefs are in this area. Coral assemblages haven't formed extensive veneers, are easily navigated by divers, and do not represent large fishing grounds. Therefore, this area can support augmented water sport-based tourism.

The second marine protected area, Scott's Head Soufriére Marine Reserve, is in an area with two of the largest fishing communities of the southwest. Driving forces behind its establishment were the dive centers to the south of Roseau, which actively promoted conservation measures in their cooperation with the Division of Fisheries. In ecological terms, placing the reserve in the Soufriére Bay was an odd choice, when there were larger and more diverse coral reefs around Grande Savane, with smaller fishing communities. Insufficient information on coral reefs at alternative locations is one explanation for such a decision. In commercial terms, however, the sites lining Soufriére Bay are topographically attractive dive sites that are closest to the established dive centers. The reserve secures commercial interests by enhancing the marketability and profitability of nearby sites that incur reduced operational expenses (e.g. fuel), in an area that keeps fishermen and their gear away from paying dive tourists. Unfortunately, little feedback leading to the mitigation of the local disturbances in the reserve and to a better protection of the reefs outside of the reserve can be expected from an increasing number of divers with a downward shifting baseline of what is consider to be a reef or a healthy reef. However, a notable positive ecological outcome of the Scott's Head Soufriére Marine Reserve (SSMR) is the greater abundance of adult fishes, in comparison to the shallow waters of most west coast reefal settings. This can be attributed to the reduced fishing activities coupled with the adjacent deep waters and the structurally complex benthic environment. Spill-over effects also benefit fishing activities in the reserve's vicinity. Furthermore, concentrating recreational divers in areas not harboring substantial coral reefs opens the possibility for protecting the islands largest reef complexes in good or poor condition via stricter access limitations.

The distribution of carbonate remains of dead reefs and those of reefs in critical condition should be considered if and when reef restoration projects are envisioned, as long as local stressors are reduced. Non-reefal settings need to be avoided, as demonstrated by failed artificial reef trials (Reef Balls) in Mero in 2001. Based on 2007 habitat surveys, artificial structures could also be established in depths of 15–20 m and always below the deep limits of *S. filiforme* seagrass meadows. Providing permanent settlement grounds to sessile organisms will, in the long-run, also attract fishes of commercial value to areas outside of coral reefs, allowing a recovery of fish populations on coral reefs.

Perpetuated misconceptions

The historically low population density and comparatively modest infrastructural development in Dominica, has undoubtedly positively affected the preservation of its natural resources, in particular its extensive primary rainforests, unparalleled in the Lesser Antilles. However, given its size, topography, climatic features and human activities, it has not been spared from the drastic degradation of its sublittoral habitats. This is very clear in an island-wide assessment of coral reefs. It is therefore difficult to concur with statements such as "…the low population density and lack of extensive coastal development has meant the reef communities have not been severely impacted by human activities" (SMITH et al. 1997), and the sources for such conclusions must be questioned.

Similarly, conclusions that because Hurricane David (1979) did not hit Dominica directly, "the island's marine environments were only minimally impacted" (SPALDING et al. 2001) cannot be supported by year-round observations on the effects of winds, storms and rain on the island's coastal habitats. As described above under Oceanographic Setting, the specific physical features of the island require do not require a direct hit by a hurricane for severe destruction to occur among its sublittoral habitats. And in fact Hurricane David brought the young nation of Dominica to a halt, with grave losses of lives, infrastructure and natural resources (Honychurch 1995). When statements of such inaccuracy come from international organizations, they can bear political weight and the temptation to apply them in the promotion of a country via national profiles.

Far less troubling, but equally misleading are common inaccurate descriptions of the distribution of coral reefs, especially if a strict coral reef definition is applied. The point of contention does not lie within early distribution maps of "reefs" including all shallow obstacles to ships, because a clear definition of coral reefs was not required. However, the first maps focusing on the presence of coral reefs are by default often based on the sites frequented by dive operators, hence on local knowledge. In some cases the distribution of dive sites mirrors the distribution of coral reefs. In the case of Dominica this is not so. Promoted dive sites, where most visiting researchers are taken to, are in the southwest and have been equated with the island's coral reef resources. The southwestern sites have, in essence, become the caricature of the island's coral reefs, and the focus of marine conservation efforts promoted internationally. Even where a strict definition of coral reefs is applied, the sources for statements such as "…reef development is limited. At a few locations on the south, west and northwest coral veneers on rock are well developed" (Smith et al. 1997) misrepresents the true extent of Dominica's coral reefs.

While Dominica's distribution of reefs has been underrepresented, its reef area has been overestimated by two orders of magnitude. The most widely cited estimates on the island's coral reef area are based on a combination of mapping efforts using bathymetric charts, maps and remote sensing data of varying resolution, fitted to 0.5 km and 1 km grids. These approaches rendered values of 7,000 ha, 4,700 ha and an unspecified value of less than 10,000 ha, tabulated in a regional comparison in Bruke & Maidens (2001). Most recently Jackson et al. (2014) reported 4,900 ha. Even if the still-to-be-described reefs between Pointe La Soie and Crompton Point, and the coral assemblages found on some of Dominica's rocky environments were to be added to the actual 80.4 ha of coral reefs, the total area would be less than 300 ha.

Finally, the distribution and condition of seagrass beds, Dominica's largest marine organism-built ecosystem, has also been misrepresented in the distribution maps by Onuf et al. (2003) and the Government of Dominica (2005). The reports do not name species, but show seagrass beds in some areas where seagrasses do not grow, and not in others where they do, as discussed in Steiner et al. (2010). Given that the best-developed seagrass beds are found in areas of the best-developed coral reefs (Steiner & Willette 2010), meaningful coral reef conservation efforts will have to include the preservation of contiguous seagrass beds.

The abovementioned misconceptions have been perpetuated in reports from national and international organizations, apparently without validation through field surveys or taking into account the existing local knowledge and studies. It must be emphasized that the mere consideration of the dictating oceanographic and topographic parameters (e.g. narrow shelf, limited substrate availability, chronic natural disturbance levels) would question the validity of the erroneous statements cited above. Whatever the reasons for such developments may be, the consequences are that the true dimensions, status and peculiarities of Dominica's coral reefs are still outside of national-level planning. Until this changes, conservation efforts will continue to be based on perceptions that have little to do with reality.

Outlook

After more than 50 years of in-field coral reef studies in the Caribbean, thanks to technological developments including the self-contained breathing apparatus (SCUBA), basic aspects such as the location, dimensions, and shaping oceanographic parameters of many coral reefs are still poorly documented at a scale relevant to local resource assessments and conservation efforts. Since the human influence on coral reefs started centuries ago (JACKSON 1997), it is difficult to grasp or define a baseline of what these resources used to be like. The state of Caribbean coral reefs prior to human interference and multiple cascading phase shifts in community structure will likely remain an unsolved mystery. Dominica belongs to those island's in the region with historically low population densities, coupled with moderate infrastructural development; circumstances in which coral reefs in comparatively good state may be expected. This could be supported by the examination of a few selected sites within the healthiest reefs. However, when the entire island is considered, and the surface area and condition of all reefs accounted for, it is very clear that the deterioration of these resources has been severe. Only an island-wide assessment facilitates an understanding of the vulnerability of Dominica's coral reefs and the possibilities of ameliorating the current situation. It is a process which must incorporate the geological, climatic, and historical premises that have and will shape coral reefs, in order to generate a realistic outlook to options in the conservation of finite natural resources.

Where technical or financial limitations hinder the preservation of natural environments and the livelihoods of its dependants, priority will have to be placed on some areas while and others must be written off. As unsatisfying as this may be, deciding which areas shall be preserved pivots on a comprehensive overview of the resources at hand. Obtaining this perspective is never stringently linked to new environmental studies, but it does require a systematic and wide-ranging consolidation of local knowledge and field data. This guide serves as replicable case study for such an approach.

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Over one thousand hours of field observations are at the center of my account. Drawn to the seemingly endless turns and habitat configurations of the island and encouraged by Dominicans, I gradually built this description of its corals reefs and shared my findings through local media. Despite the disheartening degradation of reefs throughout the region, my appreciation for Dominica grew during my ten years on the island and it is strengthened with every return. I therefore dedicate this report to the people of Dominica. Although I carried out the majority of surveys alone, several persons assisted me over the years. In the order of our collaboration, these were K. Hurley, J. Borger, J. Lorber, S. Williams, K. McDonald, D. Willette, J. Kerr, N. Wallover, K. Macfarlane and L. Price. I further thank L. Honychurch, A. Magloire, H. Guiste, S. John, R. Joseph, E. Harris, N. Prevost and J. Kirby among numerous others who shared their historical, ecological, economic and soci-political insights with me. All the underlying projects were supported and funded by the Institute for Tropical Marine Ecology under the careful guidance of M. Akers. To all I am indebtedly grateful. Lastly, I thank J. Cortés, M. Akers, D. Willette, E. Weil, R. Kikinger and an anonymous reviewer for their comments during the preparation of the manuscript.

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