MARINE BIODIVERSITY OF BONAIRE: A BASELINE SURVEY

Preliminary results of the Bonaire Marine Biodiversity Expedition

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Contents

Abstract The Bonaire Marine Biodiversity Expedition (2019) was organized by Naturalis Biodiversity Center in Leiden (the national museum of natural history of the Netherlands), ANEMOON Foundation (a Dutch organisation of marine ecological research involving citizen science), and STINAPA Bonaire National Parks Foundation. This field survey explored the marine biota of Bonaire, an island in the southern Caribbean. Species lists were produced of several groups of organisms, which include many new records for Bonaire and also some species new for science.

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Cover photo: Floris P. Bennema

1. General introduction

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Bonaire is a small island, which is part of the Dutch Caribbean, previously known as the Netherlands Antilles. The Dutch Caribbean consists of the ABC Islands (Aruba, Bonaire and Curaçao) in the southern Caribbean and the SSS Islands (Saba, St. Eustatius, southern part of St. Maarten, and the submerged Saba Bank) at the boundary between the Caribbean Sea and the western Atlantic Ocean (Fig. 1.1). Since 10 October 2010, like Saba and St. Eustatius, Bonaire is a Dutch municipality in the Caribbean Netherlands.

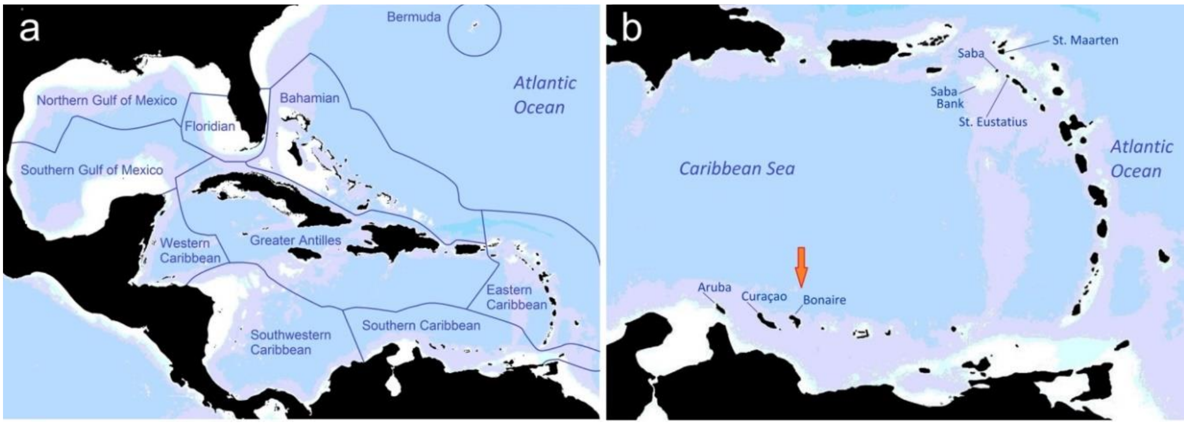

Fig. 1.1. a. The Greater Caribbean**; b.** Location of Bonaire in the southern Caribbean (arrow).

While Bonaire's economy depends for an important part on dive tourism, the marine biodiversity of Bonaire is poorly investigated. Therefore, in order to establish a baseline, Naturalis Biodiversity Center developed a plan for a marine expedition to Bonaire in collaboration with 'ANEMOON Foundation', and STINAPA Bonaire (National Parks Bonaire Foundation). A strong stimulant was the call for project proposals from the WWF Biodiversity Fund of WWF Netherlands. Therefore, an application was submitted for funding with matching from Naturalis.

The coastal area of Bonaire (especially its coral reefs) is world-famous for its marine biodiersity and spectacular underwater landscapes. This suggests that the marine biota of Bonaire is well investigated, but this is not entirely correct. In the last 100 years only 70 new marine species have been described from Bonaire, which is a small number compared to Curaçao with 330 and Aruba with 260 species. This indicates that the marine fauna and flora of Bonaire are less well documented than that of the nearby islands. Ons reason for this may be that Bonaire does not have the same research infrastructure as, for instance, Curaçao (Hoeksema et al. 2017).

Coral reefs are threatened worldwide and in need of proper management. This is also evident for Bonaire. Therefore the marine underwater life on Bonaire is protected through the establishment of a marine park, which is managed by STINAPA Bonaire. Gaps in our knowledge must be eliminated in order to know what we want to protect. Such baseline research is urgent and can only be performed by a team of experts who are able to recognize species of interest. The results should be made accessible to a wide audience in order to be used for control measures, education and public awareness through publications and websites.

During a marine biodiversity inventory in October–November 2019, 48 dive sites on Bonaire were investigated for the species composition of stony corals, fishes, sponges, algae, shrimps, molluscs, and other coral reef species. The research has been conducted by a team of full-time researchers and community scientists who have proven their expertise through publications in professional journals, popular science articles, websites, and field guides.

The results will serve as a baseline for monitoring later changes in the local species composition as a result of local extinction or the introduction of alien species. The presence of these species will then be checked through volunteer monitoring against the Dutch Caribbean Species Register (https://www.dutchcaribbeanspecies.org/). The shallow part of the reef on the leeward side of Bonaire is popular among diving tourists. Conversely, the deeper parts (10–30 m) and the exposed side are less known and therefore, species that are yet unknown for Bonaire are most likely found here.

The researchers used the roving diving technique with standard diving and snorkeling equipment (https://definedterm.com/roving_diver_technique). Specimens were photographed in the field and in the laboratory. Representative samples were used as voucher material and for molecular analyses. For some species, small tissue samples were fixed in alcohol and further analysed for DNA barcoding in Naturalis' molecular laboratory. This was done according to standards that are also used for the European part of the Netherlands. This molecular method enables the discovery of cryptic species that otherwise cannot be found.

At the start of the fieldwork a workshop was organized by STINAPA and DCNA, in which the researchers gave presentations of their work and residents of Bonaire were able to ask questions. Plans were revealed for collaboration with local community scientists. Later in the fieldwork period, a meeting was organized for the expedition members and the local community scientists to exchange experiences and ideas for collaboration.

Meanwhile, various results have been published in scientific literature, newsletters, websites, and the public media. In the coming years (until December 2025) the results will be analyzed further and be published in additional articles, which will become availabe through the webiste: https://www.researchgate.net/project/Biodiversity-research-on-Dutch-Caribbean-coral-reefs.

Species richness will be plotted on maps showing the variation in biodiversity around Bonaire, showing which areas are the most species rich. The analyses will also reveal rare species and habitats in need of special protection, in order to combat a decline in species richness.

Participants from the Netherlands and abroad

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13. Lukas Verboom (University of Groningen)
14. Ronald Vonk (Naturalis, Leiden)

Local participation and support

1. Caren E. Eckrich (STINAPA Bonaire)
2. Sabine M. Engel (STINAPA Bonaire)
3. Tineke van Bussel (DCNA)
4. Ellen Muller (citizen scientist, Bonaire)
5. Alev Ozten Low (citizen scientist, Bonaire)

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Diploria labyrinthiformis (Linnaeus, 1758), reef flat of Sweet Dreams (Bon.07). Photo B.W. Hoeksema.

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2. Survey sites

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Fig. 2.1. Map of the survey sites.

Table 2.1. List of survey sites (stations BON.01–48).

Station nr.	Date	Locality name	Coordinates N	Coordinates W
BON.01	22-10-2019	Delfins Reef	N 12°06.908'	W 68°17.659'
BON.02	23-10-2019	Pink Beach (Kabayé)	N 12°03.849'	W 68°16.896'
BON.03	23-10-2019	1000 Steps	N 12°12.654'	W 68°19.276'
BON.04	24-10-2019	Alice in Wonderland	N 12°05.993'	W 68°17.118'
BON.05	24-10-2019	Corporal Meiss (North Belnem)	N 12°07.888'	W 68°16.996'
BON.06	25-10-2019	Oil Slick Leap	N 12°12.029'	W 68°18.512'
BON.07	25-10-2019	Sweet Dreams	N 12°02.137'	W 68°15.722'
BON.08	25-10-2019	Inland bay / Tidal pool south of White Slave	N 12°03.023'	W 68°16.215'
BON.09	26-10-2019	Karpata	N 12°13.171'	W 68°21.123'
BON.10	26-10-2019	Salt Pier	N 12°05.006'	W 68°16.912'
BON.11	26-10-2019	Bachelor's Beach (Fondu Di Kalki) - night dive	N 12°07.522'	W 68°17.233'
BON.12	27-10-2019	Lac Cai (Inside of lagoon)	N 12°06.255'	W 68°13.347'
BON.13	27-10-2019	Tidal pool near Punt Vierkant	N 12°06.558'	W 68°17.534'
BON.14	28-10-2019	Bari Reef	N 12°10.036'	W 68°17.219'
BON.15	28-10-2019	Red Beryl	N 12°02.819'	W 68°16.073'
BON.16	29-10-2019	Tailor Made	N 12°13.407'	W 68°24.223'
BON.17	29-10-2019	Willemstoren Lighthouse	N 12°01.703'	W 68°14.246'
BON.18	29-10-2019	Red slave	N 12°01.605'	W 68°15.079'
BON.19	30-10-2019	Hilma Hooker (wreck)	N 12°06.271'	W 68°17.291'
BON.20	30-10-2019	Baby Beach (Pretty Rough)	N 12°04.882'	W 68°13.926'
BON.21	31-10-2019	Something Special (Pali Grande)	N 12°09.696'	W 68°17.016'
BON.22	31-10-2019	Lac Cai (Outside of lagoon)	N 12°06.183'	W 68°13.333'
BON.23	1-11-2019	Playa Funchi	N 12°16.957'	W 68°24.822'
BON.24	1-11-2019	Boka Slagbaai	N 12°15.830'	W 68°24.820'
BON.25	2-11-2019	Lagun (Tidal area)	N 12°10.914'	W 68°12.976'
BON.26	3-11-2019	Small Wall	N 12°10.685'	W 68°17.539'
BON.27	3-11-2019	Red Slave	N 12°01.592'	W 68°15.063'
BON.28	3-11-2019	Something Special (Pali Grande) - night dive	N 12°09.696'	W 68°17.016'
BON.29	4-11-2019	Front Porch	N 12°09.904'	W 68°17.194'
BON.30	4-11-2019	Invisibles	N 12°04.646'	W 68°16.800'
BON.31	5-11-2019	Tolo (Ol' Blue)	N 12°12.923'	W 68°20.218'
BON.32	5-11-2019	Playa Frans	N 12°14.781'	W 68°24.825'
BON.33	6-11-2019	Invisibles	N 12°04.646'	W 68°16.800'
BON.34	6-11-2019	Boka Onima (Tidal area)	N 12°15.187'	W 68°18.663'
BON.35	6-11-2019	Boka Washikemba (Tidal area)	N 12°10.408'	W 68°12.611'
BON.36	6-11-2019	Lac Cai (Inside of lagoon)	N 12°05.550'	W68° 13.848
BON.37	6-11-2019	Andrea I	N 12°11.285'	W 68°17.795'
BON.38	6-11-2019	Delfins Reef - night dive	N 12°06.908'	W 68°17.659'
BON.39	7-11-2019	The Lake	N 12°06.629'	W 68°17.586'
BON.40	7-11-2019	Klein Bonaire: Monte's Divi	N 12°09.010'	W 68°18.911'
BON.41	7-11-2019	Klein Bonaire: Sampler	N 12°10.153'	W 68°18.648'
BON.42	7-11-2019	Aquarius	N 12°06.017'	W 68°17.127'
BON.43	8-11-2019	Tori's Reef	N 12°04.247'	W 68°16.835'
BON.44	8-11-2019	Klein Bonaire: South Bay	N 12°09.001'	W 68°19.234'
BON.45	8-11-2019	Klein Bonaire: Carl's Hill	N 12°09.886'	W 68°19.379'
BON.46	8-11-2019	Courtyard Marriott Hotel, jetty	N 12°08.266'	W 68°16.201'
BON.47	9-11-2019	Alice in Wonderland (Tidal area)	N 12°05.993'	W 68°17.118'
BON.48	9-11-2019	Kralendijk Boulevard (south)	N 12°09.047'	W 68°16.649'

3. Marine habitats

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Fig. 3.1. Reef flat (<10m depth).

Fig. 3.2. Coral reef slope (10–30 m depth)


Fig. 3.3. Sedimentary lagoon (BON.25)


Fig. 3.4. Highly exposed bay, east coast (BON.34)


Fig. 3.5. Sheltered intertidal zone, west coast (BON.04)

Fig. 3.6. Shallow bay with mangroves and seagrass (BON.08)

Fig. 3.7. Deeper bay with mangroves and seagrass (BON.22)

4. A depth gradient of macroalgae

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Introduction

Macroalgae play an important role in the functioning of coral reef ecosystems. They do not only constitute an important component in the biodiversity of tropical marine ecosystems, but they are also responsible for their high primary productivity (Littler & Littler 1994). In addition, some macroalgae (like crustoase calcareous algae) provide mechanical stability and support to reef structures as a natural cement. This is essential for the formation of coral reefs (Littler & Littler 2013). However, algae are also notorious as aggressive competitors for space that can overgrow reef corals (Lirman 2001; Bonaldo & Hay 2014; Adam et al. 2015).

The coral reefs on Bonaire generally consist of a fringing reef: away from the shore there is a small intertidal zone, followed by a long, shallow sandy area (reef flat) with patches of coral to approximately 10 m depth. This is followed by a sharp drop-off or ledge (reef slope) to approximately 30 m depth. The species composition of corals and fish has been reported to change with this depth gradient on Bonaire (Bak & Nieuwland 1995). The vertical zonation of macroalgal species composition has however never been described before from Bonaire, but can be compared with that of Curaçao (Van den Hoek et al. 1975, 1978)

Methods

In order to describe the vertical gradient of macroalgae associated with coral reefs on Bonaire, the presence/absence of a predetermined list of algal species was recorded each dive for 15 min at 30 m, 15 min at 20 m, 15 min at 10 m, and 15 min at 5 m (until the intertidal area was reached). In total, 29 sites were visited on Bonaire and Klein-Bonaire.

The predetermined list of algal species was composed of 15 Rhodophyta (red macroalgae), 28 Chlorophyta (green macroalgae) and 16 Phaeophyceae (brown macroalgae) (Tables 4.1–4.3). The species on these lists were chosen based on ecological importance (like overgrowing coral), previous literature and the feasibility to positively identify this species underwater.

In addition to the depth gradient for a predetermined list of species, the presence of additional macroalgal species was noted. To this end, care was taken to sample at different habitats, not limited to coral reefs, but extending to mangrove areas, seagrass beds, sedimentary lagoons, and highly exposed bays (Bokas) (Chapter 3). Specimens that could not be identified in the field were sampled for further examination by microscope in the laboratory.

Preliminary results:

Vertical gradient of macroalgae associated with coral reefs

At 30 m depth, 7 Chlorophyta, 10 Rhodophyta, and 10 Phaeophyceae species of the predetermined list were found across all sites. At 20 m depth, 9 Chlorophyta, 12 Rhodophyta and 8 Phaeophyceae were observed. At 10 m depth, 10 Chlorophyta, 15 Rhodophyta, and 10 Phaeophyceae were recorded. And finally, at 5 m depth, 16 Chlorophyta, 15 Rhodophyta, and 15 Phaeophyceae were found. See Table 4.1 for the Chlorophyta, Table 4.2 for the Rhodophyta, and Table 4.3 for the Phaeophyceae. Examples of typical macroalgal species observed at deeper communities, shallow communities and species occurring at the southeast coast are presented in Fig. 4.1.

Additional results

Apart from the 59 species monitored during diving, an additional ~40 species were recorded. Several of these may represent new records for Bonaire, including *Phyllodictyon pulcherrimum*, a green macroalgal species that is only 1–2 cm high (Fig. 4.2). It typically grows at depths of 20–30 m. The full species list awaits confirmation after further study of the collected specimens.

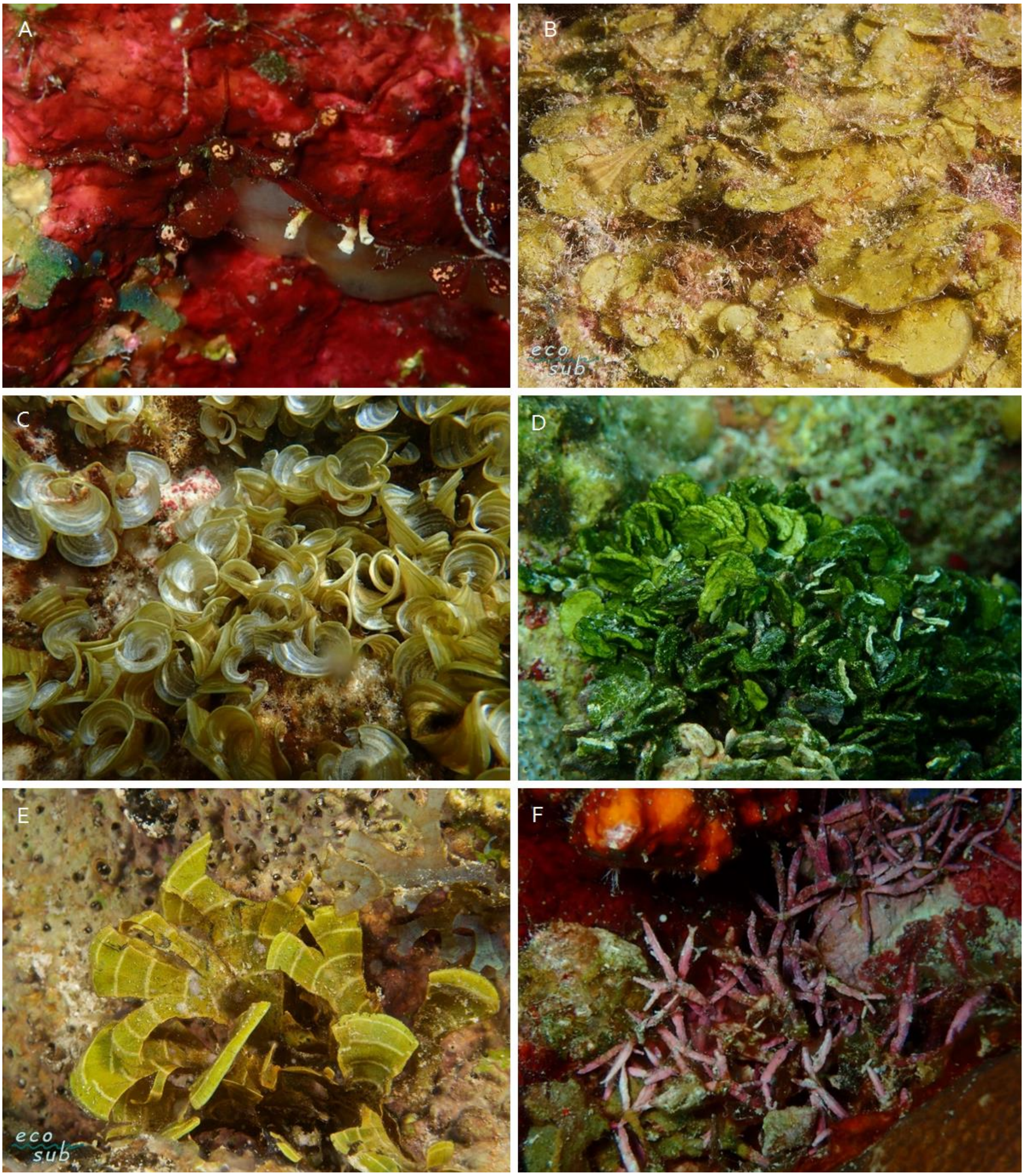

Fig. 4.1. Representative images of macroalgal species typically observed at deeper communities around Bonaire (A = *Botryocladia* sp., B = *Lobophora* sp.), shallow communities (C = *Padina* sp., D = *Halimeda opuntia*) and southeast coast communities (E = *Stypopodium* sp., F = *Amphiroa tribulus*).

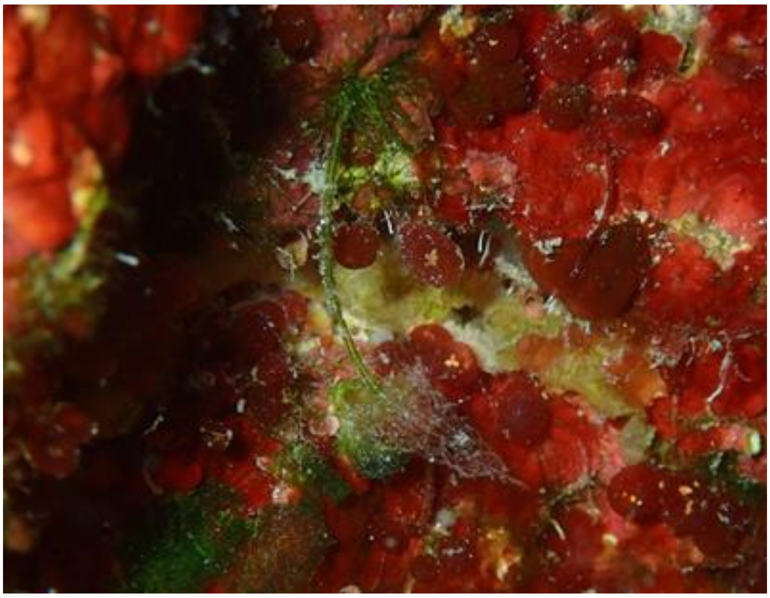

Fig 4.2. *Phyllodictyon pulcherrimum*, a green macroalgal species, represents a new record for Bonaire. It typically grows at depths of 20–30 m.

Table 4.1. Numbers of coral reef sites around Bonaire where green macroalgae (Chlorophyta) were recorded at depths of 30, 20, 10, and 5 m.

Species / **Depth**	**30 m**	**20 m**	**10 m**	**5 m**
Acetabularia sp.	0	0	1	1
Anadyomene sp.	16	20	21	15
Avrainvillea sp.	0	0	0	2
Bryopsis sp.	1	1	4	5
Caulerpa ashmeadii	0	0	0	1
Caulerpa cupressoides	0	0	0	0
Caulerpa macrophysa	0	0	0	1
Caulerpa mexicana	0	0	0	0
Caulerpa prolifera	0	0	0	0
Caulerpa racemosa	0	0	0	0
Caulerpa serrulata	1	2	3	5
Caulerpa sertularioides	0	0	0	0
Caulerpa webbiana	0	0	0	0
Chaeotomorpha sp.	0	0	0	1
Codium intertextum	0	0	0	1
Codium taylori	0	0	0	1
Dictyosphaeria cavernosa	0	2	7	10
Ernodermis verticillata	0	1	0	0
Halimeda goreaui	2	2	2	0
Halimeda incrassata	0	0	0	0
Halimeda sp.	5	8	9	8
Halimedia opuntia	0	0	1	14
Neomeris annulata	3	8	7	15
Penicillus sp.	0	0	0	1
Udotea cyathiformis	0	0	0	0
Udotea sp.	0	0	0	0
Ulva sp.	0	0	0	0
Valonia ventricosa	13	15	15	13

Table 4.2. Numbers of coral reef sites around Bonaire where red macroalgae (Rhodophyta) were recorded at depths of 30, 20, 10, and 5 m.

Depth Species	30 m	20 m	10 m	5 m
Amphiroa fragilissima	22	26	27	22
Amphiroa hancockii	0	0	1	3
Amphiroa rigida	1	4	12	15
Amphiroa tribulus	2	4	4	7
Botryocladia sp.	17	17	6	1
Ceramium sp.	0	1	1	1
Coelothrix irregularis	0	3	10	18
Dasya sp.	1	6	4	4
Galaxaura sp.	7	10	8	10
Hypnea sp.	0	0	3	2
Laurencia sp.	0	0	1	7
Martensia pavonina	1	1	1	2
Peysonnelia sp.	23	27	16	13
Porotlithon sp.	24	27	26	15
Pterocladiella capillacea	23	27	26	19

Table 4.3. Numbers of coral reef sites around Bonaire where brown macroalgae (Phaeophyceae) were recorded at depths of 30, 20, 10, and 5 m.

Depth Species	30 m	20 m	10 m	5 m
Dictyopteris delicatula	1	0	0	2
Dictyopteris sp.	1	0	1	1
Dictyota bartayresiana	24	27	25	15
Dictyota crispata	0	0	0	2
Dictyota martensii	0	0	0	4
Dictyota pfaffi	13	20	27	24
Dictyota pinnatifida	2	2	3	4
Dictyota pulchella	12	17	13	3
Dictyota sp.	1	1	4	4
Hydroclathrus clathrus	0	0	0	0
Lobophora variegata	21	24	7	2
Padina sp.	0	0	1	9
Sargassum hystrix	3	4	2	1
Stypopodium sp.	1	2	2	4
Turbinaria tricostata	0	0	0	6
Turbinaria turbinata	0	0	0	4

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5. Diversity and distribution of stony corals

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Introduction

Surprisingly little has been published about the coral fauna of Bonaire. The last report was by Roos (1971) based on a survey in 1967 supplemented by information from museum collections. Bak (1975) published an overview of corals in the Dutch Caribbean as a report on surveys carried out in 1972, but he only distinguished coral faunas of the Leeward islands and the Windward islands and not of each separate island. During the 2019-survey, corals were recorded for each locality but in this preliminary report we only present a species list for the whole island and compare this (Table 5.1) with the reports by Roos (1971) and Bak (1975) and with our previous surveys in Curaçao (unpublished) and St. Eustatius (Hoeksema & van Moorsel 2016; Hoeksema et al. 2022).

Results and discussion

The present list (Table 5.1) shows a higher number of coral species (n=45) than the previous list by Roos (1971; n=36), which can partly be attributed to changes in coral taxonomy. For instance, at present three *Orbicella* species are distinguished compared to only one (*Orbicella annularis*) in 1971. Furthermore, there are also species that were described recently and could not have been noted in 1967, such as *Agaricia grahamae*, *Madracis carmabi* and *Meandrina jacksoni*, which were described in 1973, 2003, and 2011, respectively or *Agaricia humilis*, which was elevated to species level in 1983. Diving was technically less advanced in 1967 than it is now and therefore the relatively low number of species encountered at present could be attributed to species loss.

It is more remarkable that several species observed in 1967 were not found during the present survey: *Manicina areolata*, *Isophyllia sinuosa*, and *Solenastrea bournoni*. These are large species that are cannot easily be overlooked (see Hoeksema et al. 2022:ESM1). Bak (1975) did not record hydrocorals (*Millepora* spp. and *Stylaster* spp.), but he recorded an equal number of coral species (n=45) as during the 2019-survey, although Aruba and Curaçao were also covered in his survey. The 2017-survey in Curaçao, also resulted in an almost similar species count (n=44).

It is striking that *Cladopsammia manuelensis*, which has recently been observed to be very common in Curaçao and Aruba (Hoeksema et al. 2019, and also in some other Caribbean localities (Hammerman et al 2021), was not present in Bonaire and Sint Eustatius. On the other hand, *Mycetophyllia ferox*, was frequenly found in Bonaire but not in Curaçao. *Agaricia undata* was observed in Bonaire (García-Hernández et al. 2020) but not in Curaçao, where it appears to live at greater depths (Bongaerts et al. 2015). Although, the coral faunas of Bonaire and Curaçao are almost similar, the differences are still striking considering that they are only 40 km apart (see also Reimer et al. 2022).

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Table 5.1. Records of stony corals at Bonaire (=Bon) dating from 2019 (present report) and 1967 (Roos 1971), at the Leeward islands (= Lee) of the Dutch Caribbean dating from 1972 (Bak 1975), and a comparison with data from recent surveys at Curaçao (Cur 2017) and St. Eustatius (Eux 2015). Nomenclature according to Hoeksema & Cairns (2022).

	Bon 2019	Bon 1967	Lee 1972	Cur 2017	Eux 2015
Scleractinia					
Acroporidae					
Acropora cervicornis (Lamarck, 1816)	1	1 `	1	1	1
Acropora palmata (Lamarck, 1816**)**	1	1	1	1	1
Acropora prolifera (Lamarck, 1816) *	0	0	1	0	1
Agariciidae					
Agaricia agaricites (Linnaeus, 1758)	1	1	1	1	1
Agaricia fragilis Dana, 1848	1	1[1]	1	1	1
Agaricia grahamae Wells, 1973	1	0	1	1	0
Agaricia humilis Verrill, 1901	1	0	0	1	1
Agaricia lamarcki Milne Edwards & Haime, 1851	0	0	1	1	1
Agaricia tenuifolia Dana, 1848	1	0	1	0	0
Agaricia undata (Ellis & Solander, 1786)	1	0	1	0	0
Helioseris cucullata (Ellis & Solander, 1786)	1	0[2]	1	1	1
Astrocoeniidae					
Madracis auretenra Locke, Weil & Coates, 2007	1	1[3]	1[4]	1	1
Madracis carmabi Vermeij, Diekmann & Bak, 2003	1	0	0	1	1
Madracis decactis (Lyman, 1859)	1	1	1	1	1
Madracis formosa Wells, 1973	0	0	1	0	0
Madracis myriaster (Milne Edwards & Haime, 1848)	0	0	1	0	0
Madracis pharensis (Heller, 1868)	1	0	1	1	1
Madracis senaria Wells, 1973	0	0	1	1	1
Stephanocoenia intersepta (Lamarck, 1836)	1	1	1[5]	1	1
Caryophyllidae					
Caryophyllia cf. *antillarum* (De Pourtalès, 1874)	0	0	1	0	0
Colangia immersa Pourtalès, 1871	0	0	1	0	1
Phyllangia americana Milne Edwards & Haime, 1850	0	0	1	0	0
Rhizosmilia maculata (Pourtalès, 1874)	0	0	1	0	1
Thalamophyllia riisei (Duchassaing & Michelotti, 1860)	0	0	1[6]	0	0

Dendrophylliidae					
Cladopsammia manuelensis (Chevalier, 1966)	0	0	0	1	0
Tubastraea coccinea Lesson, 1829	1	1[7]	1	1	1
Meandrinidae					
Dendrogyra cylindrus Ehrenberg, 1834	1	1	1	1	1
Dichocoenia stokesii Milne Edwards & Haime, 1848	1	1	1	1	1
Eusmilia fastigiata Pallas, 1766	1	1	1	1	1
Meandrina danai (Milne Edwards & Haime, 1848)	0	0	0	0	1
Meandrina jacksoni Pinzón & Weil, 2011	1	0	0	0	1
Meandrina meandrites (Linnaeus, 1758)	1	1	1	1	1
Merulinidae					
Orbicella annularis (Ellis & Solander, 1786)	1	1[8]	1[8]	1	1
Orbicella faveolata (Ellis & Solander, 1786)	1	0	0	1	1
Orbicella franksi (Gregory, 1895)	1	0	0	1	1
Montastraeidae					
Montastraea cavernosa (Linnaeus, 1767)	1	1	1	1	1
Faviidae: Faviinae					
Colpophyllia breviserialis Milne Edwards & Haime, 1849	0	0	1	1	0
Colpophyllia natans (Houttuyn, 1772)	1	1	1	1	1
Diploria labyrinthiformis (Linnaeus, 1758)	1	1	1	1	1
Favia fragum (Esper, 1795)	1	1	1	1	1
Manicina areolata (Linnaeus, 1758)	0	1	1	0	1
Pseudodiploria clivosa (Ellis & Solander, 1786)	1	1[9]	1[9]	1	1
Pseudodiploria strigosa (Dana, 1846)	1	1[10]	1[10]	1	1
Faviidae: Mussinae					
Isophyllia rigida (Dana, 1848)	1	1[11]	1[11]	0	1
Isophyllia sinuosa (Ellis & Solander, 1786)	0	1	1	0	1
Mussa angulosa Pallas, 1766	1	1	1	1	1
Mycetophyllia aliciae Wells, 1973	1	0	1	1	1
Mycetophyllia ferox Wells, 1973	1	0	1	0	0
Mycetophyllia lamarckiana Milne Edwards & Haime, 1848	0	1[12]	0	0	0
Mycetophyllia reesi Wells, 1973	0	0	1	0	0
Scolymia cubensis (Milne Edwards & Haime, 1848)	1	0	1	1	1
Scolymia lacera (Pallas, 1766)	1	1	1	1	1
Oculinidae					
Oculina diffusa Lamarck, 1816	0	0	1	0	0
Poritidae					
Porites astreoides Lamarck, 1816	1	1	1	1	1
Porites branneri Rathbun, 1888	1	1	1	1	0
Porites divaricata Le Sueur, 1820	1	1	1	1	1
Porites furcata Lamarck, 1816	1	0	1	0	1
Porites porites (Pallas, 1766)	1	1	1	1	1
Rhizangiidae					
Astrangia solitaria (Le Sueur, 1818)	0	1	1	0	1
Siderastreidae					
Siderastrea radians (Pallas, 1766)	1	1	1	1	1
Siderastrea siderea (Ellis & Solander, 1768)	1	1	1	1	1
Scleractinia incertae sedis					
Cladocora arbuscula (Le Sueur, 1820)	0	0	1	0	0
Solenastrea bournoni Milne Edwards & Haime, 1849	0	1	1	0	1
Hydrozoa					
Milleporidae					
Millepora alcicornis Linnaeus, 1758	1	1	-	1	1
Millepora complanata Lamarck, 1816	1	1	-	1	1
Stylasteridae					
Stylaster roseus (Pallas, 1766)	1	1	-	1	1
Stylaster sp.	-	-	-	0	1
Species numbers	**45**	**36**	**45**	**43**	**51**

Notes: * Hybrid species but with a distinct morphotype. Some species have been recorded by their synonyms, alternative combinations, wrong identities or misspelled names: [1] as *Agaricia agaricites* var. *fragilis*; [2] as *Agaricia cucullata* considered a synonym of *Agaricia agaricites*; [3] as *Madracis asperula* Milne Edwards & Haime, 1849; [4] as *Madracis mirabilis* (Duchassaing & Michelotti, 1860); [5] as *Stephanocoenia michelini* Milne Edwards & Haime, 1848; [6] as *Desmophyllum riissei*; [7] as *Tubastraea tenuilamellosa* (Milne Edwards & Haime, 1848); [8] as *Montastrea annularis*; [9] as *Diploria clivosa*; [10] as *Diploria strigosa*; [11] as *Isophyllastrea rigida*; [12] as *Mycetophyllia lamarcki*.

6. Species diversity of Zoantharia (Cnidaria: Anthozoa: Hexacorallia)

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Introduction

The order Zoantharia, commonly called colonial anemones, are a group of benthic anthozoans most closely related to the true anemones and other hexacorals, such as stony corals and corallimorpharians. Although zoantharians can be found in a wide variety of marine ecosystems from the polar regions to the equator, and from the intertidal zone to the deep sea, they are most abundant on tropical and sub-tropical coral reefs. In such ecosystems, many zoantharian species contain endosymbiotic photosynthetic dinoflagellates of the family Symbiodiniaceae, allowing these species to obtain much of their nutrition via photosynthetic products (Trench 1974; Burnett 2002). Other species and genera of zoantharians live in close associations with other marine invertebrates such as sponges or benthic hydrozoans, utilizing the water currents and planktonivorous nature of their host to themselves also acquire planktonic food sources (e.g. Lewis & Finelli 2015).

Worldwide, there are estimated to be between 300 to 700 species of zoantharians (Appeltans et al. 2012; WoRMS 2020). Research on the species diversity of zoantharians started on the reefs of the Caribbean in the second half of the 1700s (e.g. Ellis 1768), and in general it is considered that the species diversity of this region is relatively well understood, particularly in comparison with other less-examined marine regions. However, recent works have shown there are still undescribed species remaining to be discovered in the Caribbean (e.g. Swain 2009; Reimer et al. 2012; Montenegro et al. 2020; Kise et al. 2022). As well, recent re-examinations of zoantharian species diversity using molecular phylogenetic techniques combined with morphological and field data have led to a large-scale reconsideration of the species identities of many zoantharians. Such work has focused more on Indo-Pacific regions, and there is a clear need to perform new focused surveys in the Caribbean.

In recent years, surveys by the first author have been conducted in Costa Rica (2010, 2018), the Yucatan Peninsula of Mexico (2018), St. Eustatius (2015; Reimer 2016), and Curaçao (2017; Reimer et al. 2018). This small report focuses on the initial results from recent surveys in 2019 in Bonaire (see Reimer et al. 2022), and includes a species list along with discussion of future needs to help further develop our understanding of this important coral reef taxon.

Materials and Methods

A total of 50 Zoantharia specimens were collected from 20 sites around Bonaire, via the roving diving technique while SCUBA diving. Specimens were photographed in situ and then collected in individual containers. Specimens were identified following relevant literature (e.g. West 1979; Reimer 2016; Low et al. 2016), and fixed in 99% ethanol for subsequent analyses. The nomenclature of species follows that of the World Register of Marine Species (WoRMS 2020).

Results and Discussion

The 50 specimens collected represented 17 species, seven genera, five families, and two suborders of Zoantharia, are listed below (Table 6.1), along with comments on each of the genera observed plus on some of the more interesting species records. While most collected specimens could be identified to species based on their gross external morphology or via associations with specific species of sponges, several specimens (n=10) were preliminarily identified as undescribed species as detailed below.

Conclusions

As this and other recent works have shown, undescribed species of Zoantharia are present on the coral reefs of the Caribbean (Swain 2009; Reimer et al. 2012). These findings echo recent findings in other taxa that have until now not been thoroughly examined in the Caribbean (e.g. Montano et al. 2017), and it is clear focused surveys by taxonomic experts can greatly increase our knowledge of marine biodiversity (Hoeksema et al. 2017). Such surveys should continue to shed light on the biodiversity of threatened reefs of the Caribbean.

Table 6.1. Preliminary species list of the order Zoantharia Rafinesque, 1815 for coral reefs of Bonaire

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Suborder Brachycnemina Haddon & Shackleton, 1891

Family Zoanthidae Rafinesque, 1815
Genus *Zoanthus* Lamarck, 1801
Remarks: This genus was rare to uncommon, similar to as seen at both St. Eustatius and Curacao. Species of this group all formed small colonies on carbonate substrate, often in cracks between scleractinians. Only one colony each of *Z. sociatus* and *Z. pulchellus* were observed, while *Z. solanderi* was observed in small numbers on reef slopes between 6 to 30 m depths. No specimens were observed from the intertidal zone, and only one colony (=*Z. sociatus*) was reported shallower than 5 m.

1. *Zoanthus pulchellus* (Duchassaing de Fonbressin & Michelotti, 1860)
2. *Zoanthus sociatus* (Ellis, 1768)
3. *Zoanthus solanderi* Le Sueur, 1818 (Fig. 6.2)

Family Sphenopidae Hertwig, 1882
Genus *Palythoa* Lamouroux, 1816
Remarks: Similar to *Zoanthus*, this genus was rare to uncommon around Bonaire. *Palythoa grandis* (n=2) and *P. grandiflora* (n=1) were only found in very small numbers at sites around Bonaire. On the other hand, *P. caribaeorum*, although not found at most sites, was observed in at sites close to the south end of Bonaire, perhaps due to stronger currents or greater availability of plankton.

4. *Palythoa caribaeorum* (Duchassaing de Fonbressin & Michelotti, 1860)
5. *Palythoa grandiflora* (Verrill, 1900)
6. *Palythoa grandis* (Verrill, 1900)

Suborder Macrocnemina Haddon & Shackleton, 1891

Family Parazoanthidae Delage & Herouard, 1901
Genus *Parazoanthus* Haddon & Shackleton, 1891
Remarks: Most *Parazoanthus* observed around Bonaire were colonies of *P. swiftii* on sponge species, usually on reef slopes at depths of >10 m in sites with some exposure and corresponding stronger currents. However, we did collect three specimens of two potentially undescribed species.

7. *Parazoanthus swiftii* (Duchassaing de Fonbressin & Michelotti, 1860)
8. *Parazoanthus* sp. 1

Remarks: This species was similar in size of polyps and its bright yellow color to *P. swiftii*, but could be distinguished from this species by its sponge associations, as it was found only on overhangs and walls associated with a variety of encrusting sponge species, on the reef slope at depths >15 m (n=2). Preliminary molecular data from similar specimens in Curaçao confirm that this species is different from *P. swiftii*, and it will be formally described in the near future.

9. *Parazoanthus* sp. 2

Remarks: Only one specimen of this putatively undescribed species was collected. Similar in size to *P. swiftii*, it could be distinguished from *P. swiftii* and *Parazoanthus* sp. 1 by its bright pink color. Found associated to a massive sponge species within a small crack/cave on the reef slope, further examinations are needed to confirm the identity of this specimen. No similar specimens have been collected from the first author's other surveys in the Caribbean, and it does not match with any other previously described species in the literature.

Genus *Bergia* Duchassaing de Fonbressin & Michelotti, 1860

Remarks: This genus, along with *Umimayanthus*, is the most common genus on Bonaire reefs, with all three species observed in association with various sponge species at depths >10 m on reef slopes.

10. *Bergia catenularis* Duchassaing de Fonbressin & Michelotti, 1860

11. *Bergia* cf. *cutressi* (West, 1979)

Remarks: Two specimens of this species were collected from deep reef slopes, in association with massive sponges. Both specimens fit well with the original description of *B. cutressi*, and additional molecular data will likely confirm the identity of these specimens.

12. *Bergia puertoricense* (West, 1979)

Genus *Umimayanthus* Montenegro, Sinniger & Reimer, 2015

Remarks: A genus recently erected separate from *Parazoanthus*, the species *U. parasiticus* is the most common zoantharian on reefs around Bonaire, observed in association with a variety of sponges and present at all sites examined.

13. *Umimayanthus parasiticus* (Duchassaing de Fonbressin & Michelotti, 1860)

14. *Umimayanthus* sp.

Remarks: Five specimens of this potentially undescribed species were collected from depths >30 m on the deep reef slope. All specimens were associated with encrusting sponges on the bottom sides of foliose or laminar scleractinian corals. Much smaller in size than the congener *U. parasiticus*, this potentially undescribed species is similar in habitat and size to Indo-Pacific congeners.

Family Hydrozoanthidae Sinniger, Reimer & Pawlowski, 2010

Genus *Hydrozoanthus* Sinniger, Reimer & Pawlowski, 2010

Remarks: Both Atlantic species of this genus are found exclusively associated with *Dentitheca* hydroid colonies, which are found in areas with strong currents. In this survey, only three colonies of this genus were observed, and it can be considered rare around Bonaire.

15. *Hydrozoanthus antumbrosus* (Swain, 2009)

16. *Hydrozoanthus tunicans* (Duerden, 1900)

Family Microzoanthidae Fujii & Reimer, 2011

Genus *Microzoanthus* Fujii & Reimer, 2011

Remarks: This family has only been previously reported from the Indo-Pacific. Two small colonies were collected during the present survey, and represent the first records of the family and genus from the entire Atlantic basin. Morphological and molecular data are being obtained to formally describe the species.

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Fig. 6.1. Yellow zoantharian living in association with a dark-green sponge. Photo: J.D. Reimer

Fig. 6.2. A colony of *Zoanthus solanderi* at 13 m depth (BON.21).

7.1. Sea anemones (Actiniaria & Ceriantharia), Bryozoa and sabellid Polychaeta

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Introduction

This report deals with Actiniaria, Ceriantharia, Bryozoa and sabellid Polychaeta in the waters around Bonaire. No written reports are known on the occurrence of these invertebrates at this locality, except the one by Den Hartog (1977), which mentions the cerianthid *Isaracnanthus nocturnus* from Klein Bonaire. On a greater Caribbean scale, none of the species recorded until now is particularly rare. The nomenclature of the species follows that of the World Register of Marine Species (WoRMS Editorial Board 2019).

Fig. 7.1. *Actinostella flosculifera*, BON 11. Nightdive. Usually photos of this species are made during daytime, when the tentacles are retracted and only the collar is shown. The tentacles have characteristic narrow whitish bands with an uncoloured spot in the middle of the oral side.

Results

Sea anemones (Actiniaria and Ceriantharia)

Fourteen species of Actiniaria were recorded (Table 7.1).

Table 7.1. Species of Actiniaria recorded during the expedition

Actinostella flosculifera (Le Sueur, 1817) (Fig. 7.1)
Bartholomea annulata (Le Sueur, 1817)
Bellactis spec. (Fig. 7.2)
Bunodosoma granuliferum (Le Sueur, 1817)
Condylactis gigantea (Weinland, 1860)
Exaiptasia diaphana (Rapp, 1829)
Isarachnanthus nocturnus (den Hartog, 1977)
Lebrunia coralligens (Wilson, 1890)
Lebrunia neglecta Duchassaing & Michelotti, 1860
Phymanthus pulcher (Le Sueur, 1817)
Laviactis lucida (Duchassaing & Michelotti, 1860)
Stichodactyla helianthus (Ellis, 1768)
Telmatactis cricoides (Duchassaing, 1850
Viatrix globulifera (Duchassaing, 1850)

The number of actiniarians is relatively high. In a comparable survey effort at Sint Eustatius seven species were found (Faasse 2017). Some zooxanthellate species (i.e. *Condylactis gigantea* and *Bartholomea annulata*) were relatively rare on Sint Eustatius, which may be related to its paucity of shallow coral reefs. The surface and variety of shallow water habitats is larger on Bonaire, which may explain its higher biodiversity.

The genus *Bellactis* currently comprises two species. *Bellactis coeruleus* has only been recorded from the eastern Atlantic (Santiago Island, Cape Verde Islands) (Ocaña et al. 2015) and *Bellactis ilkalyseae* Dube, 1983 from Brasil at 0–2 m depth (Grajales & Rodríguez 2014). One of the differences between the two species would be the maximum number of tentacles, 120 for *B. coeruleus* (see Ocaña et al. 2015) and 204 for *B. ilkalyseae* (see Grajales & Rodríguez 2014). On my clearest photo of the species from Bonaire, 190 tentacles may be counted (Fig. 7.2), which would preclude *B. coeruleus.* It was impossible to collect material for comparison of DNA, cnidom and/or internal morphology. Species not recorded during the expedition but known to occur around Bonaire are *Actinoporus elongatus*, *Anemonia sargassiensis* and *Bunodosoma cavernata* (unpublished records of the author). *Calliactis tricolor* (Le Sueur, 1817) and an unidentified actiniarian that has some resemblance to species of the genus *Telmatactis* have been photographed by E. Muller https://pbase.com/imagine/image/167601678).

Fig. 7.2. *Bellactis* spec., Bonaire 2007.

Ascidiacea

Five species of ascidians were recorded (Table 7.2) and four more could not be identified because no specimens could be collected.

Table 7.2. Species of Ascidiacea recorded during the expedition.

Didemnum conchyliatum (Sluiter, 1898)
Distaplia bermudensis Van Name, 1902
Distaplia corolla Monniot F., 1974
Rhopalaea abdominalis (Sluiter, 1898)
Trididemnum solidum (Van Name, 1902)

Bryozoa

Four species of bryozoans were recorded, one of which. *Trematooecia aviculifera* (order Cheilostomatida), could be identified from photographs. The orders Ctenostomatida and Cyclostomatida are represented as well.

Sabellidae and Serpulidae (fan worms)

Three species of fanworms were recorded to species level and four more to genus level (Table 7.3). No material was collected as most species recorded live in holes inside live corals. Other worm species recorded were *Hermodice carunculata* (Pallas, 1766), *Malmgreniella variegata*, and unidentified Terebellidae. *Branchiomma* spec. was photographed by Lukas Verboom on mangrove roots in the Lac. The number of fanworm species recorded was not much different from the number recorded around St. Eustatius (five).

Table 7.3. Species of Polychaeta (Sabellidae and Serpulidae) recorded during the expedition..

"Anamobaea spec." 'ghost feather duster worm'
Anamobaea orstedii Krøyer, 1856
Bispira brunnea (Treadwell, 1917)
Bispira melanostigma (Schmarda, 1861)
Acromegalomma spec.
Branchiomma spec.
Protula spec.
Spirobranchus spec.

Conclusion

In comparison with Sint Eustatius, the actiniarian fauna of Bonaire seems richer in species. The surface and variety of shallow water habitats is larger on Bonaire, which may enhance biodiversity. On the other hand the reef bryozoan fauna of Bonaire seems poorer. The number of fanworm records around St. Eustatius and Bonaire is comparable.

Acknowledgements. Prof. P. Wirtz (Madeira) suggested the name *Bellactis coeruleus* Ocaña, den Hartog & Brito, 2015 for the Caribbean *Bellactis* species. Some participants of the expedition provided valuable additions to the list of sea anemones. *Exaiptasia diaphana* was photographed by L. Verboom on mangrove roots in the Lac. *Viatrix globulifera* was recorded by L. van der Loos on eelgrass in the Lac. *Distaplia bermudensis* was recorded by A.H.M. Ligthart.

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8. Hydroids associated to the coral reef fauna and coral diseases

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Introduction

Most hydroids (Cnidaria, Hydrozoa) are considered substrate generalists that live indiscriminately on many different types of biotic and abiotic substrates. Other hydroids are symbiotic with metazoan organisms, such as sponges, cnidarians, molluscs, annelids, bryozoans, crustaceans, echinoderms, tunicates, and vertebrates (fish) (Gili & Hughes 1995; Boero & Bouillon 2005; Puce et al. 2008). These associations range from simple epibiosis to strict symbiosis, in which the hydroid settles on the living epithelium or inside the tissue of the host (Puce et al. 2007).

The hydroids of the Caribbean Sea have been the subject of a few taxonomical accounts. In particular little information is present regarding the hydroids associated to the coral reef fauna, such as sponges, bryozoans and octocorals, with until recently the total absence of reports related to hydroids living in association with scleractinian reef-building corals.

Coral diseases represent a serious threat to reef ecosystems. In recent decades, outbreaks of emerging diseases have become more frequent, possibly due to global ocean warming and human activities, contributing substantially to the speed-up of coralloss and reef decline (Green and Bruckner 2000, Harvell et al. 2007, 2009). Although coral diseases are well reported in the Caribbean, which is considered to date as a hotspot locality for coral diseases, little scattered information has been documented about coral diseases on the Bonaire's coral reefs.

During the Bonaire survey in 2019, 21 dives were performed in order to:

- report *Zanclea*-scleractinian association, and implement finding related to hydroids belonging to the genus *Pteroclava* living in association with soft corals
- report on the hydroids beloging to the genera *Sphaerocoryne* and *Heterocoryne* living in association with sponges
- contribute as much as possible to an inventory of the hydroid diversity of the island
- to asses previously unreported coral diseases

Methods

The field method used was the roving diving technique (presence / absence records per dive with ca. 60 min. observation time, including photography and collecting of voucher specimens and dna samples). All photographs herein were made with a Canon Gx7 in underwater housing.

Results

A total of 18 species of hydrozoans, belonging to seven families of Athecata and six families of Thecata were found. In addition, a protozoan belonging to the species *Halofolliculina corallasia* has been identified to be related to the Caribbean ciliate infection (CCI) coral disease.

Regarding athecate hydroids, the most important results concern *Zanclea* sp. found in association with the bryozoan *Trematooecia* sp. and several *Sphaerocoryne bedoti* colonies living in association with different species of sponges. In contrast, no *Heterocoryne* and *Pteroclava* hydrozoans living in association with sponges and octocoral, respectively, were recorded.

An apparently very rare association was observed to be very common on Bonaire's coral reefs, concerning the hydrocoral *Millepora alcicornis* as host species for the filiferan hydrocoral *Stylaster roseus*. This is a rare example of an association involving two hydrozoan species. All observed hydroids are listed in Tables 8.1 and 8.2 and partially shown in Figs. 8.1 and 8.2.

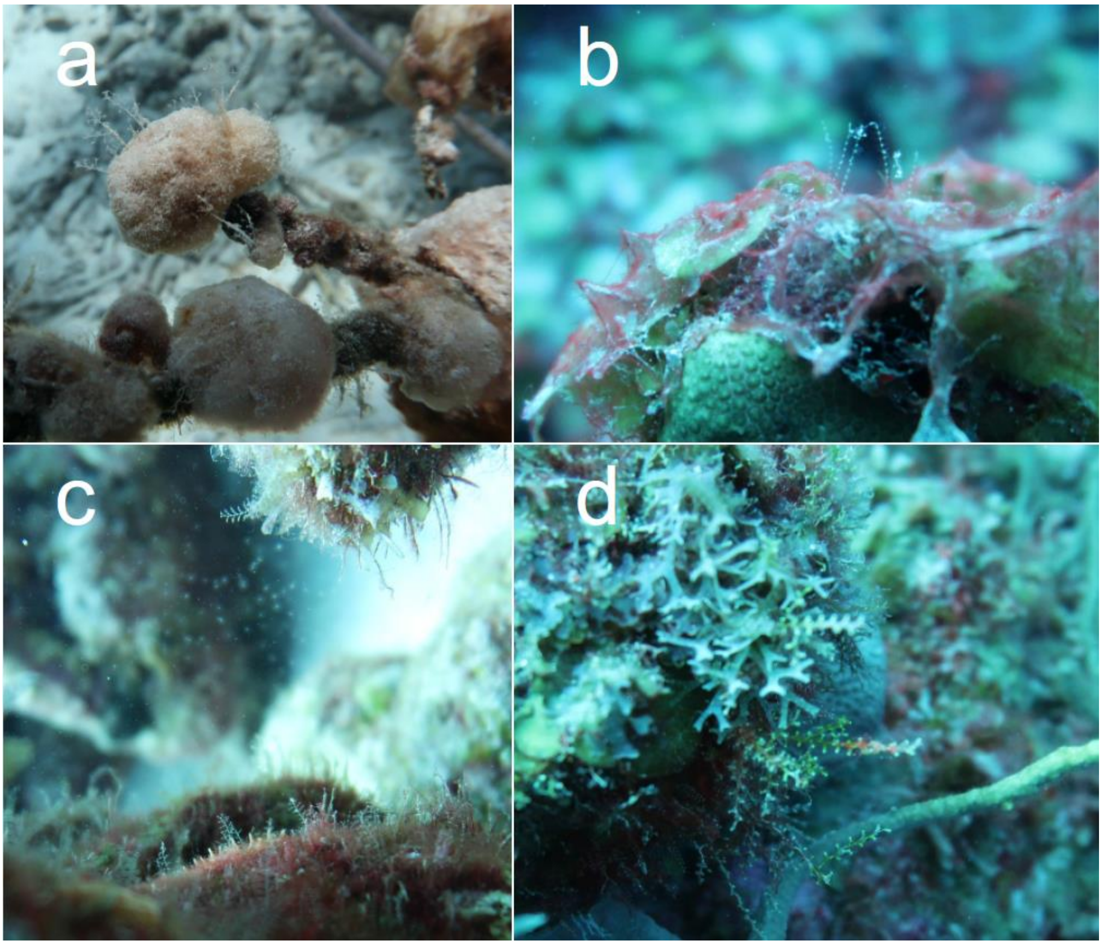

Fig. 8.1. Leptothecata hydrozoans found on Bonaire's coral reefs: **a** *Nemalecium ligthi*; **b** *Antennella secundaria*; **c** *Halopteris* sp.; **d** *Tyroscyphus* sp.

Furthermore, various coral diseases have been observed to be very common. In particular, on about the 70% of the sites explored, the coral *Orbicella faveolata* was reported to be severely affected by the dark spot syndrome. In line with this, several sites were observed to host the disease CCI. This disease is caused by the protozoan *Halofolliculina corallasia* and was found to affect scleractinians belonging to the genera *Acropora*, *Agaricia*, *Eusmilia*, *Meandrina*, and *Colpohyllia*. All observed diseases are shown in Fig. 8.3.

Table 8.1. List of thecates hydroids observed in Bonaire and the figure references.

Phylum	**Class**	**Order**	**Family**	**Taxon**	**Figures**
Cnidaria	Hydrozoa	Leptothecata			
			Aglaopheniidae	*Aglaophenia* cf. *latecarinata*	
			Camanulariidae	*Clytia gracilis*	
			Haleciidae	*Nemalecium lighti*	8.1A
			Halopterididae	*Antennella secundaria*	8.1B
			Halopterididae	*Halopteris* sp.	8.1C
			Plumulariidae	*Dentitheca* cf. *dendritica*	
			Sertulariidae	*Thyroscyphus* sp.	8.1D
				Dynamena sp.	
				Sertularella sp.	

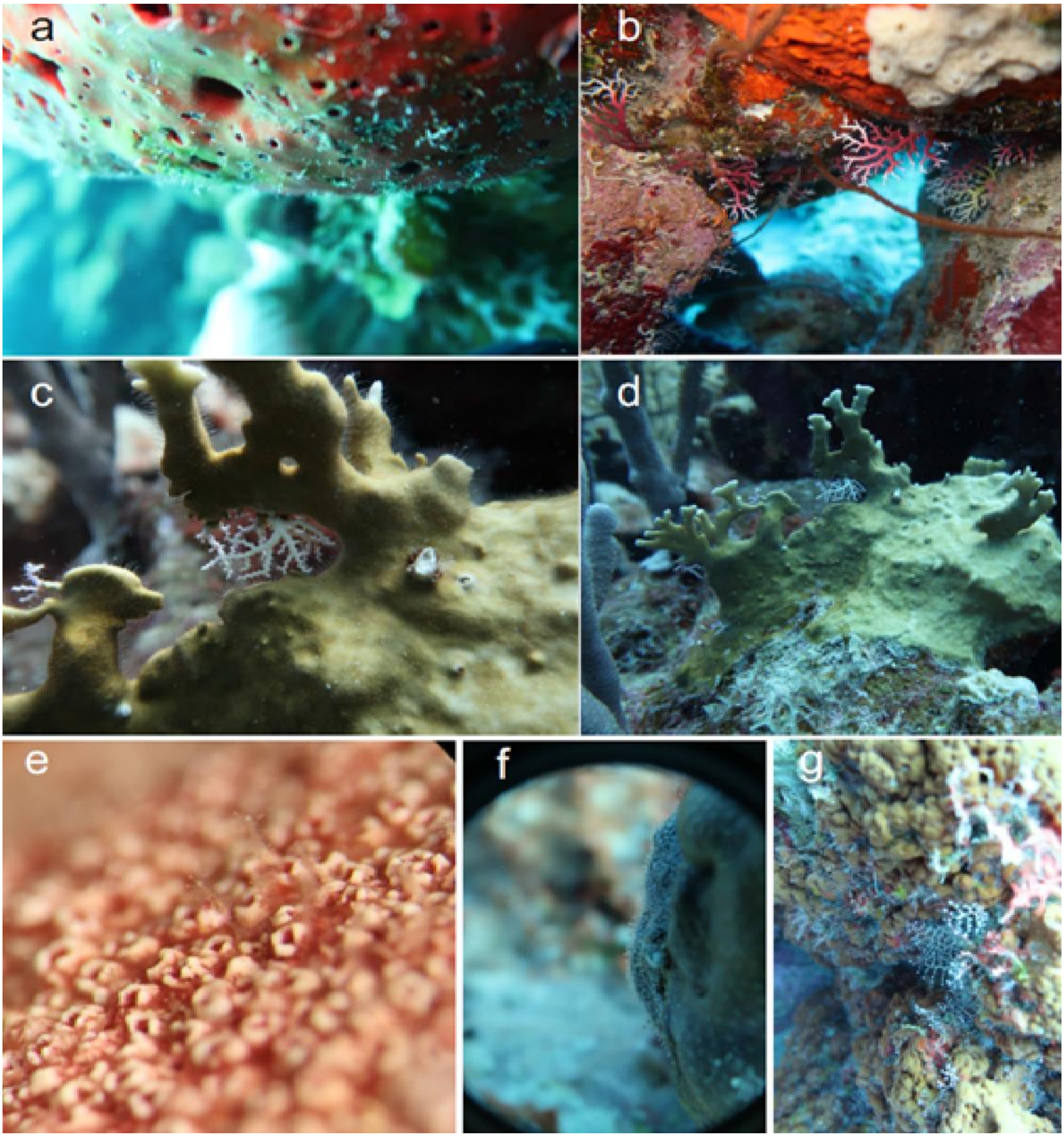

Fig. 8.2. Antoathecata hydrozoans found on Bonaire coral reefs. **a** colonies of *Sphaerocoryne bedoti*; **b** *Stylaster roseus*; **c–d** colonies of *Millepora alcicornis* in association with *Stylaster roseus*; **e–f** *Zanclea* sp. found on the bryozoan *Trematooecia*; **g** *Pennaria disticha*.

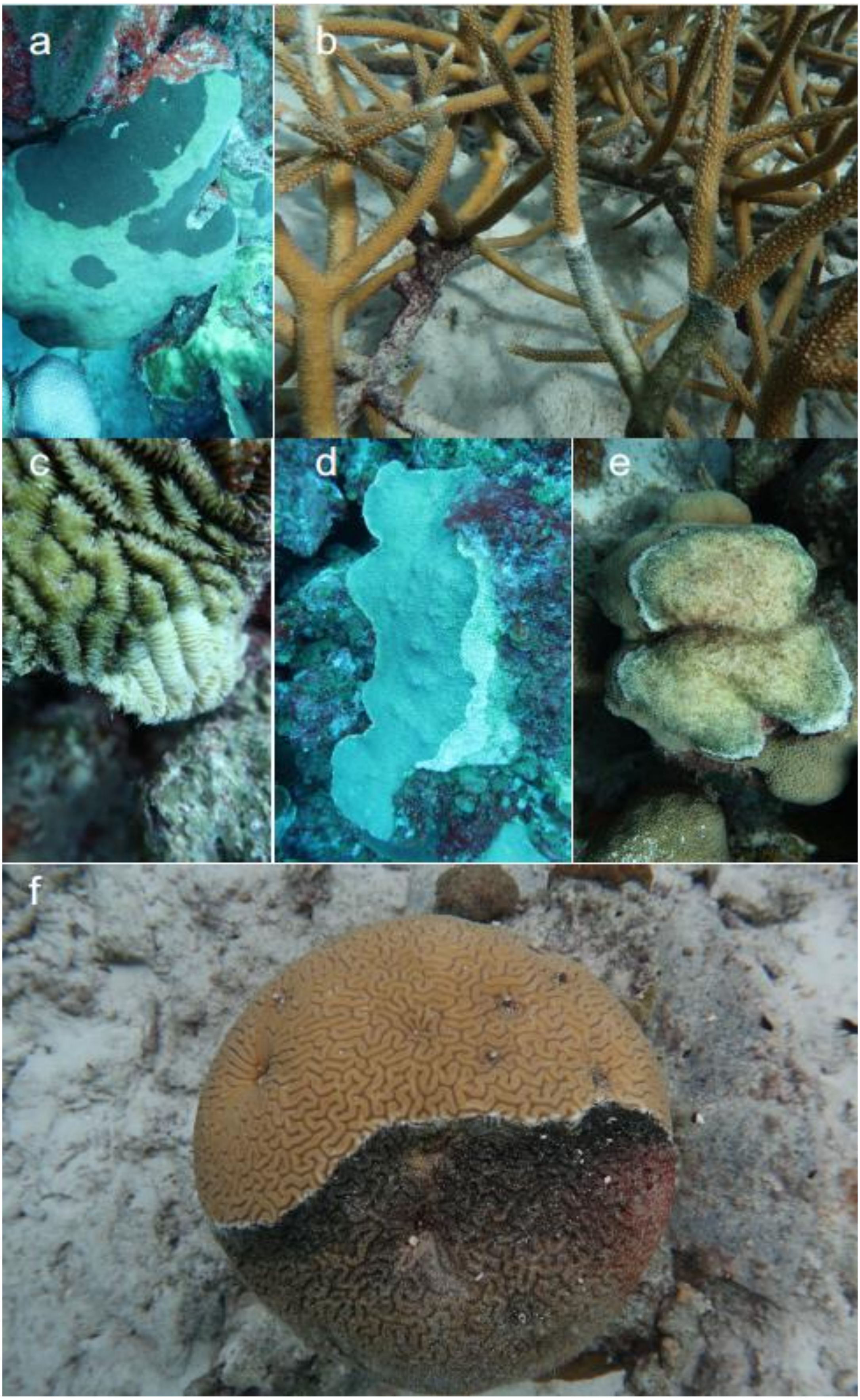

Fig. 8.3 Coral diseases observed on the Bonaire coral reefs. **a** Dark spot syndrome affecting *Orbicella faveolata*; **b** Caribbean ciliate infection affecting *Acropora cervicornis*; **c** CCI on *Meandrina meandrites*; **d** white syndrome on *Orbicella faveolata*; **e** Black band disease affecting *Orbicella faveolata*; **f** cluster of *Halofolliculina corallasia* affecting *Diploria labyrinthiformis*.

Table 8.2. List of athecates hydroids observed in Bonaire and the figure references.

Phylum	Class	Order	Family	Taxon	Figures
Cnidaria	Hydrozoa	Anthoathecata			
			Milleporidae	*Millepora alcicornis, M. complanata, M. squarrosa*	8.2CD
			Pennariidae	*Pennaria disticha*	8.2G
			Oceaniidae	*Turritopsis nutricola*	
			Eudendridae	*Eudendrium spp.*	
			Sphaerocorynidae	*Sphaerocoryne* cf. *bedoti*	8.2A
			Stylasteridae	*Stylaster roseus*	8.2B
			Zancleiidae	*Zanclea* sp.	8.2EF

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9. Symbiotic copepod crustaceans from marine invertebrates

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Introduction

Caribbean symbiotic copepods are a group of diverse and abundant microscopic crustaceans that have been poorly investigated (Ivanenko 2016; Ivanenko et al. 2017; Shelyakin et al. 2018; Korzhavina et al. 2019a, 2019b). In total, 115 valid species of symbiotic copepods have been found on less than 4% of potential Caribbean invertebrates hosts. Copepods have been reported on 47% of scleractinians, 9% of octocorals, 3% of echinoderms and < 1% of sponges. So far, only three species of copepods were reported from invertebrates hosts at Bonaire (Humes 1969; Humes & Stock 1973; Stock 1975; Korzhavina et al. 2019b). Therefore, the main purpose of our survey was to explore the diversity and ecological features of copepods living in symbiosis with the most common invertebrates. Special attention was given to (1) hosts with diseases, such as the Multiple Purple Spots Syndrome (MPSS) in sea fans, caused by copepods; (2) symbionts also obtained during surveys at St Eustatius in 2015, Curaçao in 2017, and Cuba in 2019 (Korzhavina et al. 2019a).

Methods

Sampling was mainly conducted at the leeward side of Bonaire (Fig. 9.1). The invertebrate hosts (mainly sponges, echinoderms and corals) were photographed and isolated in plastic bags underwater. In the laboratory, ethanol was added to the bags (adjusting solution 5%). Then, after 20–30 min, each host was shaken and the residue with symbionts was passed through a fine sieve. Galls in sea fans were photographed and cut from the hosts underwater, and dissected in the laboratory under a microscope to examine the presence of copepods. All copepods found living on and in sponges, echinoderms and corals were preserved in 96% ethanol, stored at -20° C and prepared for molecular and morphological studies. Subsamples of hosts were dried and preserved in ethanol for follow-up studies of their skeletons and DNA.

Results

In total, 83 samples (47 cnidarians, 32 sponges and four echinoderms), including bulk subsamples of copepods and host tissues, were collected from 27 sites by SCUBA at depths up to 31 m (Table 9.1, Fig. 9.1). Details about sampling including depth, coordinates, taxonomy and images of the hosts can be found in the GBIF dataset (Korzhavina et al. 2020; https://doi.org/10.15468/7seoi4).

MPSS in the sea fan *Gorgonia ventalina* Linnaeus, 1758 (Figs. 9.2–9.5) is caused by a recently recorded gall-inducing copepod of the family Lamippidae, which was discovered at St. Eustatius (Ivanenko et al. 2017; Shelyakin et al. 2018). The samples of MPSS were found at seven sites off the southern and eastern coasts of Bonaire, where there is a high density of host. The morphological and molecular analysis of these copepods and their sea-fan hosts from Bonaire, as well as from St. Eustatius, Cuba and Curaçao resulted in unusual geographic patterns in the distribution of this complex of new species of congeneric copepods (Fig. 9.4). Interestingly, the specimens from St. Eustatius, Bonaire, and Curaçao represent only one of three new cryptic species. We assume that the evolving of a complex of gall-inducing species of copepods was possible due to a weaker dispersal ability of their nauplii deposited in coral tissue (Fig. 9.3).

It should be emphasized that our rather extensive sampling and observations of MPSS on Bonaire and other Caribbean islands indicate that assumptions that it can be caused by other organisms may be a result of misidentification with other poorly known diseases (Dennis et al. 2020). The symbiotic complex formed by the widespread Caribbean *Gorgonia ventalina* and gall-forming copepods is an interesting model object that needs additional study (Korzhavina et al. 2021; Tracy et al. 2021). The presence of MPSS can possibly be used as an indicator of the state of stress in coral communities. To clarify this interesting queston, we are conducting a pilot study of biochemical markers new to corals that can be used to study inflammations of corals caused by diseases and parasites, as well as poor environmental conditions for corals and their symbionts.

Fig. 9.1. Localities of samples of symbiotic copepods around Bonaire. More information including photos of the hosts is in the GBIF dataset https://doi.org/10.15468/7seoi4 (Korzhavina et al. 2020).

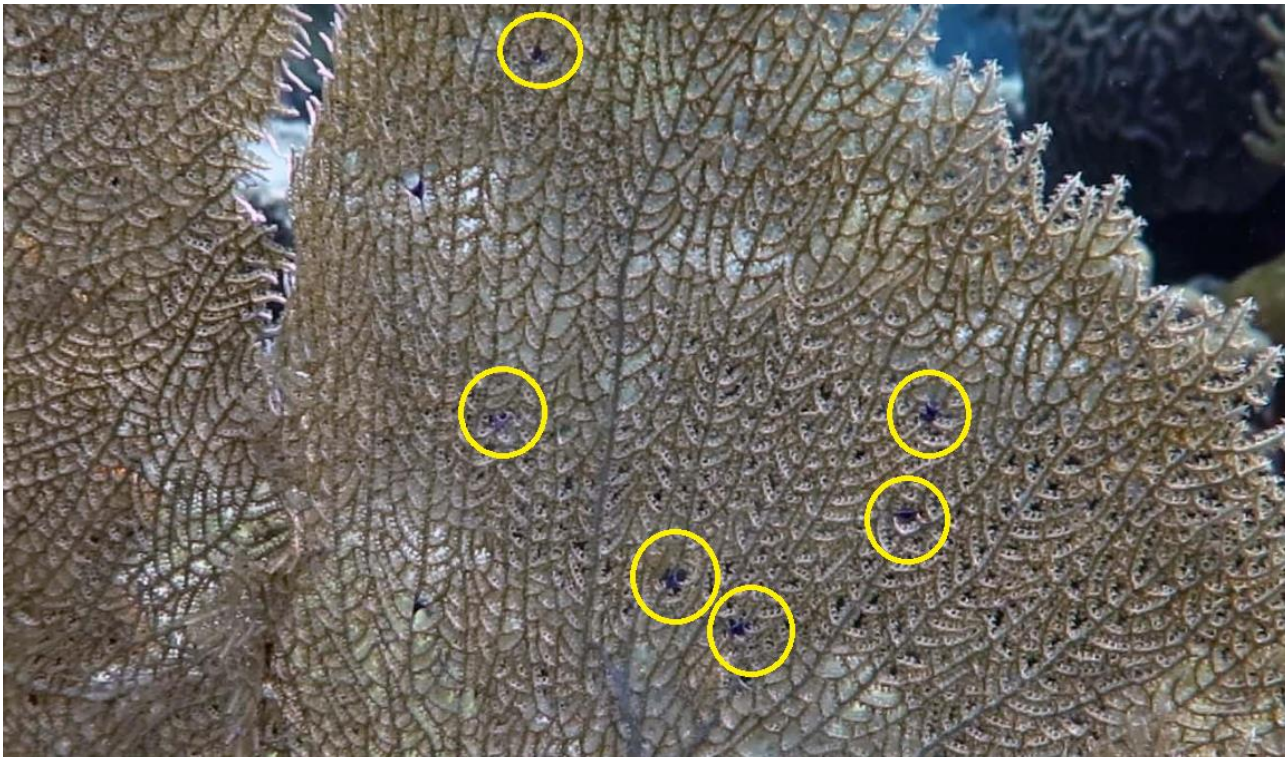

Fig. 9.2. The sea fan *Gorgonia ventalina* from Bonaire with the Multiple Purple Spots Syndrome (marked by yellow circles), which is caused by a new species of copepod of the family Lamippidae.

Diverse and abundant copepods living in symbiosis with most of the collected sponges and corals were found. Copepods living on scleractinian corals and sponges are represented by diverse species of copepods previously unknown for the island and mostly belonging to the order Siphonostomatoida. During the analysis of samples, our attention was attracted by unusual rod-shaped copepods found around Bonaire living in sponges of the genus *Agelas*, collected at depths of 15–30 m. The males and fmales of these copepods have a body length <400 μm and represent a new genus and species of the order Siphonostomatoida. The copepods are close to the single species of the monotypic family Samarusidae recently described from a marine sponge collected near Madagascar (Lee & Kim 2018). The study of the morphology of the Caribbean copepods with light and scanning electron microscopy revealed a number of features distinguishing them from the Samarusidae (Fig. 9.6). The Caribbean species have a smaller number of abdominal somites, short caudal rami and many distinctive details of their limbs. The morphological features of the new genus indicate its relation not only to Samarusidae but also to the heterogeneous Asterocheridae.

The molecular phylogenetic analysis conducted by us on the new genus and asterocherids collected by us in the Caribbean and in other regions of the World ocean revealed a paraphyletic relationship of asterocherids requiring revision of this family, as well as a group of families closely related to it. Finding of this and other copepods in our samples from Bonaire and other Caribbean islands indicates significant gaps, including methodological ones, in the study of microscopic symbionts of the Caribbean invertebrates.

The samples collected in Bonaire are a significant addition to our Caribbean collection of copepods collected by us previously at Saint Eustatius, Curaçao and Cuba and are important for studies of the diversity, zoogeography, evolution and ecology of the symbiotic copepods of Bonaire and the entire Caribbean region.

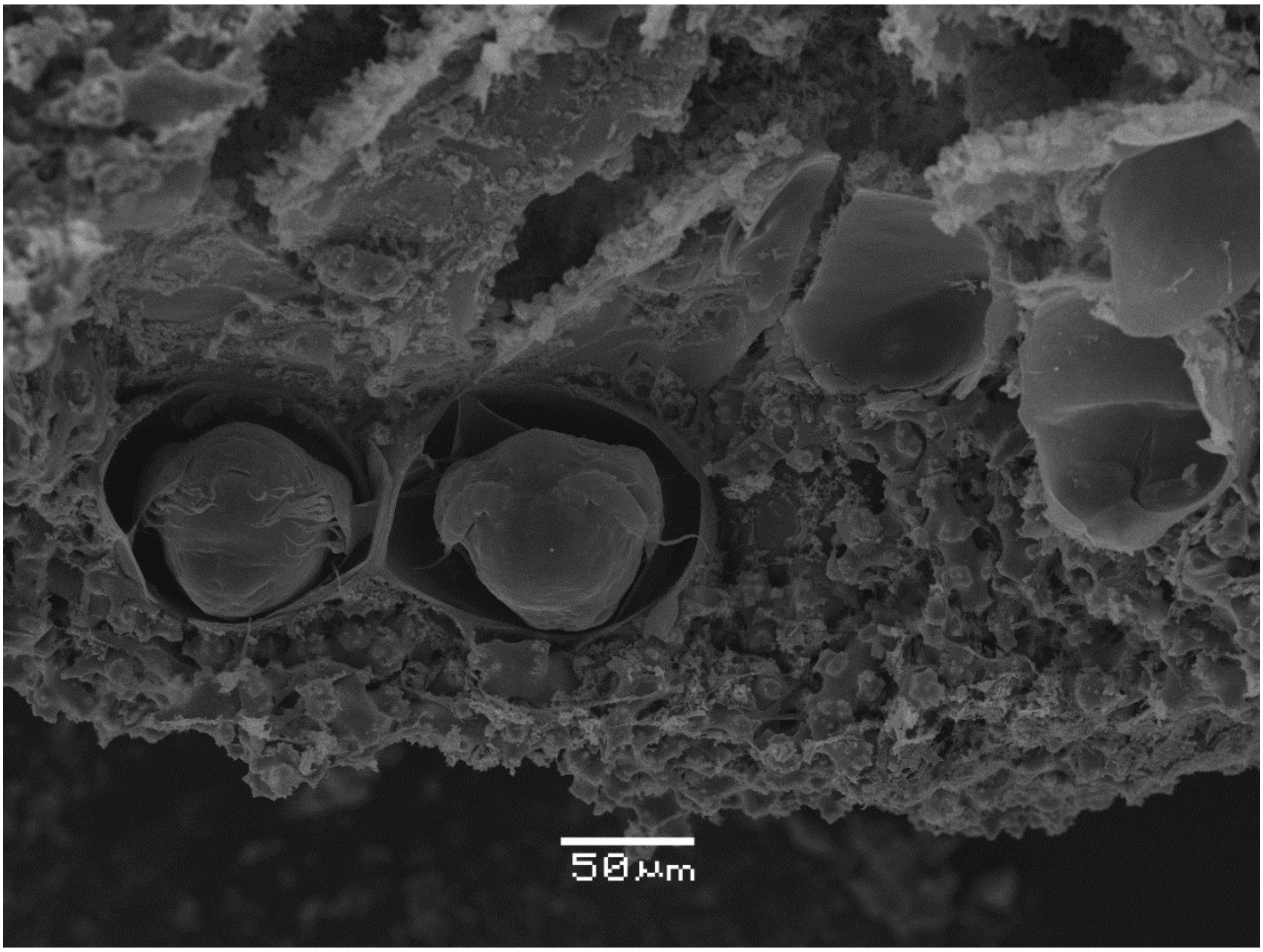

Fig. 9.3. SEM photograph showing embryonic sacs with nauplii of a copepod of the family Lamippidae in the ectodermal part of gall of the sea fan *Gorgonia ventalina* (see female of the copepod in Ivanenko et al 2017).

Among the abundant and diverse copepods found by us, many are still waiting for identification and very likely represent a number of new species. Four new species and one new genus of copepod representing two orders, Cyclopoida and Siphonostomatoida, are already studied in detail using light and electron microscopy, as well as methods of molecular phylogeny. The results are currently being prepared for publications in two papers (Ivanenko et al. in prep; Korzhavina et al. in prep.). The collected copepods and host tissues continue to be studied in cooperation with the participants of the expedition and with the participation of staff and students of Lomonosov Moscow State University.

Acknowledgements. The laboratory research of the Caribbean samples is carried out with the support of a 3-year grant of Russian Foundation for Basic Research (18-54-34007; P.I. – VN Ivanenko).

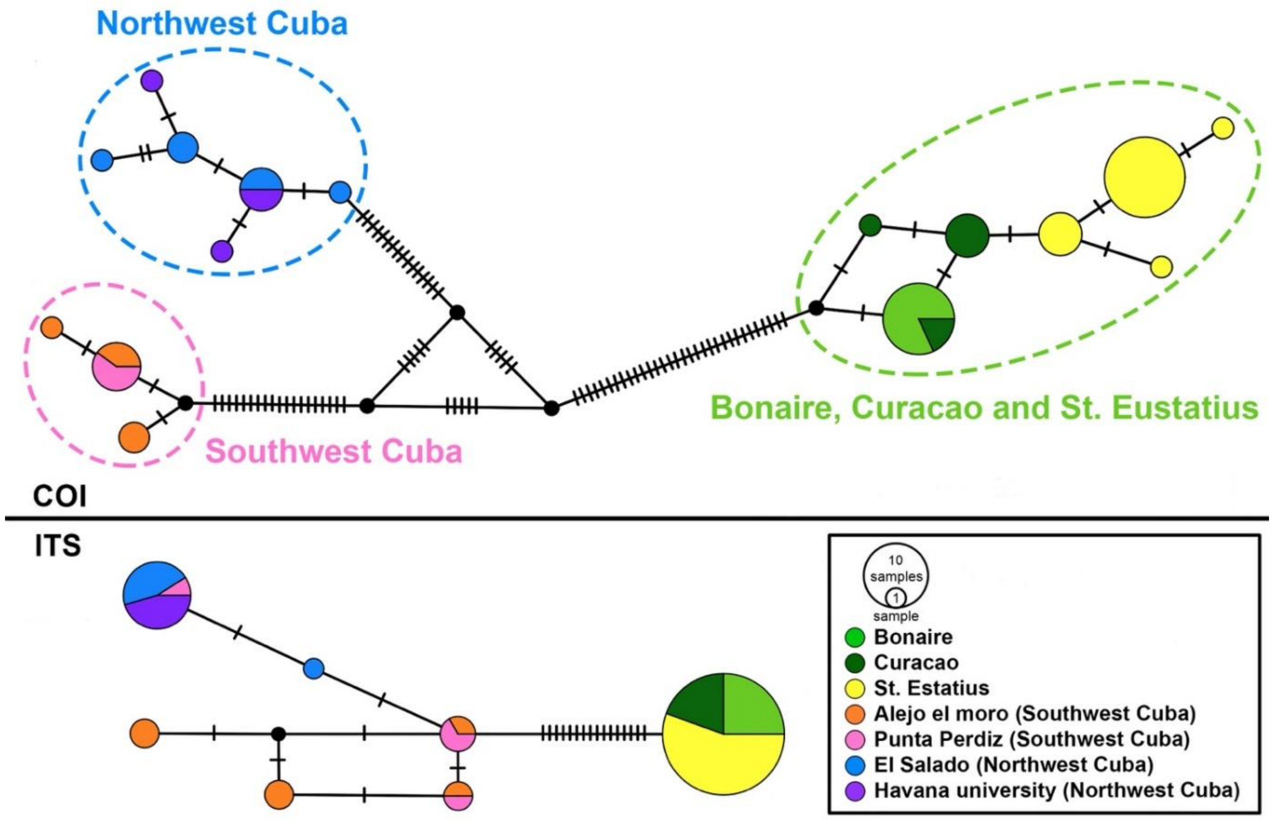

Fig. 9.4. Median-joining networks of COI and ITS2 haplotypes for *Sphaerippe* spp. Circle size depicts haplotype frequency, notches on lines – number of substitutions between haplotypes. Yellow indicates specimens from St. Eustatius, light and dark green from Bonaire and Curaçao, orange and pink from Southwest Cuba, blue and purple from Northwest Cuba (Korzhavina et al. in prep.)

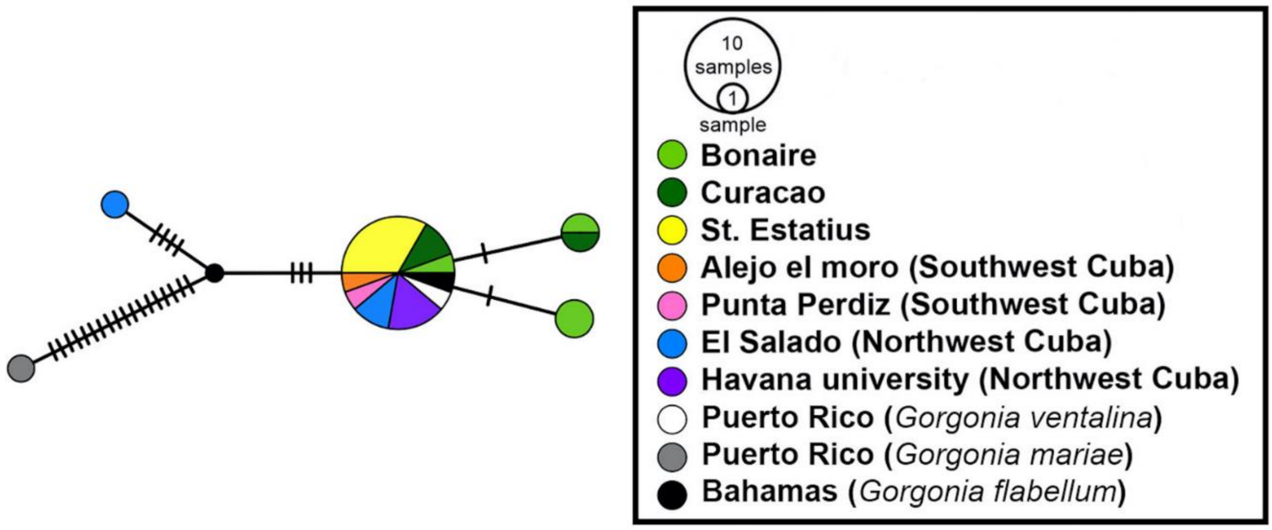

Fig. 9.5. Median-joining network of msh1 haplotypes for hosts of copepods *Gorgonia ventalina*. Circle size depicts haplotype frequency, notches on lines – number of substitutions between haplotypes. Yellow indicates specimens from St. Eustatius, light and dark green from Bonaire and Curaçao, orange and pink from Southwest Cuba, blue and purple from Northwest Cuba, white and grey from Puerto Rico (Genbank samples), black from Bahamas (Genbank samples) (Korzhavina et al. in prep.).

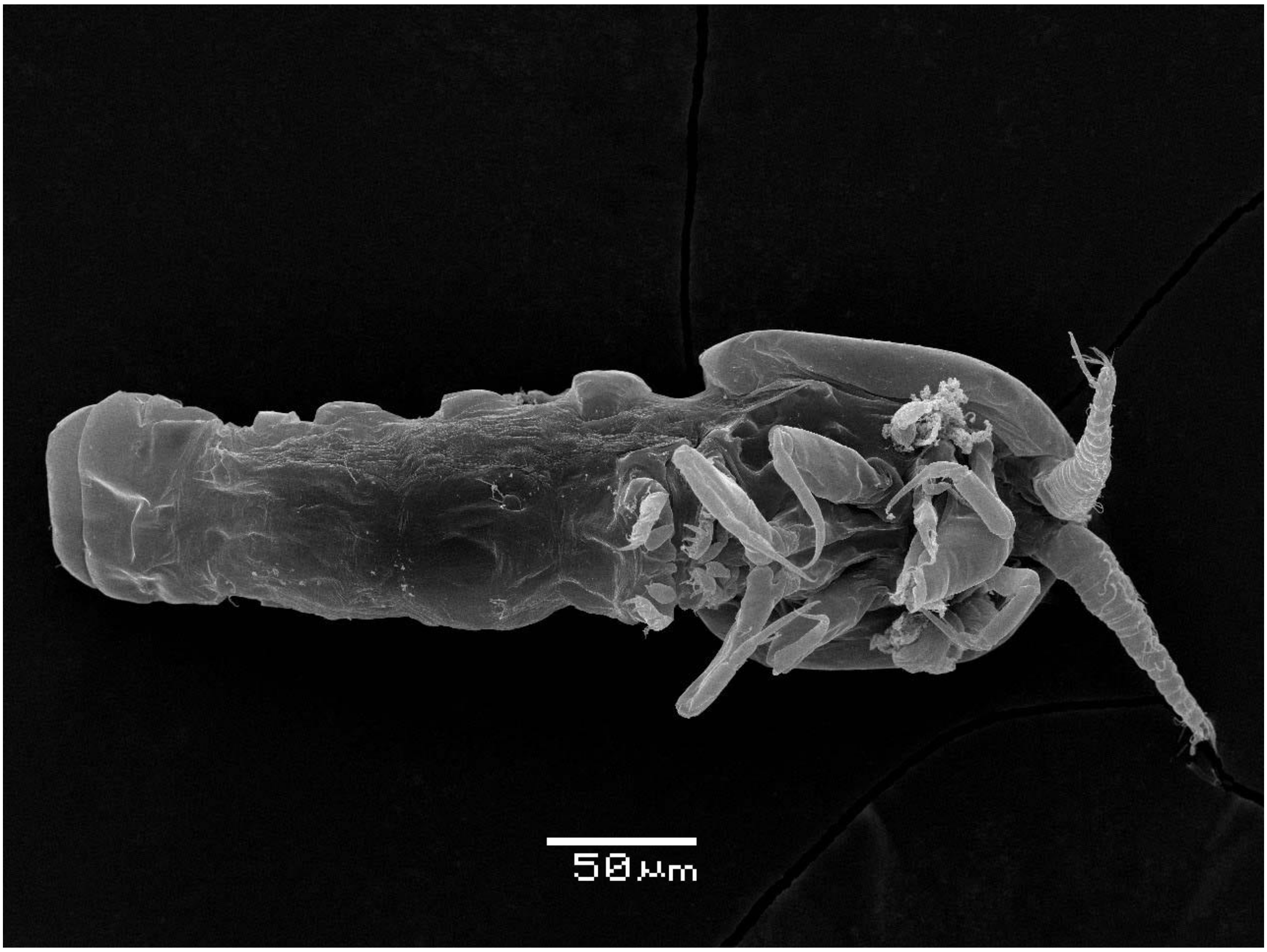

Fig. 9.6. Female of a new genus and species of copepod crustaceans (order Siphonostomatoida) found in a marine sponge *Agelas* sp of Bonaire (Ivanenko et al. in prep.).

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Table 9.1. Invertebrates, hosts of copepod crustaceans, collected by SCUBA at Bonaire in 2019.

Host phylum	Host Class	Host Family	Host species	Depth (m)	St. nr.
Porifera	Demospongiae	Callyspongiidae	*Callyspongia plicifera*	29	BON.02
Porifera	Demospongiae	Agelasidae	*Agelas* sp.	24	BON.02
Porifera	Demospongiae	Agelasidae	*Agelas conifera*	17	BON.02
Porifera	Demospongiae	Callyspongiidae	*Callyspongia plicifera*	31	BON.03
Cnidaria	Anthozoa	Agariciidae	*Agaricia lamarcki*	24	BON.03
Porifera	Demospongiae	Aplysinidae	*Verongula sp. (rigida)*	6	BON.03
Porifera	Demospongiae	Aplysinidae	*Aplysina archeri*	6	BON.03
Echinodermata	Crinoidea	Comatulidae	*Nemaster grandis*	26	BON.04
Porifera	Demospongiae	Niphatidae	*Niphates erecta*	31	BON.04
Porifera	Demospongiae	Aplysinidae	*Verongula* sp. *(fouled)*	28	BON.06
Porifera	Demospongiae	Callyspongiidae	*Callyspongia plicifera*	22	BON.06
Porifera	Demospongiae	Aplysinidae	*Aplysina archeri*	22	BON.06
Echinodermata	Ophiuroidea	Gorgonocephalidae	*Astrophyton muricatum*	4	BON.06
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	8	BON.07
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	8	BON.07
Porifera	Demospongiae	Callyspongiidae	*Callyspongia vaginalis*	26	BON.09
Cnidaria	Anthozoa	Agariciidae	*Agaricia lamarcki*	25	BON.09
Porifera	Demospongiae	Aplysinidae	*Aiolochroia crassa*	29	BON.10
Porifera	Demospongiae	Agelasidae	*Agelas* sp.	29	BON.10
Cnidaria	Anthozoa	Dendrophylliidae	*Tubastraea coccinea*	11	BON.10
Cnidaria	Anthozoa	Agariciidae	*Agaricia lamarcki*	30	BON.14
Porifera	Demospongiae	Petrosiidae	*Xestospongia muta*	30	BON.14
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	6	BON.15
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	5	BON.15
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	5	BON.15
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	5	BON.15
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	5	BON.15
Porifera	Demospongiae	Irciniidae	*Ircinia campana*	5	BON.15
Cnidaria	Anthozoa	Meandrinidae	*Dendrogyra cylindrus*	12	BON.17
Cnidaria	Anthozoa	Merulinidae	*Orbicella faveolata*	20	BON.17
Cnidaria	Anthozoa	Agariciidae	*Agaricia agaricites*	20	BON.17
Cnidaria	Anthozoa	Poritidae	*Porites astreoides*	28	BON.17
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	5	BON.18
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	14	BON.18
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	18	BON.18
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	21	BON.18
Cnidaria	Anthozoa	Pocilloporidae	*Madracis auretenra*	15	BON.18
Cnidaria	Anthozoa	Poritidae	*Porites porites*	27	BON.19
Cnidaria	Anthozoa	Acroporidae	*Acropora cervicornis*	7	BON.19
Porifera	Calcarea	Clathrinidae	*Clathrina* sp.	-	BON.20
Porifera	Demospongiae	Aplysinidae	*Aiolochroia crassa*	29	BON.21
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	3	BON.22

Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	3	BON.22
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	5	BON.22
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	11	BON.22
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	7	BON.22
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	7	BON.22
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	7	BON.22
Porifera	Demospongiae	Callyspongiidae	*Callyspongia plicifera*	28	BON.23
Porifera	Demospongiae	Niphatidae	*Niphates amorpha*	21	BON.23
Porifera	Homoscleromorpha	Unknown	Unknown	20	BON.23
Porifera	Demospongiae	Irciniidae	*Ircinia strobilina*	21	BON.24
Echinodermata	Crinoidea	Comatulidae	*Nemaster grandis*	40	BON.26
Echinodermata	Ophiuroidea	Gorgonocephalidae	*Astrophyton muricatum*	5	BON.26
Porifera	Demospongiae	Aplysinidae	*Aplysina fistularis*	20	BON.26
Cnidaria	Anthozoa	Faviidae	*Mycetophyllia aliciae*	24	BON.26
Cnidaria	Anthozoa	Antipathidae	*Antipathes* sp.	25	BON.27
Porifera	Demospongiae	Callyspongiidae	*Callyspongia vaginalis*	27	BON.27
Porifera	Demospongiae	Aplysinidae	*Verongula sp. (fouled)*	15	BON.29
Porifera	Demospongiae	Aplysinidae	*Aplysina archeri*		BON.29
Cnidaria	Anthozoa	Agariciidae	*Agaricia agaricites*	20	BON.30
Cnidaria	Anthozoa	Agariciidae	*Agaricia lamarcki*	25	BON.30
Porifera	Demospongiae	Agelasidae	*Agelas sp. (sventres)*	25	BON.31
Cnidaria	Anthozoa	Pocilloporidae	*Madracis auretenra*	14	BON.31
Porifera	Demospongiae	Agelasidae	*Agelas* sp. *(clathrodes or citrina)*	25	BON.32
Porifera	Demospongiae	Agelasidae	*Agelas conifera*	21	BON.33
Cnidaria	Anthozoa	Agariciidae	*Agaricia lamarcki*	28	BON.33
Cnidaria	Anthozoa	Poritidae	*Porites porites*		BON.33
Cnidaria	Anthozoa	Agariciidae	*Agaricia agaricites*	25	BON.37
Cnidaria	Anthozoa	Poritidae	*Porites astreoides*	24	BON.37
Cnidaria	Anthozoa	Montastraeidae	*Montastraea cavernosa*	20	BON.37
Cnidaria	Anthozoa	Merulinidae	*Orbicella franksi*	29	BON.39
Cnidaria	Anthozoa	Merulinidae	*Orbicella faveolata*	27	BON.39
Cnidaria	Anthozoa	Montastraeidae	*Montastraea cavernosa*	27	BON.39
Porifera	Demospongiae	Agelasidae	*Agelas* sp. *(clathrodes* or *citrina)*	26	BON.40
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	7	BON.40
Porifera	Demospongiae	Agelasidae	*Agelas* sp. *(sventres)*	24	BON.41
Porifera	Demospongiae	Irciniidae	*Ircinia campana*	10	BON.43
Porifera	Demospongiae	Callyspongiidae	*Callyspongia plicifera*	14	BON.43
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	9	BON.43
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	8	BON.43
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	8	BON.44
Cnidaria	Octocorallia	Gorgoniidae	*Gorgonia ventalina*	3	BON.44

10. Reef-dwelling shrimps

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Introduction

The first surveys of reef-dwelling shrimps from Bonaire were published by Rathbun (1920) and Schmitt (1936) who recorded six and 17 species respectively. Since then, no surveys focusing on shrimps have been carried out. Records of shrimps from Bonaire can be found scattered in the scientific literature as compiled by Poupin (2018). A total of 40 species are hitherto known from the island. The majority of these reef-dwelling shrimps live in symbiosis with invertebrates. The present inventory focused on these symbiotic shrimps and is compared with the known reef-dwelling shrimp fauna.

Methods

Historical records were compiled from the scientific literature (Rathbun 1920; Schmitt 1936; Holthuis 1951; Chace 1972; Criales 1981; Westinga & Hoetjes 1981; Abele & Kim 1986; Fransen 2000; Rhyne & Lin 2006; Snijders & Fransen 2010; Anker et al. 2012; Giraldes et al. 2012; Goy & Martin 2013; Humann et al. 2013 (Table 10.1).

During the fieldwork, 46 stations around the island were visited. Shrimps were mostly recorded by SCUBA diving in reef areas at depths of 0–30 m, some stations were sampled snorkeling. Shrimps were photographed (Fig. 10.1) with a Nikon D80 reflex camera in a Sea & Sea under water housing, or filmed (see supplementary video) with a GoPro Hero 4 silver with a Backscatter Macromate Mini 55 mm +15 Flip Macro Lens, and collected by hand. Material will be subsampled for molecular analyses and stored in the collection of Naturalis. The nomenclature of the species follows that by the World Register of Marine Species (WoRMS Editorial Board 2020).

Results and Discussion

During the survey, 36 reef-dwelling shrimps species were recorded of which 19 had not been listed from Bonaire before (Table 10.1). This brings the known reef-dwelling shrimp fauna of Bonaire at 65 species. Several species are new to science and various associations have now been recorded for the first time. During a night dive at BON.28, specimens of a new species of *Cinetorhynchus* were collected. A new association was found between a new species in the *Periclimenes iridescens* species complex and the scleractinian coral *Madracis pharensis* (Heller, 1868) (BON.31, BON.36, see also supplementary video). This constitutes the second association between a palaemonid shrimp and a stony coral in the Atlantic. Another new association recorded is that between another member of the *Periclimenes iridescens* species complex and the crinoid *Nemaster grandis* A.H. Clark, 1909 (BON.29). The new species will be described in scientific journals in the near future. The present findings will be published in an extensive checklist of reef-dwelling shrimps of Curaçao and Bonaire.

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Table 10.1. Published records of reef-dwelling shrimps from Bonaire: 1 Rathbun 1920; 2 Schmitt 1936; 3 Holthuis 1951; 4 Chace 1972; 5 Criales 1980; 6 Westinga & Hoetjes 1981; 7 Abele & Kim 1986; 8 Heard 1986; 9 Spotte 1995; 10 Wicksten 1995a; 11 Wicksten 1995b; 12 Wicksten 1998; 13 Fransen 2000; 14 Rhyne & Lin 2006; 15 Snijders & Fransen 2010; 16 Anker et al. 2012; 17 Giraldes et al. 2012; 18 Goy & Martin 2013; 19 Humann et al. 2013; 20 Wicksten et al. 2014; 21 present study.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Suborder Dendrobranchiata Spence Bate, 1888																					
Superfamily Penaeoidea Rafinesque, 1815																					
Family Penaeidae Rafinesque, 1815																					
Metapenaeopsis goodei (Smith, 1885)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Metapenaeopsis smithi (Schmitt, 1924)	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Suborder Pleocyemata Burkenroad, 1863																					
Infraorder Stenopodidea Spence Bate, 1888																					
Family Spongicolidae Schram, 1986																					
Microprosthema semilaeve (von Martens, 1872)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
Family Stenopodidae Claus, 1872																					
Stenopus hispidus (Olivier, 1811)	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x
Stenopus scutellatus Rankin, 1898	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x
Infraorder Caridea Dana, 1852																					
Superfamily Bresilioidea Calman, 1896																					
Family Disciadidae Rathbun, 1902																					
Discias serratirostris Lebour, 1949	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Family Rhynchocinetidae Ortmann, 1890																					
Cinetorhynchus manningi Okuno, 1996	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Cinetorhynchus spec. nov.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Superfamily Palaemonoidea Rafinesque, 1815																					
Family Gnathophyllidae Dana, 1852																					
Gnathophylloides mineri Schmitt, 1933	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Gnathophyllum americanum G.-Méneville, 1856	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gnathophyllum circellum Manning, 1963	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Family Palaemonidae Rafinesque, 1815																					
Ancylomenes pedersoni (Chace, 1958)	-	-	-	-	-	-	x	-	x	x	x	x	-	-	-	-	-	-	-	-	x
Ascidonia quasipusilla (Chace, 1972)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Brachycarpus biunguiculatus (Lucas, 1846)	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Cuapetes americanus (Kingsley, 1878)	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Neopontonides chacei Heard, 1986	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Periclimenaeus ascidiarum Holthuis, 1951	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Periclimenaeus caraibicus Holthuis, 1951	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Periclimenaeus maxillulidens (Schmitt, 1936)	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Periclimenaeus spec. nov.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Periclimenes antipathophilus Spotte et al., 1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x
Periclimenes colesi De Grave & Anker, 2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Periclimenes crinoidalis Chace, 1969	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Periclimenes harringtoni Lebour, 1949	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x
Periclimenes aff.*iridescens* Lebour, 1949*	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Periclimenes mclellandi Heard & Spotte, 1997	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Periclimenes perryae Chace, 1942	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Periclimenes rathbunae Schmitt, 1924	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Periclimenes yucatanicus (Ives, 1891)	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	x
Pontonia manningi Fransen, 2000	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-
Pontonia mexicana Guérin-Méneville, 1855	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-
Pseudocoutierea antillensis Chace, 1972	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Pseudopontonides principis (Criales, 1980)	-	-	-	-	x	-	-	x	-	-	-	-	-	-	x	-	-	-	-	-	x

Superfamily Alpheoidea Rafinesque, 1815																					
Family Alpheidae Rafinesque, 1815																					
Alpheus polystictus Knowlton & Keller, 1985	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Alpheus bahamensis Rankin, 1898	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alpheus cristulifrons Rathbun, 1900	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alpheus floridanus Kingsley, 1878	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alpheus heterochaelis Say, 1818	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alpheus malleator Dana, 1852	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alpheus peasei (Armstrong, 1940)	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alpheus vanderbilti Boone, 1930	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parabetaeus hummelincki (Schmitt, 1936)	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus apioceros apioceros Coutière, 1909	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus brooksi Coutière, 1909	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus curacaoensis Schmitt, 1924	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus fritzmuelleri Coutière, 1909	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus goodei Coutière, 1909	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus hemphilli Coutière, 1909	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Synalpheus longicarpus (Herrick, 1891)	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus minus (Say, 1818)	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus paraneptunus Coutière, 1909	-	?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus pectiniger Coutière, 1907	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synalpheus sanctithomae Coutière, 1909	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Family Barbouriidae Christoffersen, 1987																					
Janicea antiguensis (Chace, 1972)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x	-	x
Family Hippolytidae Spence Bate, 1888																					
Hippolyte zostericola (Smith, 1873)	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Tozeuma carolinense Kingsley, 1878	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Family Lysmatidae Dana, 1852																					
Lysmata grabhami (Gordon, 1935)	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x
Lysmata intermedia (Kingsley, 1878)	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lysmata moorei (Rathbun, 1901)	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lysmata pederseni Rhyne & Lin, 2006	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	x
Family Thoridae Kingsley, 1879																					
Thor amboinensis (De Man, 1888)	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Thor floridanus Kingsley, 1878	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thor manningi Chace, 1972	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Superfamily Processoidea Ortmann, 1896																					
Family Processidae Ortmann, 1896																					
Processa spec.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**
Number of species	**6**	**19**	**3**	**2**	**2**	**6**	**1**	**1**	**1**	**2**	**5**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**3**	1	**36**

Note: *The record of this species by Holthuis (1951) is dubious as at that time it was not known that *Periclimenes iridescens* constituted a complex of species.

Fig. 10.1. **A** *Periclimenes rathbunae* Schmitt, 1924, hosted by the sleractinian coral *Dendrogyra cylindrus* Ehrenberg, 1834 (BON.14); **B** *Ancylomenes pedersoni* (Chace, 1958) on *Bartholomea annulata* (Lesueur, 1817) (BON.15); **C** Periclimenaeus *ascidiarum* Holthuis, 1951, in encrusting compound the ascidian *Diplosoma* spec. (BON.15); **D** *Periclimenes yucatanicus* (Ives, 1891) on sea anemone *Condylactis gigantea* (Weinland, 1860) (BON.10); **E** *Periclimenes antipathophilus* Spotte, Heard & Bubucis, 1994, on black coral *Plumapathes pennacea* (Pallas, 1766) (BON.09).

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11. Marine interstitial crustaceans in silted up coralline sand

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Introduction

Interstitial aquatic crustaceans are present in the spaces between sand grains. This sand grain microhabitat stretches from deep-sea sediments to shallow reef debris and to terrestrial groundwater. The size of hollow space between particles determines the type of fauna present, next to the biogeographic history of the area and numerous ecological parameters. On Bonaire the presence of groundwater crustaceans, offshore and on the island, has been observed on different occasions from the 1930s onward (Chappuis 1933; Wagenaar Hummelinck 1953; Stock 1982).

Methods

During the 2019 expedition, samples of sediment were taken from 35 localities, mostly on the sheltered west side of the island. A search for well aerated and coarse sand between coral colonies was done at depths less than ca. 25 m. The first relevant result of the more special and uniquely in-faunal coral sand elements concerns the presence of obligate interstitial-living ingolfiellids (Fig. 11.1). These are small crustaceans with a worldwide distribution but with quite specific environmental demands. They are mostly found, if at all, in low abundance. They were recently taken out of the order Amphipoda (with almost 10,000 species) and placed in the new order Ingolfiellida Lowry & Myers, 2017 (~50 species). The evolution of amphipods shows the largest radiation of species on coral reefs and it is an interesting fact that a representative of this basal Ingofiellida order, which gave rise to the entire clade of Amphipoda, was found on Bonaire, Curaçao and Aruba. The marine-polyhaline *Ingolfiella tabularis* Stock, 1977 was used in a molecular phylogenetic analysis (Verheye et al. 2015) of amphipods as a group that is also known from Bonaire. It was found in sediment at a marine cave entrance.

The species found during the 2019 survey in Bonaire's shallow reef waters resembles the one reported from Curaçao in a comparable microhabitat. It was described by Stock (1979) as *Ingolfiella quadridentata* (Fig. 11.1). The specimen (1.4 mm long) was collected from 15 m depth in coral sediment (BON.06). It is one of six species found on Curaçao and Bonaire as from 1976 (Stock 1976) onward in brackish to freshwater conditions in wells and cave entrances, mostly in low numbers and usually as only a single female or male. The scarceness of material makes morphological species delimitations not easy and we refrain from putting a definite label on the individuals from Bonaire before a DNA analysis is performed.

Fig. 11.1. *Ingolfiella cf quadridentata* Stock, 1979.

A visual observation on overall silt content of the coastal sediment on the fore-reef and the slope leads to the conclusion that there is more fine silt on Bonaire's sheltered coast than on Curaçao. This may be caused by its geographic situation, the crescent form of Bonaire's west coast, and the location of the island Klein Bonaire at the most sheltered part, but the silting up is probably also caused by the very fast urbanization on the coastal fringe. Dust is produced by non-stop construction building, harbor dredging, particle-laden rainwater runoff after removal of mangrove, and the outflow of filtered and unfiltered sewage (De Bakker et al. 2019).

The influence of clogged interstices between sand grains on the presence of typical stygofaunal elements such as Lepidocharontid isopods is apparent; not a single representative of this group was found, while they were abundant in comparable microhabitats on St. Eustatius and Curaçao during sampling surveys in 2015 and 2017. Most sample locations yielded, in remarkably low abundance, eyeless and semi-occulate amphipods, harpacticoid and cyclopoid copepods, and tanaids.

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12. The echinoid-associated pea crab *Dissodactylus primitivus* Bouvier, 1917

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Introduction

Most pea crabs of the subfamily Pinnotherinae (Decapoda: Brachyura: Pinnotheridae) are endosymbiotic commensals that live inside ascidians, bivalved molluscs, or other soft-bodied invertebrates (e.g., Castro 2015; de Gier & Becker 2020). Exceptions to this rule are species found in the *Dissodactylus* species-complex. This complex consists of 12 episymbiotic parasitic crabs (genera *Dissodactylus* and *Clypeasterophilus*), which can be found in the East Pacific and the West Atlantic (e.g., Griffith 1987a). Most species forage on the tube feet of irregular urchins and sand dollars (Martinelli Filho & Dos Santos 2014), leaving scarred tissue on their host (De Bruyn et al. 2009). Of the 12 species, only one can solely be found on spatangoid sea urchins, making *Dissodactylus primitivus* Bouvier, 1917 (Fig. 12.1) a unique species to study host-switching in pinnotherids. Sadly, this particular species has not been included in the latest molecular phylogenetic reconstruction of Palacios Theil et al. (2016). It can be found in shallow Caribbean waters living on the heart urchins *Meoma ventricosa* (Lamarck, 1816) and *Plagiobrissus grandis* (Gmelin, 1791), both common sea-grass grazers. The species was previously found in the waters around Jamaica (De Bruyn et al. 2009), Florida, Barbados and San Blas (Panama) (Griffith 1987b).

The record of *D. primitivus* from Bonaire extents its currently known range and gives us an indication of the suitable habitat of this association. A phylogenetic analyse will shed light on host-switching in the *Dissodactylus* complex, and might help resolving the species-complex by completing the genetic dataset of the Atlantic representatives.

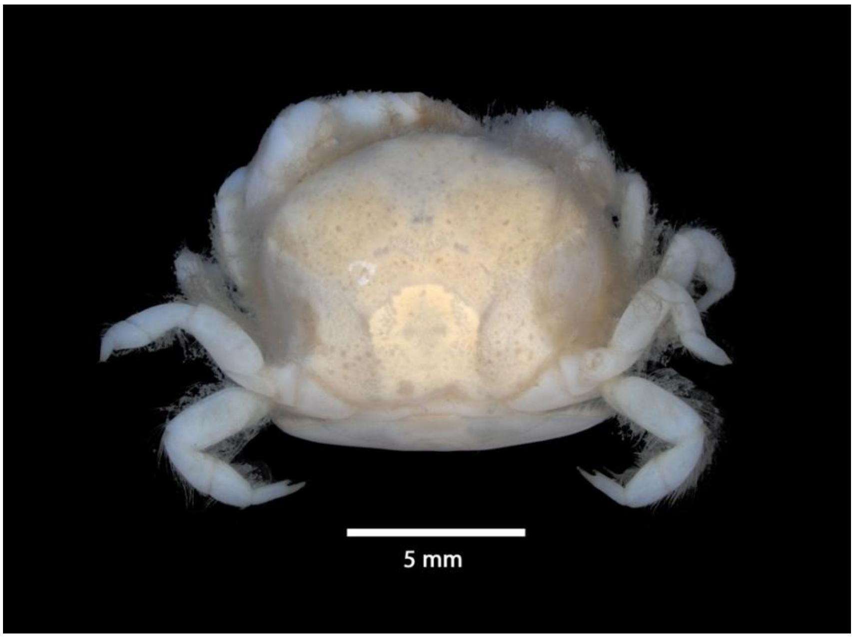

Fig. 12.1. A female individual of *Dissodactylus primitivus* Bouvier, 1917 found in Bonaire.

Fig. 12.2. An injured sea urchin, *Meoma ventricosa* (Lamarck, 1816), showing scarred tissue (arrows) caused by the crab *Dissodactylus primitivus.*

Materials and methods

Potential urchin hosts were identified and collected while snorkeling from the shallow water areas of Lac Bay at 12°05'33.0"N 68°13'50.9"W. The hosts were shaken underwater to get rid of loose sand, after which the crabs were identified and collected with tweezers, and stored in tubes with sea water. The urchins were placed back into the sand after grooming. The crabs were the same day preserved in 70% ethanol, and were photographed once back in Leiden.

Results and further study

Host urchins were identified as *M. ventricosa,* of which the viable populations of Bonaire were only found in the lower middle of the Lac (S. Engel 2019, pers. comm.). *Dissodactylus primitivus* was the only pinnotherid that was found on the urchins, but between the spines of the urchins also a parasitic eulimid snail (Gastropoda: Eulimidae) was found, a common parasite of echinoderms in Caribbean waters (e.g. Campos et al. 2009).

Not all collected hosts had parasitic crabs on them, but when present, a single female or a sexual pair of crabs was found. On one urchin, also a juvenile crab was found together with a sexual pair of adults. Some urchins without any crabs on them showed circular scars caused by the crabs' grooming (resembling the affected areas of Pacific urchins infected with the pilumnid *Zebrida adamsii* White, 1847 (Saravanan et al. 2015)), mainly on the outermost area of the body (Fig. 12.2). Some of these deserted urchins were covered in thread-like cyanobacteria, making us believe that the crabs left when living conditions were not favorable. Movement from one host to another is known from *Dissodactylus* species (De Bruyn et al. 2010). The specimens are yet to be barcoded by the facilities in the Naturalis Biodiversity Center, and will be published later together with a redescription of the species, and an updated phylogeny recontruction.

Acknowledgements The entire expedition team, the author in particular, is indebted to Sabine Engel (DCNA) for her help during the collection of the host urchins and for her overall knowledge about Lac Bay. In addition, the author would like to thank the three local fishermen who helped during the collection. Sabine and the fishermen continue to protect the area and its many ecosystems.

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13. Decapoda (except Caridea/Stenopodidea)

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Introduction

This report deals with Decapoda, except shrimps, in the waters around Bonaire. No written reports are known on the occurrence of this taxon at this locality. On a greater Caribbean scale, none of the species recorded until now is particularly rare. The nomenclature of the species follows that of the World Register of Marine Species (WoRMS Editorial Board 2020).

Decapoda (shrimps and crabs)

Thirty-two non-shrimp species of decapods were recorded (Table 13.1). New records for Bonaire, exclusively based on the Dutch Caribbean Species Register, are indicated with an asterisk (*) before the species name. Many of these are known from other Dutch Caribbean islands (Table 13.1), except *Batodaeus urinator* and *Paguristes erythrops*. We know a number of the new records, e.g. *Paguristes cadenati* and *Pelia mutica* are commonly observed around Bonaire by recreational divers. The crab *Platypodiella spectabilis* was recorded in the zoantharian *Palythoa caribaeorum* (Duchassaing & Michelotti, 1860).

Fig. 13.1. *Petrolisthes tonsorius.* All three observed specimens were coloured vividly blue.

Table 13.1. Non-shrimp decapod rccords: * = new record for Bonaire. Previous records from other Dutch Caribbean islands: E = St. Eustatius, M = St. Maarten, C = Curaçao.

Species	Previous records Dutch Caribbean
Achelous sebae (H. Milne Edwards, 1834)	
**Batodaeus urinator* (A. Milne-Edwards, 1880)	
Calcinus tibicen (Herbst, 1791)	
Callinectes ornatus Ordway, 1863	
Carpilius corallinus (Herbst, 1783)	
**Charybdis helleri* (A. Milne-Edwards, 1867)	M
Coenobita clypeatus (Fabricius 1787)	
**Cyclograpsus integer* H. Milne Edwards, 1837	M
**Dissodactylus primitivus* Bouvier, 1917	EM
Gecarcinus lateralis (Guérin, 1832)	
Iridopagurus reticulatus García-Gómez, 1983	
Macrocoeloma spec.	
Maguimithrax spinosissimus (Lamarck, 1818)	
**Neogonodactylus curacaoensis* (Schmitt, 1924)	C
Omalacantha bicornuta (Latreille, 1825)	
**Paguristes cadenati* Forest, 1954	ESC
**Paguristes erythrops* Holthuis, 1959	
**Paguristes punticeps* Benedict, 1901	EM
**Pagurus brevidactylus* (Stimpson, 1859)	MC
Panulirus guttatus (Latreille, 1804)	
Panulirus argus (Latreille, 1804)	
Parribacus antarcticus (Lund, 1793)	
**Pelia mutica* (Gibbes, 1850)	
Percnon gibbesi (H. Milne Edwards, 1853)	
**Petrolisthes cf. armatus* (Gibbes, 1850)	
Petrolisthes quadratus Benedict, 1901	
**Petrolisthes tonsorius* Haig, 1960	M
**Phimochirus operculatus* (Stimpson, 1859)	C
**Pilumnus floridanus* Stimpson, 1871	C
Plagusia depressa (Fabricius, 1775)	
Platypodiella spectabilis (Herbst, 1794)	
Scyllarides aequinoctalis (Lund, 1793)	
Stenorhynchus seticornis (Herbst, 1788)	

Conclusion

The number of decapod species is high for a 3-week period of recording, not specifically aimed at decapods. A more focussed effort or a more prolonged period of recording could easily yield many more species. Our records by no means constitute a nearly complete list of decapods of Bonaire.

Two of the species recorded may have been introduced by man. The crab *Charybdis helleri* is an alien species originating from the Pacific Ocean, now occurring in the east Atlantic region as well. The crab *Cyclograpsus integer* is considered a circumtropical species, wich might well be an early alien species in part of the world.

On St. Eustatius 22 non-shrimp decapod species were recorded (Faasse 2016), while no night dives were made there. The night dives explain part of the difference in number of recorded species with Bonaire. Another reason for the higher species number is recording in the littoral zone and secluded bays on Bonaire.

Acknowledgements. Participants of the expedition L. Verboom and L. van de Loos provided an addition to the species list; they recorded *Scyllarides aequinoctalis*.

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14. Coral-eating snails

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Introduction

Corallivorous molluscs are potential stressors in coral reef ecosystems. In the Caribbean, for instance, outbreaks of *Coralliophila* and *Cyphoma* can negatively affect reef coral populations (Rotjan & Lewis 2008). Such events are usually caused by stress, such as coral damage by hurricanes. While, *Cyphoma* snails exclusively prey on alcyonacean corals (Reijnen et al. 2010), those of *Coralliophila* eat both alcyonacean and scleractinian corals (Potkamp et al. 2017a).

Methods

Snail-coral associations were recorded during 28 dives. Per dive, 20 min was spent at depths of 5–10, 10–20, and 20–30 m. When *Cyphoma* or *Coralliophila* was found, approximately one minute was taken to count the specimens. The coral was photographed for identification and measured, and its depth was noted. The snails were identified *in situ*; a picture was taken as reference to verify their identity (Figs. 14.1, 14.2).

Results

Three species of coral-eating snails were found: 575 individuals of *Coralliophila galea* (Dillwyn, 1823), 34 of *Coralliophila caribaea* R.T. Abbott, 1958, and 79 of *Cyphoma gibbosum* (Linnaeus, 1758). They were recorded on 18 host-coral taxa: ten scleractinians and eight alcyonaceans. *Coralliophila galea* was recorded exclusively on scleractinian corals, and was most abundant on *Orbicella annularis* (Ellis & Solander, 1786). *Coralliophila caribaea* was found on alcyonacean corals, with one individual on a colony of the scleractinian species *Madracis auretenra* Locke et al., 2007. *Cyphoma gibbosum* was only found on alcyonacean corals. There was a significant variation in diet among the species.

Cyphoma gibbosum and *Coralliophila caribaea* were most abundant at 5–10 m depth, where its hosts are most abundant. *Coralliophila galea* was more evenly distributed across depths, but also most abundantly at 5–10 m, where the host coral *Orbicella annularis* was dominant. The observations in deeper areas were made on various coral species.

Discussion

The densities of corallivorous molluscs on Bonaire are lower than those reported from other areas in the Caribbean. Compared to Curaçao, *Coralliophila caribaea* was almost exclusively found on alcyonacean corals, while on Curaçao it was also commonly found on scleractinian corals. Like in the present study, *Coralliophila galea* was also most abundant on *Orbicella annularis* in Curaçao (Potkamp et al. 2017b). *Coralliophila curaçaoensis* Potkamp & Hoeksema, 2017, recently described from a single host species (*Madracis auretenra*) on Curaçao (Potkamp et al. 2017), was not found in Bonaire.

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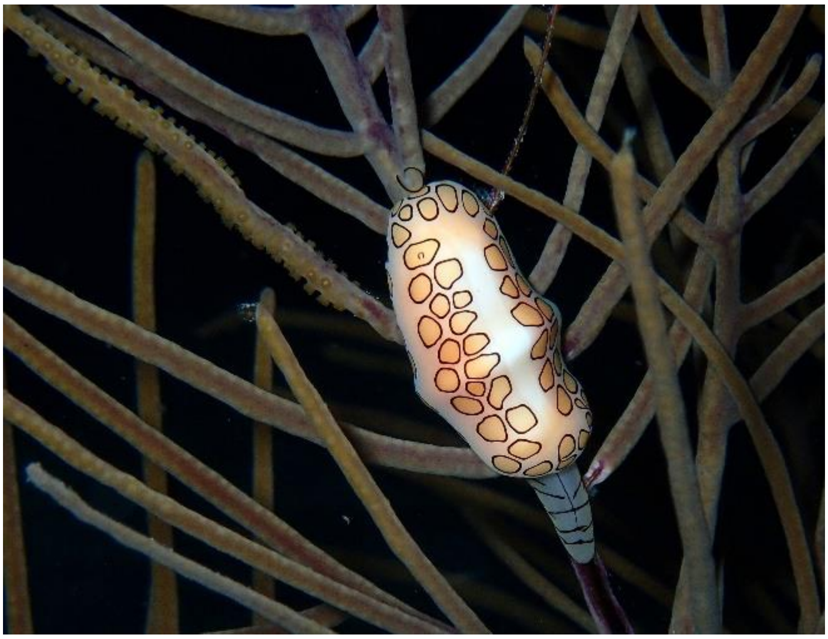

Fig. 14.1. *Cyphoma gibbosum* on an alcyonacean coral

Fig. 14.2. *Coralliophila galea* on a scleractinian coral, *Orbicella faveolata.*

15. Echinodermata and Mollusca

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Introduction

This report deals with the Echinodermata and Mollusca in the waters around Bonaire. All records are based on photos taken during SCUBA dives. The nomenclature of the species follows that of the World Register of Marine Species (WoRMS Editorial Board, 2021).

Echinodermata

Eighteen species of Echinodermata have been recorded that could be identified to species level (Table 15.1) . Two additional, unidentifiable species of the class Ophiuroidea (families *Ophiotricidae* and *Amphiurudae*) have not been included in Table 15.1.

Table 15.1. Echinodermata recorded during the Bonaire 2019 Expedition.

Asteroidea
Astropecten duplicatus Gray, 1840
Ophidiaster guildingi Gray, 1840
Oreaster reticulatus (Linneaus, 1758)
Ophiuroidea
Astrophyton muricatum (Lamarck, 1816)
Breviturma paucigranulata (Devaney, 1974)
Ophiocoma echinata (Lamarck, 1816)
Ophionereis reticulata (Say, 1825)
Ophiopsila riisei Lütken, 1859
Ophiothrix suensoni Lütken, 1856
Echinoidea
Diadema antillarum (Philippi, 1845)
Echinometra lucunter (Linnaeus, 1758)
Echinometra viridis A. Agassiz, 1863
Eucidaris tribuloides (Lamarck, 1816)
Lytechinus williamsi Chesher, 1968
Meoma ventricosa (Lamarck, 1816)
Tripneustes ventricosus (Lamarck, 1816)
Holothuroidea
Holothuria mexicana Ludwig, 1875
Isostichopus badionotus (Selenka, 1867)

The brittle star *Ophionereis reticulata* was recorded in association with the scaleworm *Malmgreniella variegata* (Treadwell, 1917), an association recorded only three times before, on different Caribbean locations (Gómez-Maduro & Díaz-Díaz 2017).

Fig. 15.1. Brittle star *Ophionereis reticulata* with associated scale worm *Malmgreniella variegata*. (BON.31). Photo M.A. Faasse.

Fig. 15.2. *Astropecten duplicatus* (BON.28). Photo A.H.M. Ligthart.

Mollusca

A list of species recorded during the expedition is provided in Table 15.2. All records except three are based on living specimens observed during SCUBA dives and rockpooling in the tidal zone. The three exceptions are two species recorded as empty shells with a hermit crab on the reef (*Voluta musica* and *Naria acicularis*) and one species recorded as a fresh empty shell on top of the reef (*Calliostoma javanicum*). We have recorded these three species as living specimens on Bonaire in 2007 and 2009. Other empty shells were not considered as records. Table 15.2 contains 52 species of Mollusca. For 15 additional taxa identification to species level was impossible on the basis of photos.

Table 15.2. Mollusca. Species marked by * have been recorded during the Statia 2015 Expedition as well. Of all listed species live specimens were found, except for *Calliostoma javanicum* (fresh empty shell on reef), *Voluta musica* and *Naria acicularis* (empty shells with hermit crabs on reef).

POLYPLACOPHORA
Acanthochitona hemphilli (Pilsbry, 1893)
**Acanthopleura granulata* (Gmelin, 1791)
Tonicella marmorea (O. Fabricius, 1780)
BIVALVIA
Atrina rigida (Lightfoot, 1786)
* *Caribachlamys ornata* (Lamarck, 1819)
* *Caribachlamys pellucens* (Linneaus, 1758)
**Chama macerophylla* Gmelin, 1791
Ctenoides scaber (Born, 1778)
**Dendostrea frons* (Linnaeus, 1758)
**Pinna carnea* Gmelin, 1791
Plicatula gibbosa Lamarck, 1801
Pteria colymbus (Röding, 1798)
Spondylus tenuis Schreibers, 1793
CEPHALOPODA
Octopus briareus Robson, 1929
**Octopus insularis* Leite & Haimovici, 2008
**Sepioteuthis sepioidea* (Blainville, 1823)
GASTROPODA
Caenogastropoda
**Cenchritis muricatus* (Linnaeus, 1758)
**Cerithium litteratum* (Born, 1778)
Conus regius Gmelin, 1791
**Coralliophila erosa* (Röding, 1798)
**Coralliophila galea* (Dillwyn, 1823)
**Cyphoma gibbosum* (Linnaeus, 1758)
**Echinolittorina angustior* (Mörch, 1876)
**Echinolittorina ziczac* (Gmelin, 1791)
**Echinolittorina tuberculata* (Menke, 1828)
**Gemophos auritulus* (Link, 1807)
**Hinea lineata* (da Costa, 1778)
**Lampasopsis thomae* (d'Orbigny, 1847)
**Leucozonia nassa* (Gmelin, 1791)

**Lobatus gigas* (Linnaeus, 1758)
**Luria cinerea* (Gmelin, 1791)
**Naria acicularis* (Gmelin, 1791)
**Probata barbadensis* (Gmelin, 1791)
Vasum capitellum (Linnaeus, 1758)
Vermicularia knorrii (Deshayes, 1843)
Vexillum histrio (Reeve, 1844)
Vexillum variatum (Reeve, 1845)
Voluta musica Linnaeus, 1758
Heterobranchia
Aplysia brasiliana Rang, 1828
Aplysia dactylomela Rang, 1828
Calipylla mediterranea A. Costa, 1867
Coryphellina hamanni (Gosliner, 1994)
Dendrodoris krebsii (Mörch, 1863)
Dolabrifera dolabrifera (Rang, 1828)
**Elysia crispata* Mörch, 1863
Elysia subornata A.E. Verrill, 1901
Felimare cf. *marci* (Ev. Marcus, 1971)
Trapania dalva Ev. Marcus, 1972
Neritimorpha
**Nerita versicolor* Gmelin, 1791
Vetigastropoda
Calliostoma javanicum (Lamarck, 1822)
**Cittarium pica* (Linnaeus, 1758)
Lucapina sowerbii (G.B. Sowerby I, 1835)

Fig. 15.3 *Felimare* cf. *marci* (BON.06). Photo A.H.M. Ligthart.

For several reasons it is not appropriate to make a detailed comparison with the results of the Statia Marine Biodiversity Expedition 2015 for Mollusca. Molluscs on Statia were mainly recorded in the littoral zone, by two specialists, with additional records by non-specialist divers (Van Leeuwen & Hewitt 2016), while on Bonaire molluscs were mainly recorded during SCUBA dives, by a single diver, with some additional records from rockpools. On St. Eustatius 99 species were found as living specimens. The lower number of observers and the limited recording time during SCUBA dives may explain part of lower number recorded during the Bonaire 2019 Expedition.

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16. Reef fishes

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Introduction

Fish studies on Bonaire have a long history. In 1904–1905, Boeke undertook an expedition to study fisheries in the Dutch West Indies. During his visits to the six Dutch Caribbean islands he systematically collected fishes. A description of his collection was published by Metzelaar (1919)[1], which shows that 70 fish species were collected at Bonaire, especially at Playa (=Kralendijk) and Lake (=Lac). The first underwater observations of fishes at Bonaire were documented by Hass (1941), who recorded a large number of species, among them large Nassau groupers *Epinephelus striatus*. Since then, many scuba fish-surveys have taken place (e.g. van Moorsel & Meijer 1993; Hawkins et al. 1999; de Graaf et al. 2016; Boenish & Ritchie 2017; Steneck & Wilson 2017).

Concern about the fish populations led to the ban of spearfishing since 1971. With the establishment of the Bonaire National Marine Park in 1979 fishing of parrotfish (2010) and sharks (2015) were banned. Although concerns about the fishing pressure remain (De Graaf et al. 2016; Steneck & Wilson 2017), the record of 286 fish species in Bonaire is high for the Caribbean (Pattengill-Semmens 2002). Our objective was to contribute to the identification and distribution of reef fish at Bonaire and to score presence and abundance for comparison with previous studies.

Methods

During the 2019 survey, we surveyed fish using the roving diver method at 32 locations. One location was visited twice. They were chosen clockwise around Bonaire from Cai at the windward east coast up to Playa Funchi in the Washington Slagbaai Park, and included four at the island of Klein Bonaire. Fish observations were made in daytime from the start of the snorkeling trip to the reef slope and continued during the 70-min dive. Forty minutes were spent at the reef slope (generally between 30 and 10 m depth) and the remaining dive time at the shallower reef flat. Presence of fish species was scored separately for the 10–30 m and 0–10 m zones while species abundances were scored for both depth ranges in categories like in REEF survey projects (Pattengill-Semmens 2002): 1: 1 fish; 2: 2–10 fish; 3: 11–100 fish and 4: 100–1000 fish. Juvenile fishes were neglected. Data were written on underwater slates and observations were recorded by underwater photography.

In addition, two night dives were made, but due to different fish behaviour and observation method these dives resulted in a species list that was not comparable to that of the other surveys. Data from these dives were only used to complement our species list. Visual records by other members of the expedition were also included in this species list. Our results were compared with data from Pattengill-Semmens (2002), collected in the volunteer fish survey project from the Reef Environmental Education Foundation (REEF.org). Additionally, we used some more recent data from the REEF project for comparing with our results.

[1] A supplement with more species from Curaçao appeared as Metzelaar 1922.


Fig. 16.1. Freckled cardinal fish *Phaeoptyx conklini* (BON.11). Photo G. van Moorsel.

Fig. 16.2. Maculated flounder *Bothus maculiferus* (BON.24). Photo G. van Moorsel.

Fig. 16.3. Venezuelan goby *Coryphopterus venezuelae* (BON.21). Photo G. van Moorsel.

Results

Numbers of fish species at different locations varied between 36 and 65 (average 52). Combined with additional data from other members of the expedition 166 fishes were observed. Combining all observations and underwater photos, five species were added to the extensive species list (286 species) of Pattengill-Semmens (2002): African pompano *Alectis ciliaris*, Roughlip cardinalfish *Apogon robinsi* (Fig. 16.7), Freckled cardinalfish *A. conklini* (Fig.16.1), Maculated flounder *Bothus maculiferus* (Fig. 16.2) and we identified the abundant member of the Bridled goby complex as *Coryphopterus venezuelae* (Fig. 16.3). As the invasive Lionfish (*Pterois volitans*) was observed in Bonaire for the first time in 2009, it constitutes also an addition to the list (Table 16.2).

In a paired sample T-test for means our sighting frequencies of species do not differ significantly from data of Pattengill-Semmens (2002) (p=0.27). For species observed at >10 locations we also compared the 'density score'. The score in our observations was slightly higher than for the same species in Pattengill-Semmens' data (2.29 vs 2.10), a difference that proved to be significant in a paired sample T-test for means (p=0.000024).

Table 16.1. Species with notable different sighting frequencies (SF) from 2002 to 2019. Data from Pattengill-Semmens (2002), our 2019 survey and from the REEF Volunteer Fish Survey Project.

Species	**Vernacular name**	**SF P-S 2002 (n=2014)**	**SF 2019 (n=33)**	**Change P-S 2002 vs 2019**	**Change REEF 1998-2001 (n=1348) vs 2016-19 (n=1722)**
Coryphopterus eidolon	Pallid goby	27%	0%	-100%	-41%
Diodon holocanthus	Balloonfish	40%	0%	-100%	-56%
Epinephelus guttatus	Red hind	15%	0%	-100%	-70%
Mycteroperca tigris	Tiger grouper	55%	6%	-89%	-90%
Epinephelus adscensionis	Rock hind	22%	3%	-86%	-87%
Haemulon vittatum	Boga	18%	3%	-83%	-79%
Scarus guacamaia	Rainbow parrotfish	13%	3%	-77%	-51%
Prognathodes aculeatus	Longsnout butterflyfish	27%	12%	-56%	-65%
Scorpaena plumieri	Spotted scorpionfish	19%	9%	-52%	-23%
Gymnothorax moringa	Spotted moray	35%	18%	-48%	-20%
Hypoplectrus puella	Barred hamlet	45%	30%	-33%	-39%
Cantherhines pullus	Orangespotted filefish	46%	58%	+26%	+18%
Anisotremus surinamensis	Black margate	17%	36%	+112%	+46%
Diodon hystrix	Porcupinefish	16%	42%	+163%	+93%

Fig. 16.4. Schoolmasters *Lutjanus apodus* and smallmouth grunts *Haemulon chrysargyreum* at Salt Pier (BON.10), a site with large congregations of schooling fish. Photo F. Bennema.

Although overall sighting frequencies in Pattengill-Semmens (2002) and our data did not differ statistically, there were notable differences at the species level (Table 16.1). Several fisheries target species were seen at a much lower frequency in our surveys. This was especially the case for the medium-sized grouper species Red hind *Epinephelus guttatus*, Tiger grouper *Mycteroperca tigris*, Rock hind *E. adscensionis*, and for the schooling grunt Boga *Haemulon vittatum*. Several other species were also found at substantial lower frequencies and three at higher (Table 16.1). Our data are limited in number and may be influenced by seasonality. As thousands of REEF fish surveys from Bonaire from 1998 to 2019 by expert level volunteers were available, we analysed these data as well. Trends in the REEF data corroborated our limited findings (Table 16.1).

Differences with REEF data may be due to the fact these also include night dive surveys. The distributions of REEF dive locations along the coast may also be more clustered than our locations that were at more or less regular intervals along the coast of Bonaire.

Discussion

The reef fish fauna of Bonaire has been studied by many divers, professionals and naturalists alike. As a result of long-term REEF surveys by expert level volunteers, Bonaire's species record has become one of the highest of the Caribbean. Next to the invasive Lion fish (*Pterois* sp.), we added five species to the list of REEF data as compiled by Pattengill-Semmens (2002).

Among these, the Cardinal fish and Apogonids were observed during a night dive. The Venezuelan goby *Coryphopterus venezuelae* may have been observed before, but recorded as the Bridled goby *Coryphopterus glaucofraenum*. The presence of the Maculated founder *Bothus maculiferus* at Bonaire is confirmed by Robertson and Van Tassell (2019) and by de Gier et al. (2020).

Fig. 16.5. Bluespotted cornetfish *Fistularia tabacaria* on a reef flat. Photo F. Bennema.

Fig. 16.6. Whitespotted filefish *Cantherhines macrocerus.* Photo F. Bennema.

Both our and REEF data show a strong decline in sighting frequency of several commercially exploited fish species. The negative effect of fisheries on fish populations, especially on groupers, has been mentioned before (Steneck & Wilson 2017; Debrot et al. 2018; Vermeij et al. 2019), but these authors mentioned the lack of long-term quantative data. The data of REEF surveys and to a lesser extend our 2019 data may help to fill this gap.

Our results indicate that the earlier disappearance of practically all large groupers from the leeward reef of Bonaire (Roberts 2007; Debrot et al. 2018) was succeeded by a strong decline in medium-sized (40–60 cm long) groupers after the establishment of Bonaire's Marine Park. The schooling Boga is another species that appears to diminish by fisheries. We also found long-term trends in non-commercial fish species: six species clearly decreased while three species increased. Remarkably, Porcupinefish and Balloon fish, species in the same genus (*Diodon*) showed strongly opposing trends.

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Fig. 16.7. Roughlip cardinal fish *Apogon robinsi* (BON.11). Photo G. van Moorsel.

Fig. 16.8. Spinyhead blenny *Acanthemblemaria spinosa* (BON.05). Photo G. van Moorsel.

Table 16.2. Fish species observed by all expedition members. Species with data: observations of fish-surveys. Density (average of abundance scores) and percentage of sightings made at more than 10 m depth, for species observed at >10 locations. *Not in Pattengill-Semmens (2002).

		Sighting frequency	Density	Percentage of sightings >10 m
Pomacanthidae	**Angelfishes**			
Centropyge argi Woods & Kanazawa, 1951	Cherubfish	3%		
Holacanthus ciliaris (Linnaeus, 1758)	Queen angelfish	52%	1.2	82%
Holacanthus tricolor (Bloch, 1795)	Rock Beauty	79%	1.8	69%
Pomacanthus paru (Bloch,1787)	French angelfish	79%	1.5	48%
Chaetodontidae	**Butterflyfishes**			
Chaetodon capistratus Linnaeus, 1758	Foureye butterflyfish	94%	2.3	48%
Chaetodon ocellatus Bloch, 1787	Spotfin butterflyfish	9%		
Chaetodon sedentarius Poey, 1860	Reef butterflyfish	3%		
Chaetodon striatus Linnaeus, 1758	Banded butterflyfish	88%	1.9	33%
Prognathodes aculeatus (Poey, 1860)	Longsnout butterflyfish	12%		
Acanthuridae	**Surgeonfishes**			
Acanthurus chirurgus (Bloch, 1787)	Doctorfish	18%	1.5	42%
Acanthurus coeruleus Bloch & Schneider, 1801	Blue tang	91%	2.8	52%
Acanthurus tractus Poey, 1860	Ocean surgeonfish	91%	2.5	43%
Carangidae	**Jacks, Scads**			
Alectis ciliaris (Bloch, 1787) *	African pompano			
Carangoides bartholomaei (Cuvier, 1833)	Yellow jack	15%		
Caranx crysos (Mitchill, 1815)	Blue runner	12%		
Caranx hippos (Linnaeus, 1766)	Crevalle jack	3%		
Caranx latus Agassiz, 1831	Horse-eye jack	21%		
Caranx ruber (Bloch, 1793)	Bar jack	94%	2.4	53%
Selar crumenophthalmus (Bloch, 1793)	Bigeye scad	3%		
Trachinotus falcatus (Linnaeus, 1758)	Permit	3%		
Trachinotus goodei Jordan & Evermann, 1896	Palometa	24%		
Scombridae	**Mackerels**			
Scomberomorus regalis (Bloch, 1793)	Cero	3%		
Belonidae	**Needlefishes**			
Belonidae	Needlefish	15%		
Tylosurus crocodilus (Péron & Lesueur, 1821)	Houndfish			
Sphyraenidae	**Barracudas**			
Sphyraena barracuda (Edwards, 1771)	Great barracuda	24%		
Sphyraena picudilla Poey, 1860	Southern sennet	3%		
Albulidae	**Bonefishes**			
Albula vulpes (Linnaeus, 1758)	Bonefish	12%		

Mugilidae	**Mullets**			
Mugil curema Valenciennes, 1836	White mullet	3%		
Sparidae	**Porgies**			
Calamus bajonado (Bloch & Schneider, 1801)	Jolthead porgy	6%		
Calamus calamus (Valenciennes, 1830)	Saucereye porgy	3%		
Gerreidae	**Mojarras**			
Eucinostomus melanopterus (Bleeker, 1863)	Flagfin mojarra	3%		
Gerres cinereus (Walbaum, 1792)	Yellowfin mojarra	55%	2.0	3%
Ulaema lefroyi (Goode, 1874)	Mottled mojarra	24%		
Megalopidae	**Tarpons**			
Megalops atlanticus Valenciennes, 1847	Tarpon	21%		
Kyphosidae	**Chubs**			
Kyphosus sectatrix (Linnaeus, 1758) / *K. incisor* (Cuvier, 1831)	Bermuda/Yellow chub	15%		
Haemulidae	**Grunts**			
Anisotremus surinamensis (Bloch, 1791)	Black margate	36%	1.8	71%
Haemulon carbonarium Poey, 1860	Caesar grunt	27%	1.3	
Haemulon chrysargyreum Günther, 1859	Smallmouth grunt	58%	2.5	42%
Haemulon flavolineatum (Desmarest, 1823)	French grunt	97%	2.3	44%
Haemulon parra (Desmarest, 1823)	Sailors choice	3%	2.0	
Haemulon sciurus (Shaw, 1803)	Bluestriped grunt	85%	1.7	50%
Haemulon vittatum (Poey, 1860)	Boga	3%	2.0	
Lutjanidae	**Snappers**			
Lutjanus apodus (Walbaum, 1792)	Schoolmaster	100%	2.3	61%
Lutjanus cyanopterus (Cuvier, 1828)	Cubera snapper	15%		
Lutjanus griseus (Linnaeus, 1758)	Gray snapper	9%		
Lutjanus mahogoni (Cuvier, 1828)	Mahogany snapper	76%	1.9	54%
Ocyurus chrysurus (Bloch, 1791)	Yellowtail snapper	79%	2.4	71%
Pomacentridae	**Damselfishes, Chromis**			
Abudefduf saxatilis (Linnaeus, 1758)	Sergeant major	94%	2.5	61%
Abudefduf taurus (Müller & Troschel, 1848)	Night sergeant	9%		
Chromis cyanea (Poey, 1860)	Blue chromis	97%	3.1	55%
Chromis insolata (Cuvier, 1830)	Sunshinefish	9%		
Chromis multilineata (Guichenot, 1853)	Brown chromis	97%	8.2	53%
Microspathodon chrysurus (Cuvier, 1830)	Yellowtail damselfish	82%	1.9	26%
Stegastes diencaeus (Jordan & Rutter, 1897)	Longfin damselfish	85%	2.4	30%
Stegastes partitus (Poey, 1868)	Bicolor damselfish	91%	3.9	55%
Stegastes planifrons (Cuvier, 1830)	Threespot damselfish	85%	2.3	71%
Serranidae	**Sea basses, Hamlets, Groupers, Soapfishes & Basslets**			
Cephalopholis cruentata (Lacepède, 1802)	Graysby	91%	1.9	85%

Cephalopholis fulva (Linnaeus, 1758)	Coney	88%	2.2	21%
Epinephelus adscensionis (Osbeck, 1765)	Rock hind	3%		
Gramma loreto Poey, 1868	Fairy basslet	76%	2.6	66%
Hypoplectrus chlorurus (Cuvier, 1828)	Yellowtail hamlet	61%	1.5	73%
Hypoplectrus nigricans (Poey, 1852)	Black hamlet	3%		
Hypoplectrus puella (Cuvier, 1828)	Barred hamlet	30%	1.4	95%
Hypoplectrus randallorum Lobel 2011	Tan hamlet	3%		
Hypoplectrus unicolor (Walbaum, 1792)	Butter hamlet	39%	1.4	77%
Liopropoma rubre Poey, 1861	Peppermint bass	18%		
Mycteroperca interstitialis (Poey, 1860)	Yellowmouth grouper	12%		
Mycteroperca tigris (Valenciennes, 1833)	Tiger grouper	6%		
Paranthias furcifer (Valenciennes, 1828)	Creole-fish	64%	2.3	83%
Rypticus saponaceus (Bloch & Schneider, 1801)	Greater soapfish	9%		
Serranus tigrinus (Bloch, 1790)	Harlequin bass	70%	1.8	22%
Scaridae	**Parrotfishes**			
Scarus coelestinus Valenciennes, 1840	Midnight parrotfish	6%		
Scarus guacamaia Cuvier, 1829	Rainbow parrotfish	3%		
Scarus iseri (Bloch, 1789)	Striped parrotfish	36%	2.1	42%
Scarus taeniopterus Lesson, 1829	Princess parrotfish	91%	2.6	50%
Scarus vetula Bloch & Schneider, 1801	Queen parrotfish	82%	2.2	35%
Sparisoma aurofrenatum (Valenciennes, 1840)	Redband parrotfish	94%	2.5	50%
Sparisoma chrysopterum (Bloch & Schneider, 1801)	Redtail parrotfish	45%	2.1	3%
Sparisoma rubripinne (Valenciennes, 1840)	Yellowtail parrotfish	36%	1.9	0%
Sparisoma viride (Bonnaterre, 1788)	Stoplight parrotfish	97%	2.5	52%
Labridae	**Wrasses**			
Bodianus rufus (Linnaeus, 1758)	Spanish hogfish	88%	1.8	59%
Clepticus parrae (Bloch & Schneider, 1801)	Creole wrasse	82%	2.9	83%
Halichoeres bivittatus (Bloch, 1791)	Slippery dick	79%	2.3	2%
Halichoeres garnoti (Valenciennes, 1839)	Yellowhead wrasse	91%	2.1	68%
Halichoeres maculipinna (Müller & Troschel, 1848)	Clown wrasse	6%		
Halichoeres radiatus (Linnaeus, 1758)	Puddingwife	33%	1.6	9%
Lachnolaimus maximus (Walbaum, 1792)	Hogfish			
Thalassoma bifasciatum (Bloch, 1791)	Bluehead	94%	2.2	35%
Xyrichtys martinicensis Valenciennes, 1840	Rosy razorfish	9%		
Xyrichtys splendens Castelnau, 1855	Green razorfish	24%		
Holocentridae	**Squirrelfishes**			
Holocentrus adscensionis (Osbeck, 1765)	Squirrelfish	18%		
Holocentrus rufus (Walbaum, 1792)	Longspine squirrelfish	55%	1.5	67%
Myripristis jacobus Cuvier, 1829	Blackbar soldierfish	82%	2.4	54%

Neoniphon marianus (Cuvier, 1829)	Longjaw squirrelfish	48%	1.5	94%
Plectrypops retrospinis (Guichenot, 1853)	Cardinal soldierfish	3%		
Sargocentron vexillarium (Poey, 1860)	Dusky squirrelfish	12%		
Priacanthidae	**Bigeyes**			
Priacanthus arenatus Cuvier, 1829	Bigeye	6%		
Heteropriacanthus cruentatus (Lacepède, 1801)	Glasseye snapper	18%		
Apogonidae	**Cardinalfishes**			
Apogon binotatus (Poey, 1867)	Barred cardinalfish	9%		
Apogon lachneri Böhlke, 1959	Whitestar cardinalfish			
Apogon maculatus (Poey, 1860)	Flamefish	6%		
Apogon planifrons Longley & Hildebrand, 1940	Pale cardinalfish			
Apogon robinsi Böhlke & Randall, 1968 *	Roughlip cardinalfish			
Apogon townsendi (Breder, 1927)	Belted cardinalfish	3%		
Phaeoptyx conklini (Silvester, 1915) *	Freckled cardinalfish			
Gobiidae	**Gobies**			
Coryphopterus dicrus Böhlke & Robins, 1960	Colon goby	3%		
Coryphopterus lipernes Böhlke & Robins, 1962	Peppermint goby	18%		
Coryphopterus personatus (Jordan & Thompson, 1905) / *C. hyalinus* Böhlke & Robins, 1962	Masked goby / Glass goby	64%	3.6	90%
Coryphopterus venezuelae Cervigón, 1966 *	Venezuelan goby	67%	2.5	20%
Elacatinus evelynae (Böhlke & Robins, 1968)	Sharknose goby	21%		
Elacatinus horsti (Metzelaar, 1922)	Yellowline goby	30%	1.7	70%
Elacatinus randalli (Böhlke & Robins, 1968)	Yellownose goby	15%		
Ginsburgellus novemlineatus (Fowler, 1950)	Nineline goby			
Gnatholepis thompsoni Jordan, 1904	Goldspot goby	9%		
Priolepis hipoliti (Metzelaar, 1922)	Rusty goby			
Labrisomidae	**Scaly blennies**			
Labrisomus nuchipinnis (Quoy & Gaimard, 1824)	Hairy blenny			
Malacoctenus triangulatus Springer, 1959	Saddled blenny	12%		
Starksia sp.				
Chaenopsidae	**Tube blennies**			
Acanthemblemaria spinosa Metzelaar, 1919	Spinyhead blenny	27%		
Chaenopsis limbaughi Robins & Randall, 1965	Yellowface pikeblenny			
Emblemaria pandionis Evermann & Marsh, 1900	Sailfin blenny			
Emblemariopsis carib Victor, 2010	Spikefin blenny			
Blenniidae	**Combtooth blennies**			
Ophioblennius macclurei (Silvester, 1915)	Redlip blenny	33%	1.5	0%
Tripterygiidae				
Enneanectes atrorus Rosenblatt, 1960	Blackedge triplefin			
Bothidae	**Lefteye flounders**			

Bothus lunatus (Linnaeus, 1758)	Peacock flounder	24%		
Bothus maculiferus (Poey, 1860) *	Maculated flounder	3%		
Scorpaenidae	**Scorpionfishes**			
Pterois volitans (Linnaeus, 1758)	Red lionfish	30%	1.4	85%
Scorpaena plumieri Bloch, 1789	Spotted scorpionfish	9%		
Scorpaenodes caribbaeus Meek & Hildebrand, 1928	Reef scorpionfish			
Cirrhitidae	**Hawkfishes**			
Amblycirrhitus pinos (Mowbray, 1927)	Redspotted hawkfish	15%		
Synodontidae	**Lizardfishes**			
Synodus intermedius (Spix & Agassiz, 1829)	Sand diver	33%	1.4	64%
Syngnathidae	**Pipefishes**			
Hippocampus reidi Ginsburg, 1933	Longsnout seahorse	3%		
Aulostomidae	**Trumpetfishes**			
Aulostomus maculatus Valenciennes, 1841	Trumpetfish	94%	2.0	42%
Fistulariidae	**Cornetfishes**			
Fistularia tabacaria Linnaeus, 1758	Bluespotted cornetfish	3%		
Malacanthidae	**Tilefishes**			
Malacanthus plumieri (Bloch, 1786)	Sand tilefish	15%		
Tetraodontidae	**Puffers, Porcupinefish**			
Canthigaster rostrata (Bloch, 1786)	Sharpnose puffer	76%	2.0	62%
Diodon hystrix Linnaeus, 1758	Porcupinefish	42%	1.1	57%
Sphoeroides spengleri (Bloch, 1785)	Bandtail puffer	3%		
Ostraciontidae	**Boxfishes**			
Acanthostracion polygonius Poey, 1876	Honeycomb cowfish	30%	1.3	50%
Lactophrys bicaudalis (Linnaeus, 1758)	Spotted trunkfish	36%	1.5	42%
Lactophrys trigonus (Linnaeus, 1758)	Trunkfish	6%		
Lactophrys triqueter (Linnaeus, 1758)	Smooth trunkfish	64%	1.9	62%
Balistidae	**Leatherjackets, Triggerfishes**			
Balistes vetula Linnaeus, 1758	Queen triggerfish	3%		
Canthidermis sufflamen (Mitchill, 1815)	Ocean triggerfish	6%		
Melichthys niger (Bloch, 1786)	Black durgon	45%	2.1	40%
Monacanthidae	**Filefishes**			
Aluterus scriptus (Osbeck, 1765)	Scrawled filefish	21%		
Cantherhines macrocerus (Hollard, 1853)	Whitespotted filefish	30%	1.2	55%
Cantherhines pullus (Ranzani, 1842)	Orangespotted filefish	58%	1.5	11%
Monacanthus tuckeri Bean, 1906	Slender filefish	6%		
Pempheridae	**Sweepers**			
Pempheris poeyi Bean, 1885	Shortfin sweeper	6%		
Pempheris schomburgkii Müller & Troschel, 1848	Glassy sweeper	6%		

Mullidae	**Goatfishes**			
Mulloidichthys martinicus (Cuvier, 1829)	Yellow goatfish	94%	3.0	52%
Pseudupeneus maculatus (Bloch, 1793)	Spotted goatfish	45%	1.5	20%
Sciaenidae	**Drums**			
Equetus lanceolatus (Linnaeus, 1758)	Jacknife fish	3%		
Equetus punctatus (Bloch & Schneider, 1801)	Spotted drum	45%	1.2	63%
Echeneidae	**Remoras**			
Echeneis naucrates Linnaeus, 1758	Sharksucker			
Muraenidae	**Moray eels**			
Echidna catenata (Bloch, 1795)	Chain moray			
Gymnothorax funebris Ranzani, 1839	Green moray	18%		
Gymnothorax miliaris (Kaup, 1856)	Goldentail moray	21%		
Gymnothorax moringa (Cuvier, 1829)	Spotted moray	18%		
Ophichthidae	**Snake eels**			
Myrichthys breviceps (Richardson, 1848)	Sharptail eel	15%		
Congridae	**Congers**			
Heteroconger longissimus Günther, 1870	Brown garden eel	18%		
Ginglymostomatidae	**Nurse sharks**			
Ginglymostoma cirratum (Bonnaterre, 1788)	Nurse shark			
Carcharhinidae	**Reef sharks**			
Carcharhinus perezii (Poey, 1876)	Caribbean Reef shark	3%		
Dasyatidae	**Stingrays**			
Hypanus americanus (Hildebrand & Schroeder, 1928)	Southern stingray	6%		
Myliobathidae	**Manta, Eagle rays**			
Aetobatus narinari (Euphrasen, 1790)	Spotted eagle ray			

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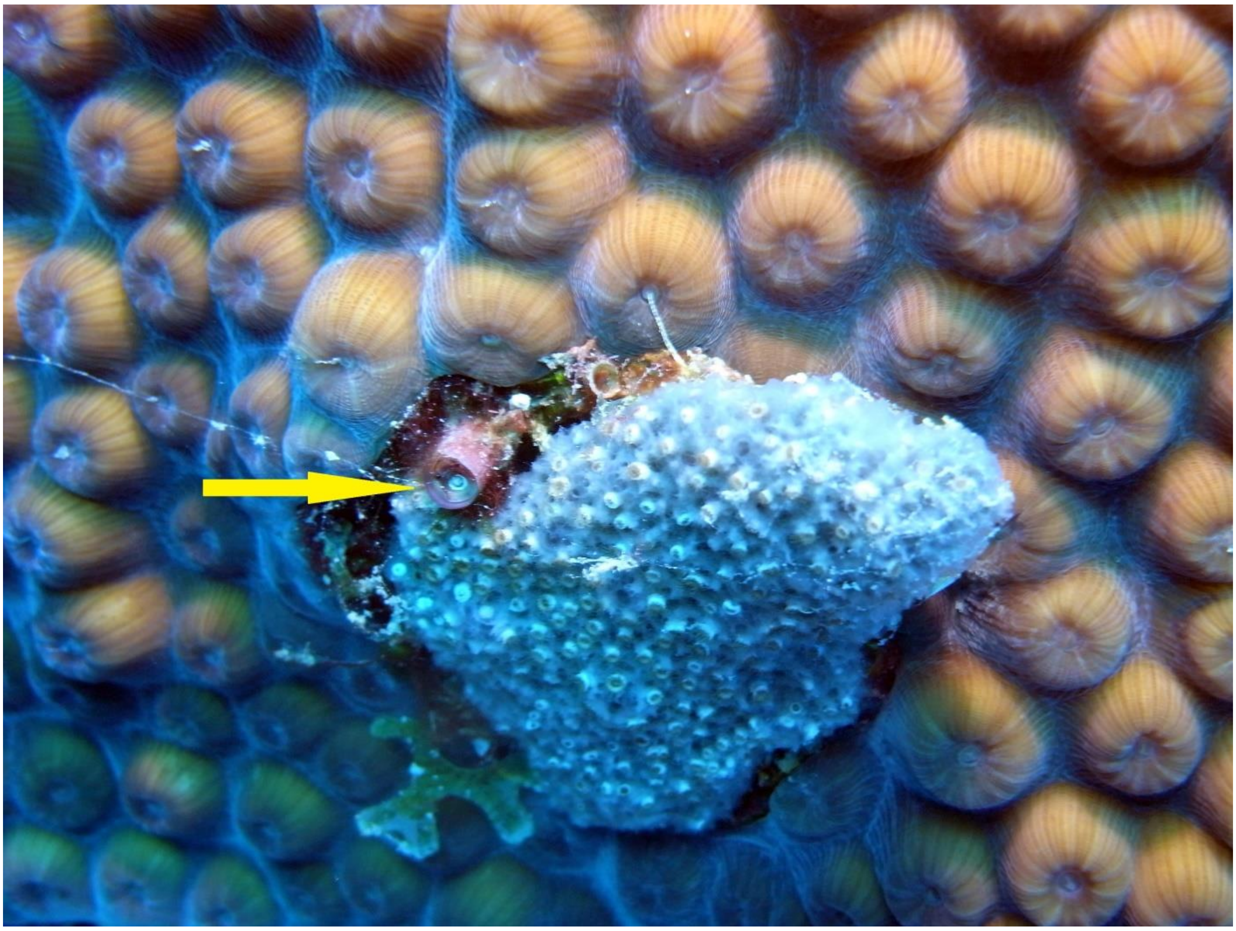
17. Organizing institutes and sponsors

Appendix 1. Publications resulting from the expedition (update Sept. 2022)

1. de Gier W, Fransen CHJM, Ozten Low A, Hoeksema BW (2020) Reef fishes stalking box crabs in the southern Caribbean. Ecology 101:e03068. https://doi.org/10.1002/ecy.3068
2. García-Hernández JE, de Gier W, van Moorsel GWNM, Hoeksema BW (2020) The scleractinian *Agaricia undata* as a new host for the Caribbean coral gall crab *Opecarcinus hypostegus* at Bonaire, southern Caribbean. Symbiosis 81:303–311. https://doi.org/10.1007/s13199-020-00706-8
3. Hoeksema BW (2020) Bonaire: biodiverse paradijs. Onderwatersport 51(2):42–45. Hoeksema BW (2022) Met Naturalis in zee: Koraalbewonende wormslak in Caribisch Nederland. Onderwatersport 53(4):22–23.
4. Hoeksema BW (2022) Een nieuwe wormslak, *Petaloconchus* spec., voor Caribisch Nederland. Spirula: 432:6–8.
5. Hoeksema BW, García-Hernández JE (2020) Host-related morphological variation of dwellings inhabited by the crab *Domecia acanthophora* in the corals *Acropora palmata* and *Millepora complanata* (Southern Caribbean). Diversity 12:143. https://doi.org/10.3390/d12040143
6. Hoeksema BW, García-Hernández JE, van Moorsel GWNM, Olthof G, ten Hove HA (2020) Extension of the recorded host range of Caribbean Christmas tree worms (*Spirobranchus* spp.) with two scleractinians, a zoantharian, and an ascidian. Diversity 12:115. https://doi.org/10.3390/d12030115
7. Hoeksema BW, Harper CE, Langdon-Down SJ, van der Schoot RJ, Smith-Moorhouse A, Spaargaren R, Timmerman RF (2022) Host range of the coral-associated worm snail *Petaloconchus* sp. (Gastropoda: Vermetidae), a newly discovered cryptogenic pest species in the southern Caribbean. Diversity 14:196. https://doi.org/10.3390/d14030196
8. Hoeksema BW, Timmerman RF, Spaargaren R, Smith-Moorhouse A, van der Schoot RJ, Langdon-Down SJ, Harper CE (2022) Morphological modifications and injuries of corals caused by symbiotic feather duster worms (Sabellidae) in the Caribbean. Diversity 14:332. https://doi.org/10.3390/d14050332
9. Montano S, Maggioni D, Liguori G, Arrigoni R, Berumen ML, Seveso D, Galli P, Hoeksema BW (2020) Morpho-molecular traits of Indo-Pacific and Caribbean *Halofolliculina* ciliate infections. Coral Reefs 39:375–386. https://doi.org/10.1007/s00338-020-01899-6
10. Korzhavina O, Hoeksema B, Armenteros M, Rodríguez García P, Garcia-Hernandez J, Ivanenko V (2020). Collection of symbiotic copepods associated with Caribbean invertebrates. Version. 1.16. Occurrence dataset https://doi.org/10.15468/7seoi4
11. Korzhavina OA, Hoeksema BW, Ivanenko VN (2019) A review of Caribbean Copepoda associated with reef-dwelling cnidarians, echinoderms and sponges. Contributions to Zoology 88:297–349. https://doi.org/10.1163/18759866-20191411
12. Montano S, Aeby G, Galli P, Hoeksema BW. (2022) Feeding behavior of *Coralliophila* sp. on corals affected by Caribbean ciliate infection (CCI): a new possible vector? Diversity 14:363. https://doi.org/10.3390/d14050363
13. Montano S, Reimer JD, Ivanenko VN, García-Hernández JE, van Moorsel GWNM, Galli P, Hoeksema BW (2020) Widespread occurrence of a rarely known association between the hydrocorals *Stylaster roseus* and *Millepora alcicornis* at Bonaire, southern Caribbean. Diversity 12:218. https://doi.org/10.3390/d12060218
14. Montenegro J, Hoeksema BW, Santos MEA, Kise H, Reimer JD (2020) Zoantharia (Cnidaria: Hexacorallia) of the Dutch Caribbean with historical distribution records from the Atlantic and one new species of *Parazoanthus.* Diversity 12:190. https://doi.org/10.3390/d12050190

15. Muller E, de Gier W, ten Hove HA, van Moorsel GWNM, Hoeksema BW (2020) Nocturnal predation of Christmas tree worms by a Batwing coral crab at Bonaire (Southern Caribbean). Diversity 12:455. https://doi.org/10.3390/d12120455
16. Muller E, Harasti D, Hoeksema BW (2022) Seahorse predation by octopuses in the Caribbean and the West Pacific. Diversity 14:125. https://doi.org/10.3390/d14020125
17. Reimer JD, Wee HB, García-Hernández JE, Hoeksema BW (2022) Same but different? Zoantharian assemblages (Anthozoa: Hexacorallia: Zoantharia) in Bonaire and Curaçao, southern Caribbean. Coral Reefs 41:383–396. https://doi.org/10.1007/s00338-022-02226-x
18. van der Loos L (2020) Identification Cards: the common seaweeds of Bonaire (Rhodophyta, Chlorophyta, Phaeophyceae). Stichting ANEMOON & Naturalis Biodiversity Center. https://www.researchgate.net/publication/340398542_Identification_cards_the_common_macroalgae_of_Bonaire_Rhodophyta_Chlorophyta_Phaeophyceae



The coral-associated worm snail *Petaloconchus* sp., a new cryptogenic species for Bonaire; BON.39, The Lake, 7 November 2019. Photo. Bert Hoeksema.