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Rapid Communication

First record of the non-indigenous brittle star species *Ophiothela mirabilis* Verrill, 1867 (Echinodermata: Ophiuroidea), off Martinique Island, French Lesser Antilles

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Abstract

Ophiothela mirabilis Verrill, 1867 is a brittle star (Ophiuroidea) originating from the Pacific Ocean, introduced into the Western Atlantic Ocean in the late 2000, probably by transporting larvae in ship ballast water or associated with hull biofouling. It is reported as a non-indigenous species from southern Brazil to the southeast Florida for the northernmost area. The present study carried out by scuba diving, between October and November 2017, on the Atlantic coast of Martinique allowed us to report, for the first time, its occurrence in the French Lesser Antilles. In addition, the surveys carried out made it possible to describe *O. mirabilis* on 8 host gorgonian species, seven of which were previously unreported as host species: *Pterogorgia anceps* (Pallas, 1766), *Muriceopsis flavida* (Lamarck, 1815), *Eunicea laxispica* (Lamarck, 1815), *Muricea muricata* (Pallas, 1766), *Muriceopsis sulphurea* (Donovan, 1825), *Antillogorgia acerosa* (Pallas, 1766) and *Eunicea flexuosa* (Lamouroux, 1821). The only hosts observed during this study were gorgonians. Our study also described a habitat where 69% of gorgonians were colonized. We were able to note that on *Gorgonia ventalina* (Linnaeus, 1758) the density of colonization could reach ~ 3 brittle stars *O. mirabilis* per cm^2 per side of gorgonian.

Key words: alien species, non-native species, gorgonian, epizoic ophiuroids, SCUBA survey, species interaction, biological invasions

Introduction

Ophiothela mirabilis Verrill, 1867 is a small ophiuroid (brittle star) with six arms. It is a marine species, native to the Indo-West central Pacific and on tropical eastern Pacific reefs (Clark 1976; Hendler et al. 2012) where it was first described off Panama in 1867 by Verrill. In 2000, it was reported for the first time in the Atlantic Ocean, off the Brazilian coast at Ilha do Pai, in a geographical area outside its range, and its unique yellow orange colour reinforces the origin of a single lineage and is therefore considered as a non-indigenous species (NIS) (Hendler et al. 2012; Thé De-Araújo et al. 2018). Its discovery near Brazilian and Caribbean ports suggests that *O. mirabilis*

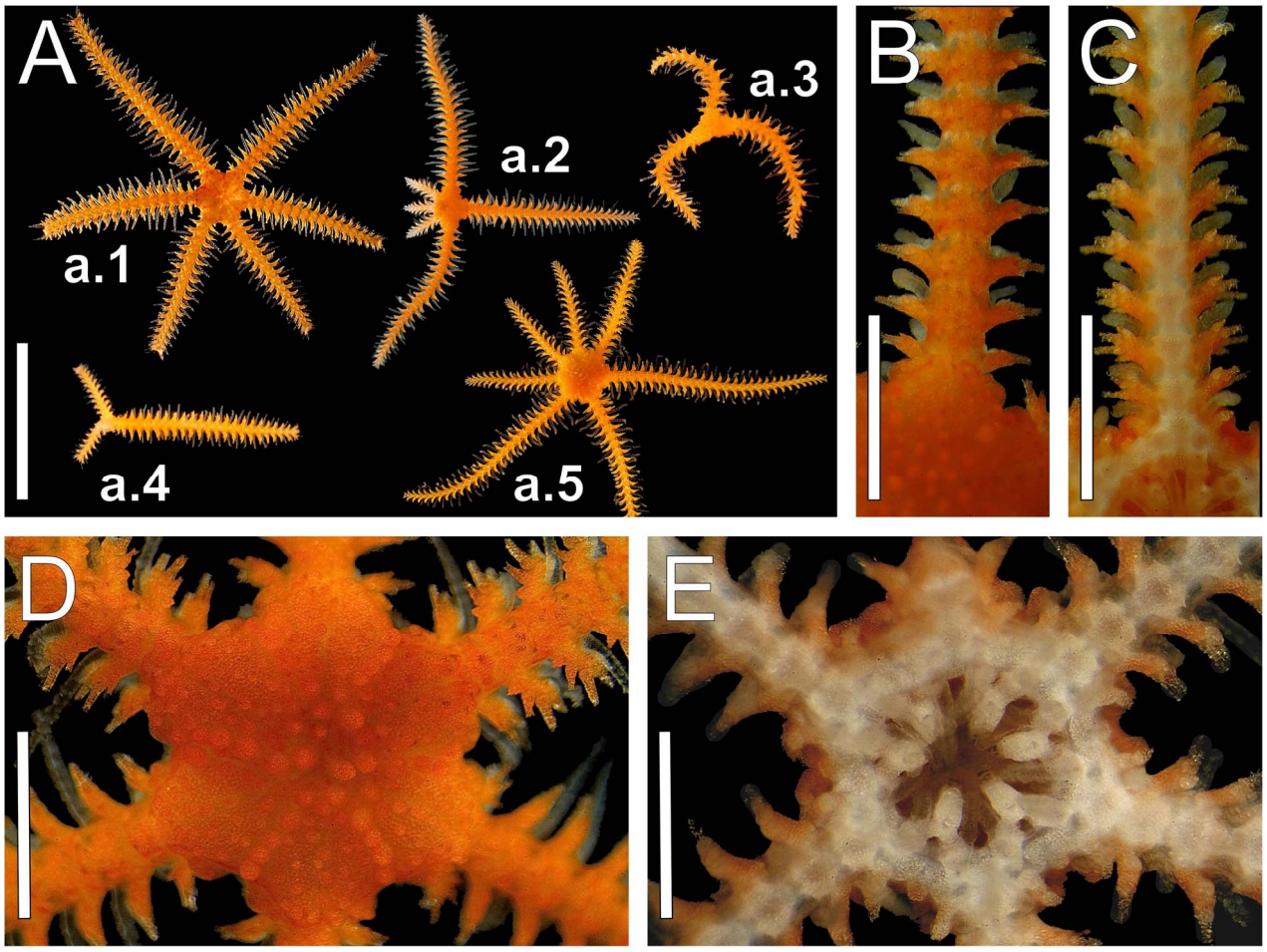

Figure 1. *Ophiothela mirabilis*. A) Dorsal view, a.1) six arms with similar size, a.2) three growing arms, a.3) recent fissiparity, a.4) regeneration from an arm and a disc piece, a.5) regeneration default; B) Dorsal view of the arm; C) Ventral view of the arm; D) Dorsal view of the disk; E) Ventral view of the disk with jaw. Scale bar: 5 mm in A; 1 mm in B, C, D and E. Photographs by R. Ferry.

may have been introduced by sea transport: either through ship ballast water or associated with hull biofouling (Hendler et al. 2012; Carlton and Geller 1993; Fofonoff et al. 2003; Hewitt et al. 2009). The distribution area of this species has gradually expanded to Santa Catarina (2013) (Hendler et al. 2012; Lawley et al. 2018) for the southernmost area of Brazil and Brazilian reefs and the coast of Ceará (2018), for the northernmost area (Hendler et al. 2012; Mantelatto et al. 2016; Thé de-Araújo et al. 2018). The species continued to move northward. It was reported in 2011 in French Guiana (Hendler and Brugneaux 2013), in 2013 in Tobago (Hendler and Brugneaux 2013), in Saint-Vincent in 2011 in the Lesser Antilles (Hendler et al. 2012), in southeast Florida at Dania Beach (Glynn et al. 2019). Hendler and Brugneaux (2013) propose in their study that current could play a role in the dispersal of the larvae. Currently, while sexual reproduction of *O. mirabilis* has not been established (Hendler et al. 2012), the species is capable of reproducing asexually by fissiparity to colonize its host (Hendler and Brugneaux 2013; Tavares et al. 2019) (Figure 1). *Ophiothela mirabilis* is an epizoic brittle star, which lives on the surface of a host. While in the Pacific *O. mirabilis* has gorgonians as its main host (Granja-Fernández et al.

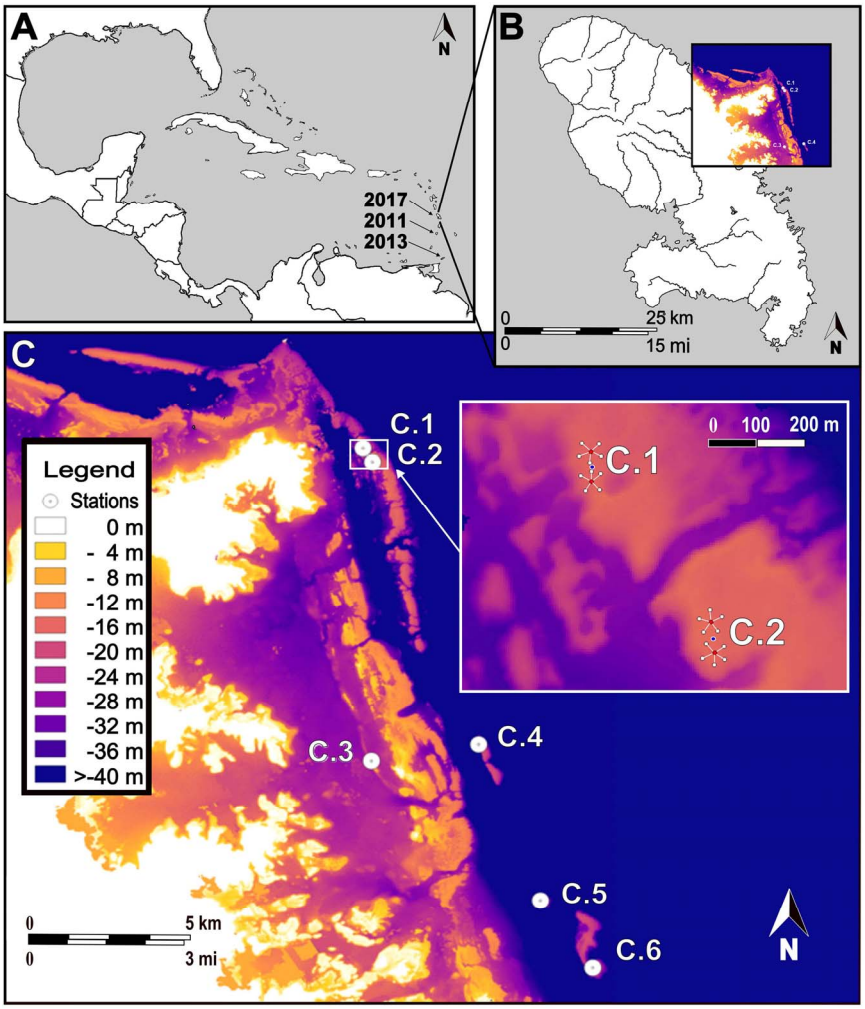

Figure 2. Location of Martinique in the Lesser Antilles and sites of observation in the Island: A) Gulf of Mexico and the Caribbean. Sea Records, with timeframe, of *Ophiothela mirabilis* in the southwest Atlantic and Caribbean, 2011 at St-Vincent, 2013 at Tobago, 2017 at Martinique; B) Martinique; C) Positions stations c.1 (14°46′32.6″N, 60°51′30.1″W), c.2 (14°46′18.4″N, 60°51′20.6″W), c.3 "Loup Marseillais" (14°41′07.5″N, 60°51′21.7″W), c.4 (14°41′24.3″N, 60°49′35.5″W), c.5 (14°38′42.8″N, 60°48′34.3″W) and c.6 (14°37′33.6″N, 60°47′42.5″W). Background of map by Litto3D® 2013 modified (Projection UTM 20 North).

2015), in the Atlantic, about 30 host species belonging to different taxonomic groups have been identified (Hendler et al. 2012; Mantelatto et al. 2016; Thé De-Araújo et al. 2018).

The first visual observation of this species was made on 8 October 2017, in Martinique, on the upper part of a barrier reef of the Atlantic coast of Martinique (14°46′32.6″N; 60°51′30.1″W) at a depth of 17 m. In this study, we have presented a new unpublished distribution of *O. mirabilis* in the French Lesser Antilles, and described host species most commonly used as hosts when a habitat is initially colonized.

Materials and methods

Survey sites

The six stations studied are located off the central Atlantic coast of Martinique (Figure 2). These stations were chosen because they were free from the

presence of *O. mirabilis* in the year preceding this study (October 2016). These stations are representative of the reef barriers of the Atlantic zone by being at different distances from the coast and at different depths. In addition, these stations are rich in gorgonians, which are the common hosts of *O. mirabilis* (Granja-Fernández et al. 2015).

The studied areas are in the neritic zone (Figure 2, Supplementary material Table S1) at a depth of between 6–12 m c.3 (14°41′07.5″N; 60°51′21.7″W) on the one hand, and two stations at a depth of 17 m c.1 (14°46′32.94″N; 60°51′29.38″W), c.2 (14°46′21.00″N; 60°51′20.91″W) and three stations at a depth of 23 m c.4 (14°41′24.3″N; 60°49′35.5″W), c.5 (14°38′42.8″N; 60°48′34.3″W) and c.6 (14°37′33.6″N; 60°47′42.5″W) on the other hand. The location was determined by means of Garmin® GPS (Model eTrex® 20; Garmin LTD, Schaffhausen, Switzerland).

Sampling method

Sampling for *O. mirabilis* was conducted by scuba diving between October 8 and November 30, 2017. Each station was studied by conducting belt transects 25 m long by 1 m wide (25 m^2) around geolocated points in the station. If the first transect did not include *O. mirabilis*, a total of 4 cross-shaped transects were made; if the first transect contained *O. mirabilis*, 5 star-shaped transects were made in two neighbouring areas, for a total of 10 transects per station (Figure 2C). During sampling, for each transect, all potential hosts were finely observed (Porifera, Cnidaria, Bryozoa, Echinodermata, Tunicata, Vertebrate and algae). More specifically in the case of gorgonians, all gorgonian species colonized or not by *O. mirabilis* were identified, counted and photographed *in situ* (TG4® Olympus®). Moreover, any host species colonized and identified at the site but not appearing on the transects would be surveyed and photographed. Seven gorgonian species were collected with brittle star specimens attached to them. Each specimen was collected either in its entirety or only in part, and each specimen was measured and photographed. To measure the surface area of a colonized gorgonian like *G. ventalina*, we used the ImageJ® software.

Identification, preservation and laboratory analyses

All specimens collected were taken to the laboratory on Martinique campus. *O. mirabilis* was identified with a binocular magnifying glass (Nikon SMZ-U) (Figure 1) based on recognition characters and identification keys according to Hendler et al. (2012), Granja-Fernández et al. (2015) and Verrill (1867). Gorgonian species were identified according to the work by Bayer (1961), Philippot (1986, 1987, 2017), and Sanchez and Wirshing (2005). For counting the brittle stars on the collected colonized gorgonians, we placed them in a tank with seawater and ice blocks in plastic. Under these conditions, the brittle stars detach themselves from the gorgonian

hosts. All samples of *O. mirabilis* were preserved in 90% alcohol and deposited in the laboratory collection of BIOSPHERES at "*Université des Antilles*", Martinique.

Results and discussion

Distribution

Of the six stations inventoried, *O. mirabilis* was present only at stations c.1 and c.2. The stations were only 350 m apart. These two stations had similar habitats both on abiotic characteristics such as depth (17 m), exposure to current and nature of the coralligenous substrate. As far as the biotic component of the habitat is concerned, it is mainly composed of communities of corals, sponges and gorgonians. We observed the presence of communities of gorgonian hosts of similar composition and dominant cover (Table S2). In October 2015 and October 2016, surveys using the same belt transect technique failed to detect the presence of *O. mirabilis*. The present study shows that the distribution of the species is very localized at the time of this study, and the absence of its detection in previous years shows that colonization is recent. It is not excluded that other areas with a similar gorgonian species composition may be colonized.

Specimen characteristics

All the individuals harvested in Martinique have an orange colour and often for the shortest, newly formed arms, a lighter colour on the tip (Figure 1). According to Hendler et al. (2012), all *O. mirabilis* harvested from Brazil to St-Vincent had this distinctive yellow-orange colour, while populations of Pacific *O. mirabilis* species had a wide variety of colours (rosy purple, creamy, burgundy and yellow) corresponding to the colour of their host gorgonians (camouflage) (Granja-Fernández et al. 2015; Mantelatto et al. 2016). This characteristic suggested that they come from the same lineage from a single introduction in the Atlantic Ocean (Hendler et al. 2012). Moreover, as Mantelatto et al. (2016) assumed, the yellow-orange colour contrasts with the host colours, which implies the absence of predators.

As shown in Figure 1, we observed within the population very heterogeneous individuals in terms of the number of arms and their length. Out of a sample of gorgonians colonized by 234 brittle stars, 24 had six arms of similar size, the rest of the population is made up of individuals exhibiting an asymmetric and anisometric arm length. In this sample, about ~ 90% of the population is from a recent fission.

The proliferation of this species can be explained by its asexual reproductive capacity by fissiparity. Individuals separate their disc into two parts, and the missing part is regenerated, which facilitates proliferation of the species (Hendler et al. 2012). Fissiparity appears to be a dominant and effective mode of reproduction for the rapid colonization of the surroundings (Mantelatto et al. 2016; Tavares et al. 2019).

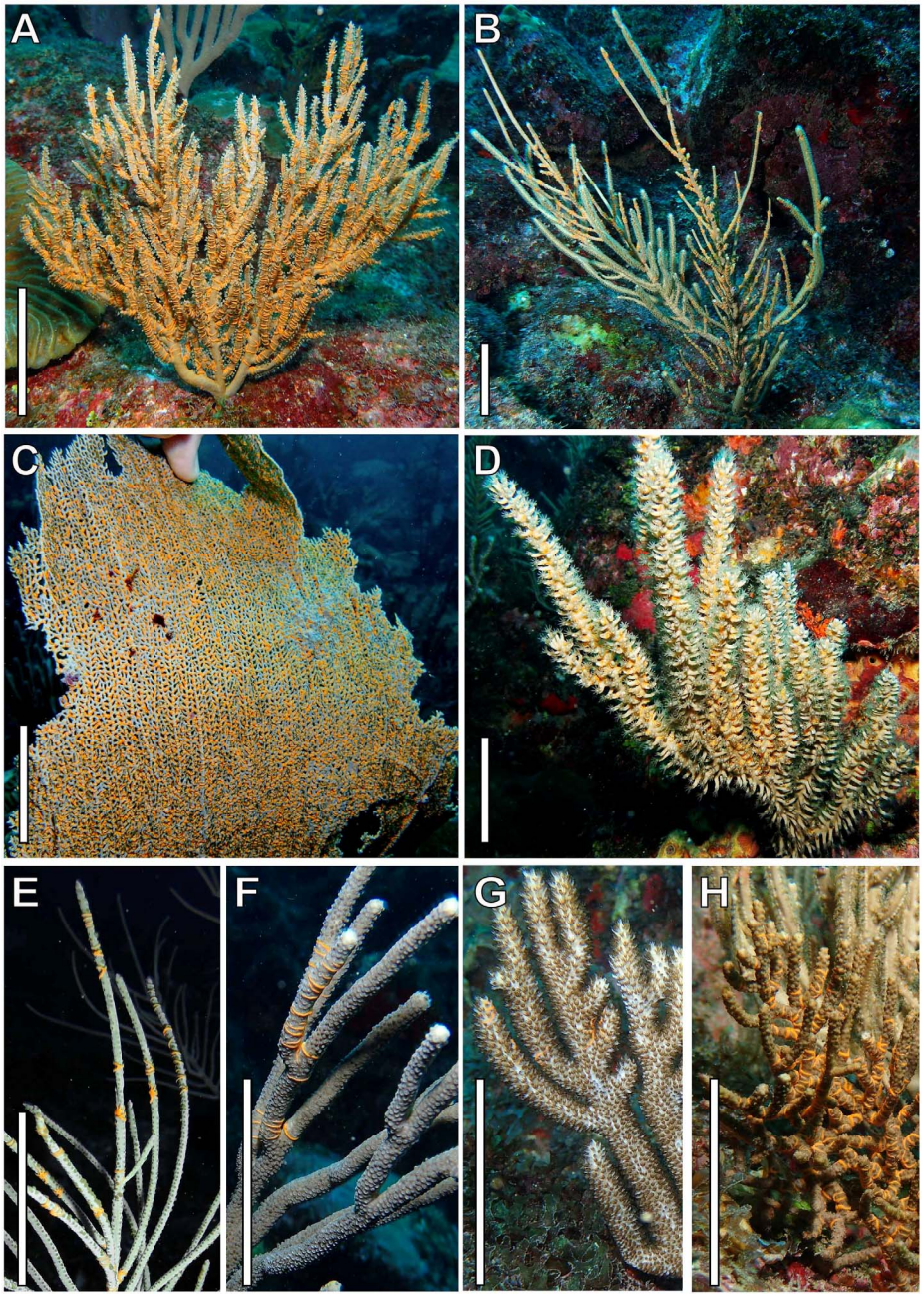

Figure 3. Diversity of the 8 species of gorgonian hosts of *Ophiothela mirabilis*: A) *Pterogorgia anceps;* B) *Muriceopsis flavida;* C) *Gorgonia ventalina;* D) *Eunicea laxispica;* E) *Antillogorgia acerosa;* F) *Eunicea flexuosa;* G) *Muricea muricata;* H) *Muriceopsis sulphurea.* Scale bar: 5 cm. White arrows: example of hanging of *O. mirabilis*. Photographs by R. Ferry and L. Hubert.

Colonized hosts

Out of the 20 belt transects carried out (500 m^2) on stations c.1 and c.2, 2 564 gorgonians were counted, of which 1 774 were colonized by *O. mirabilis*, i.e. 69% (Table S2). Moving to the surface, it is possible to calculate an average density of gorgonians per transect that is 5.13 gorgonians/m^2, of which 3.55 gorgonians/m^2 were colonized. Of the 12 species of gorgonians encountered, 8 species of gorgonians were colonized by *O. mirabilis* (Figure 3). These species were as follows: *Pterogorgia anceps* (Pallas, 1766) (1069 colonized at 91%); *Gorgonia ventalina* Linnaeus, 1758 (406, 100%);

Muriceopsis flavida (Lamarck, 1815) (392, 100%); *Eunicea laxispica* (Lamarck, 1815) (9, 67%); *Muricea muricata* (Pallas, 1766) (41, 2%) and in addition, three gorgonians were observed outside the belt transects: fully colonized *Muriceopsis sulphurea* (Donovan, 1825), a colonized branch of *Antillogorgia acerosa* (Pallas, 1766) and a colonized branch of *Eunicea flexuosa* (Lamouroux, 1821).

In the Pacific, the epizoic brittle star *O. mirabilis* (Granja-Fernández et al. 2015) had gorgonians as its main host. In the Atlantic, Hendler et al. (2012), Mantelatto et al. (2016) and Thé De-Araújo et al. (2018) have identified at least 30 host species, belonging to different taxonomic groups, including gorgonians: Porifera (10 hosts), Cnidaria (7), Bryozoa (1), Echinodermata (4), Tunicata (5), Vertebrate (seahorse) (1) and algae (2). As pointed out by Mantelatto et al. (2016), this suggests that it is opportunistic and a generalist in relation to its host species. Although it is important to know the diversity of hosts for an established population, identifying the first hosts colonized in a new territory is important for a better understanding of their ability to colonize a habitat. With regard to the number of new host species, Hendler et al. (2012) in their study on the occurrence of *O. mirabilis* show a picture of *G. ventalina* as a colonized host. This gorgonian species is also present in our study. For this reason, it is not described as a new host species.

The other gorgonian species are therefore new hosts. Not all species of gorgonians in Martinique were present at these stations or at these depths or on belt transects (Philippot 1986, 1987; Philippot and Ferry 2019). It is not certain that *O. mirabilis* has a preference for the most densely colonized gorgonian hosts. Indeed, the most abundant gorgonians are the most colonized except for two species, *A. acerosa* and *E. flexuosa,* which, despite their high abundance, were not colonized on the transects except for the two gorgonian specimens colonized only on part of their branch, found outside the transects (Figure 3). While some gorgonians appear to be good hosts for *O. mirabilis*, the fact that they are not all colonized with the same intensity appears to show that there are differences between them. It has been observed that the brittle stars roll their arms around the gorgonian forms. We can hypothesize that the form and size of the gorgonian branches are factors facilitating colonization. It is highly probable that other species of gorgonians, whose morphology offers a good support for attachment and which were absent from the stations and transects studied, could also be colonized.

Impact of colonization on host gorgonians

We observed, on all the transects and all samples, that *P. anceps*, *M. flavida*, *G. ventalina*, *M. sulphurea*, *A. acerosa* and *E. flexuosa* did not deploy their polyps on areas where *O. mirabilis* was attached, whereas under normal

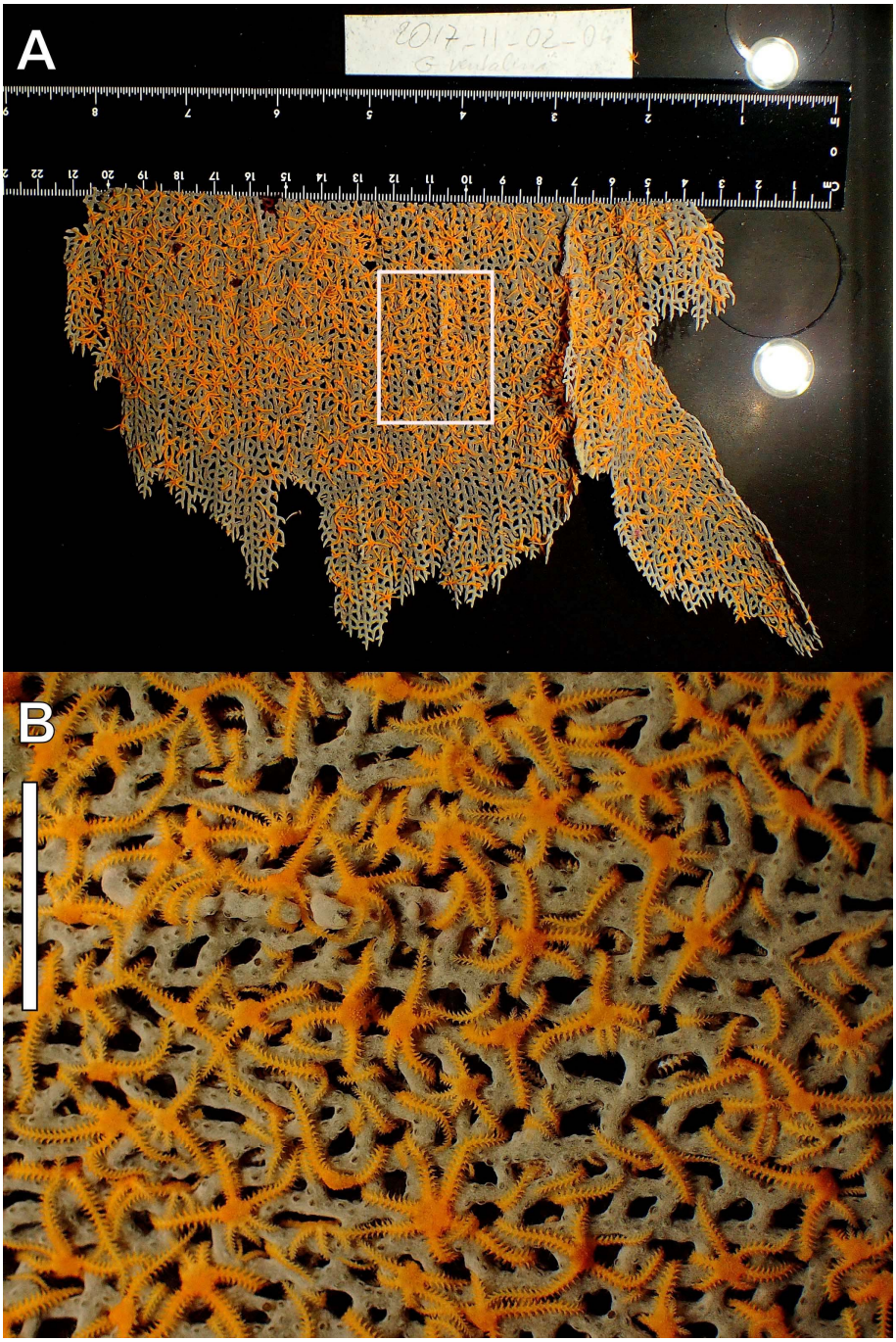

Figure 4. Evaluation of the colonization of *Gorgonia ventalina* by *Ophiothela mirabilis*. A) Sampling 167 cm^2 (by side) of specimen of *G. ventalina* presented in figure 3C with 958 *O. mirabilis*; B) Mode of attachment and colonization of *O. mirabilis* 2.8 brittle star/cm^2 per side of gorgonian. Scale bar: 1 cm. Photographs by R. Ferry.

circumstances, if there's no stress, the polyps are always deployed. For *E. laxispica* and *M. muricata*, the polyps were deployed (Figure 3). In the case of *E. laxispica*, the calyxes are long and the brittle stars cling to the base of the calyxes and do not prevent the polyps of these gorgonians from emerging. In the case of *M. muricata*, the calyx appears to protect the polyp of the arm of the brittle stars. For *G. ventalina* presented in Figure 3C, 958 individuals of *O. mirabilis* were counted over an area of 2 × 167 cm^2 (2 sides), which corresponds to 2.8 brittle stars/cm^2 per side of gorgonian (Figure 4).

We were able to observe that in most cases for this species of gorgonian, the upper parts were preferentially colonized by the brittle star. 717 *O. mirabilis* were counted for *P. anceps* (Figure 3A); 140 for *M. flavida* (Figure 3B); 538 for *E. laxispica* (Figure 3D); 27 for *A. acerosa* (Figure 3E); 11 for *E. flexuosa* (Figure 3F); 10 for *M. muricata* (Figure 3G); 11 for *M. sulphurea* (Figure 3H).

Ophiothela mirabilis is an epizoic brittle star, which lives fixed to the surface of a host by wrapping its arms and the spines of its hooked arms around its host, thus allowing it to be firmly attached (Granja-Fernández et al. 2015; Clark 1976; Hendler et al. 2012). For *E. laxispica* and *M. muricata* the polyps are partially protected either by the specific length of the calyxes or by their shape. The polyps have little contact with the brittle star. For other colonized gorgonian species, the stress caused by the presence of *O. mirabilis* could eventually weaken the colonized parts of the gorgonian and cause a lack of nutrition and the decline of the colonized parts. Furthermore, we observed on many occasions, specifically in these infested areas, that the branches of the colonized upper parts of *M. flavida* were reduced or even destroyed. It is not possible at this stage to establish a correlation between these different parameters; only a biometric study by individual monitoring of the different gorgonian species, conducted over a long period of time, would make it possible to reach a conclusion on their negative effect.

Origin of the invasion and propagation.

The activities of commercial ports and marinas take place mainly on the Caribbean coast. The bays of Fort-de-France and Marin seem to be free of the presence of this brittle star. Indeed, for another study, we also carried out 123 transect observation dives on all the cays covering these two areas between January 2018 and May 2019. On the Atlantic coast, there are mainly a few pleasure boats and fishing boats. Consequently, invasion by individuals, or larvae (Hendler et al. 1999) brought by the currents and suggested by Hendler and Brugneaux (2013) is highly probable.

In this study, we have shown the importance of gorgonians as special host in a first phase of colonization. As these host gorgonians are common and occur around Martinique and on the coasts of neighbouring islands such as Guadeloupe (Philippot 1986, 1987; Philippot and Ferry 2019), a generalised colonisation of Martinique could be expected as well as of neighbouring islands.

Conclusion

Invasive species represent a major threat to marine biodiversity (Paul and Kar 2016; Carlton and Geller 1993). In this study, we have been able to report the presence of *Ophiothela mirabilis*, a non-indigenous species (NIS) of brittle star in Martinique four years after it was observed in St-Vincent by Hendler et al. (2012). We have been able to observe the

characteristics of a habitat at the beginning of colonization. Seven of the eight species of gorgonians that were colonized had not been reported as hosts in previous studies. Four species of gorgonians were mainly colonized at the time of the study. We have been able to observe that six species had their polyps retracted on areas where *O. mirabilis* was attached. In addition, some species had a relatively large number of individuals such as *G. ventalina* with a survey of ~ 3 brittle stars per cm^2 per side. Gorgonians are common in the Caribbean and can be the dominant benthic invertebrates in some habitats where they also play an important ecological role (Yoshioka and Yoshioka 1989; Sanchez and Wirshing 2005; Burkepile and Hay 2007; Philippot 2017). Special attention should therefore be paid to their monitoring because our results have shown that they are the first to be affected and further studies should be carried out in order to assess the long-term impact of this brittle star invasion on host gorgonians.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Geo-referenced information on transects where *Ophiothella mirabilis* was found in Martinique.

Table S2. Total number of colonized and uncolonized gorgonians by *O. mirabilis* over the 20 belt transects (500 m^2) carried out on station c.1 and c.2.

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