

1 **The invasive soft coral *Xenia umbellata* has been confirmed in Cuban waters**

2 Running Title: *Xenia umbellata* in Cuba

3 Nikolaos V. Schizas<sup>1</sup>, Daniel A. Toledo-Rodriguez<sup>1,2</sup>, Nilda M. Jimenez Marrero<sup>3</sup>, Alex J. Veglia<sup>2,4</sup>, José  
4 Espinosa Sáez<sup>5</sup>, Reinaldo Estrada Estrada<sup>6</sup>, Amarilys Martínez Pérez<sup>7</sup>, Yamile del Carmen Luguera  
5 González<sup>8</sup>, J. David Muñoz-Maravilla<sup>1</sup>, Ernesto Weil<sup>1</sup>, Catherine S. McFadden<sup>9</sup>

6 <sup>1</sup>Department of Marine Sciences, University of Puerto Rico at Mayagüez, PO Box 9000, Mayagüez, PR  
7 00681, USA

8 <sup>2</sup>EcoAzul, HC01 Box 4729, Lajas, PR 00667, USA

9 <sup>3</sup>Department of Natural and Environmental Resources, San José Industrial Park, 1375 Ave. Ponce de  
10 León, San Juan, PR 00926, USA

11 <sup>4</sup>Department of Biology, University of Puerto Rico at Mayagüez, PO Box 9000, Mayagüez, PR 00681,  
12 USA

13 <sup>5</sup>Instituto de Ciencias del Mar, Calle Loma # 14, entre 35 y 37, Plaza de la Revolución, La Habana, Cuba

14 <sup>6</sup>Fundación Antonio Núñez Jiménez de la Naturaleza y el Hombre, 5ta B, no. 6611, entre 66 y 70,  
15 Miramar, Playa La Habana, Cuba

16 <sup>7</sup>Paisaje Natural Protegido “Rincón de Guanabo”, Blanca km 29 1/2, Guanabo, Habana del Este, Cuba

17 <sup>8</sup>Centro Nacional de Áreas Protegidas, Calle 18 A No. 4114 e/41 y 47. Playa. C.P. 11300, La Havana,  
18 Cuba

19 <sup>9</sup>Department of Biology, Harvey Mudd College, Claremont, CA 91711, USA

20

21 Corresponding Authors: Nikolaos V. Schizas <[nikolaos.schizas@upr.edu](mailto:nikolaos.schizas@upr.edu)> Catherine S. McFadden  
22 <[mcfadden@g.hmc.edu](mailto:mcfadden@g.hmc.edu)>

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24 Author Approvals: All authors have seen and approved the manuscript. The manuscript has not been  
25 accepted or published elsewhere.

26

27 Competing interests: The authors have declared no competing interests.

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33 **Keywords:** Caribbean, invasive species, octocorals, Xeniididae

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### 35 **Abstract**

36 Octocoral colonies with unusual morphology were detected in September 2022 and October 2023 in two  
37 coastal areas east of Havana, Cuba, and tentatively identified as *Unomia stolonifera*. *U. stolonifera* is an  
38 invasive octocoral from the Indo-Pacific that was first reported in the Caribbean off Venezuela in the  
39 2000's, where it has spread rapidly, smothering coral reefs and substantially altering benthic  
40 communities. After obtaining tissue samples from a Cuban octocoral colony, we re-examined the  
41 specimen using molecular barcoding of three mitochondrial regions (16S/ND2, mtMutS, COI) and the  
42 nuclear large ribosomal subunit (28S rRNA), and we unequivocally identified it as *Xenia umbellata*. *X.*  
43 *umbellata*, a native of the Red Sea, was first identified in southern Puerto Rico in October 2023 and has  
44 since been found in various marine ecosystems along the southern coast of the island. The presence of  
45 either invasive octocoral species in Cuba or elsewhere in the Caribbean would be of a serious  
46 environmental concern due to their documented tolerance, totipotentiality, propagation capacity and  
47 significant negative interactions with local benthic fauna. Attempts to eradicate the invasive soft coral  
48 colonies from Cuban waters have been initiated with apparent success, helping to control further  
49 expansion. The most likely introduction pathway is the accidental or intentional releases from the  
50 aquarium trade but transport via ballast water cannot be ruled out. We cannot discount the possibility of  
51 independent invasion events from different routes to Puerto Rico and Cuba occurring within a year of  
52 each other. Propagation from Cuba to Puerto Rico, or vice versa, which we consider highly improbable,  
53 would likely imply that soft coral populations may also have been established on Hispaniola but have  
54 remained undetected in the Dominican Republic and Haiti to date.

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### 56 **Introduction**

57 In September 2022, during an ecological assessment for the ongoing project “Habana Sumergida”  
58 (Underwater Havana) conducted by the Center of Marine Research at the University of Havana (CIM-  
59 UH), several colonies of an atypical crustose octocoral were encountered near Havana, Cuba. These  
60 sightings occurred in the Bacuranao Inlet, Havana del Este municipality (82°14'39.7" W; 23°10'47.4" N)  
61 (Fig. 1) with an approximate area of 1 m<sup>2</sup> and at a depth between 8 and 11 meters. The stolons were  
62 attached to the rocky matrix, encrusted with a layer of calcareous red algae. Samples of the unidentified  
63 octocoral species were collected and preserved by the Institute of Marine Sciences (ICIMAR) in 4%  
64 formalin and deposited in the collections of the National Aquarium of Cuba and the Center for Marine  
65 Research at the University of Havana (CIM-UH) with an additional sample preserved in 90 % ethanol  
66 for molecular identification. Based on gross morphological characteristics, the octocoral specimens  
67 appeared morphologically similar to *Unomia stolonifera* (Gohar, 1938) (Malacalcyonacea: Xeniididae), an  
68 invasive soft coral species previously reported from Venezuela (Ruiz-Allais *et al.* 2014, 2021; Espinosa  
69 *et al.* 2023).

70 Given the previously reported damage caused by recent octocoral invasions in the Caribbean like that of  
71 *Unomia stolonifera* in Venezuela (Ruiz-Allais *et al.* 2014, 2021), to protect Cuba's coral reef biodiversity  
72 eradication efforts were soon after initiated using knives and nylon bags (Espinosa *et al.* 2023; under  
73 permits granted by Oficina de Regulación y Seguridad Ambiental, Havana). Despite the eradication of  
74 the first colonies, subsequent reef surveys carried out in the Bacuranao Inlet (on February 17 and 23, and  
75 March 13, 2023), detected the regrowth and expansion of the invasive octocoral patch near the original  
76 sighting location. The reestablished patch overgrew a small portion of the western reef of the channel, on  
77 the wall and surface of a surge channel. Although there have been no recent visits by members of CIM-  
78 UH to the area, local underwater fishermen and divers report that they have not seen any more colonies.

79 Expanding the search area, on October 5, 2023, based on the observations of a recreational diver (Mitchell  
80 Morales), a team of specialists and divers from the Institute of Marine Sciences (ICIMAR), the Antonio  
81 Núñez Jiménez Foundation for Nature and Humanity (FANJ), the Center for Marine Research (CIM-  
82 UH), the Rincón de Guanabo Protected Natural Landscape Protected Area (PNPRdG), and associated  
83 divers surveyed Boca de Calderas, Mayabeque (82° 3' 39.21" W; 23° 10' 57.14" N, Fig. 1). These surveys  
84 revealed a second aggregate of octocorals (Figs. 2, 3, 4, 5) now to the east of the city of Havana  
85 resembling morphologically the specimens that were reported in Bacuranao Inlet (Figs 3, 4, 5). This new  
86 site is located approximately 19 km from the previously reported pulse coral patch in Bacuranao (see Fig.  
87 1), which had been apparently eradicated. The Boca de Calderas aggregate was larger than the one at  
88 Bacuranao, covering an estimated area of 150 m<sup>2</sup>. The population extended ~30 m along the edge of the  
89 first submarine terrace at depths of 8 – 13 m. Within this area, 3 to 5 soft coral aggregations were  
90 observed, each occupying a surface area of 5 to 6 m<sup>2</sup>. The main aggregation covered about 4 m<sup>2</sup> and  
91 extended over rocks and corals (Fig. 2). The coverage percentage of the invasion was normally above  
92 95% of the occupied area. The colonies in this locality, treated with chlorine tablets covered with nylon,  
93 have not been completely eradicated, but so far remain under control with approximately the same  
94 distribution.

95 Espinosa *et al.* (2023) tentatively identified the invasive octocorals as *Unomia stolonifera* based on  
96 morphological characteristics; however, they emphasized that definitive identification would require  
97 DNA analyses from the colonies. In parallel, two new allochthonous octocoral species (family Xenidae)  
98 were reported in Puerto Rico (Toledo-Rodriguez *et al.* 2025 a, b), and communication and collaboration  
99 among stakeholders were established to discuss species identification and appropriate eradication  
100 strategies to be implemented. Correct taxonomic identification was considered paramount for effective  
101 invasive species management, as it provides the basis for selecting appropriate response actions, offers  
102 insight into potential introduction pathways or modes of propagation, and reduces the risk of ineffective  
103 or misdirected interventions that may further compromise the coastal ecosystem. However, identifying  
104 xeniid species can be complicated when based solely on external and internal morphology. Overlapping  
105 shapes of colony forms, stalk growth patterns, and characteristics of the pinnate tentacles make them  
106 difficult to distinguish visually, especially in the field. Unlike most other octocoral taxa that can be  
107 identified from the characteristic shapes and distribution of sclerites (calcitic skeletal elements), the  
108 sclerites of xeniids are very homogeneous and exhibit few species-specific characters that can be  
109 observed under light microscopy (Halasz *et al.* 2019). These limitations emphasize the importance of

110 integrative taxonomy, which requires molecular analyses. In this study, we are fulfilling the need for  
111 molecular data employing multi-loci barcoding to clarify the taxonomic identity of the Cuban specimens.

112

## 113 **Methods**

114 **Sampling Sites:** Samples were collected during surveys conducted by personnel of the Institute of  
115 Marine Sciences (ICIMAR), the Antonio Núñez Jiménez Foundation for Nature and Humanity (FANJ),  
116 the Center for Marine Research (CIM-UH) and the Rincón de Guanabo Protected Natural Landscape  
117 Protected Area (PNPRdG). The analyzed samples were collected at Boca de Calderas, Province  
118 Mayabeque, near PNPRdG Rincón de Guanabo (82°14'39,7" W; 23°10'47,4" N). Samples were sent to  
119 personnel of the Puerto Rico Department of Natural and Environmental Resources, who then distributed  
120 them to the McFadden Laboratory, Harvey Mudd College and the Marine Genomic Biodiversity Lab at  
121 the University of Puerto Rico, Mayagüez for molecular identification.

122 **DNA procedures and analysis:** For each polyp, 4-5 tentacles were excised using sterile tweezers and a  
123 scalpel, then used as a tissue source for DNA extraction. DNA extraction was performed using the Qiagen  
124 DNeasy Blood and Tissue kit with manufacturer's protocol, or Qiagen DNeasy PowerSoil® kit with an  
125 additional homogenization step consisting of three sets of 20 seconds, with 1-minute intervals on ice  
126 between the sets to maximize DNA yield. PCR amplifications of three mitochondrial regions (16S/ND2,  
127 mtMutS, COI) and the nuclear large ribosomal subunit (28S rRNA) were done using the primers listed  
128 in Koido *et al.* (2022). For the PCR amplifications, we followed the protocol in Toledo-Rodriguez *et al.*  
129 (2025a). Amplified DNA was sequenced in both directions in an Applied Biosystems SeqStudio Genetic  
130 Analyzer using the Big Dye 3.1 Terminator Cycle chemistry. The DNA traces were inspected for quality  
131 and accuracy in Codon Code Aligner v. 10.0.2 (Codon Code Corp.). GenBank Accession Numbers are  
132 16S/ND2 XXXXXXXX, mtMutS XXXXXXXX, COI XXXXXXXX, and 28S sequences XXXXXXXX.

133 The resulting DNA sequences were concatenated and then aligned in MAFFT v.7 (Kato & Standley  
134 2013) with default parameters. We compared the DNA sequences from Cuba with 31 published xeniid  
135 sequences in a phylogenetic analysis. The analysis included selected 16S/ND2, mtMutS, COI, and 28S  
136 sequences from McFadden *et al.* (2017) and Benayahu *et al.* (2022) (Supplementary Table 1). A  
137 maximum likelihood (ML) tree was constructed using raxmlGUI 2.0.17 (Stamatakis 2014, Edler *et al.*  
138 2020) and rooted with *Xenia umbellata*, the sister group of *Ovabunda*. First, the program modeltest-ng  
139 (Darriba *et al.* 2020) was used in raxmlGUI to estimate the best nucleotide substitution model for the  
140 concatenated data. The best nucleotide substitution model (TPM3uf+I) for the alignment was selected  
141 using the Akaike Information Criterion. Then, an ML + thorough bootstrap search for the best tree was  
142 conducted in raxml-ng (Kozlov *et al.* 2019). Clade support was assessed with 100 bootstrap replicates  
143 (Felsenstein 1985). The consensus tree was viewed and edited in FigTree 1.4.4, then imported into Adobe  
144 Illustrator 30.2.1 to improve visualization.

## 145 **Results**

146 Sequences obtained for each of four loci used for DNA barcoding of octocorals (16S/ND2 = 710 bp;  
147 mtMutS = 714 bp; COI = 771 bp; 28S rDNA = 708 bp, a total of 2,903 bp) were 100% identical to  
148 barcodes published previously for *Xenia umbellata* from the Red Sea and from the invasive population

149 in Puerto Rico (Fig. 6). Photographs of the Cuban colonies taken in situ (Figs. 3, 4, 5) further support this  
150 identification, showing all polyps localized to the tops of the colony stalks, a diagnostic character of the  
151 genus *Xenia*. In contrast, *Unomia stolonifera* exhibits isolated polyps on the stalks and base of the colony  
152 (Benayahu *et al.* 2021).

153

## 154 Discussion

155 The occurrence of invasive octocorals from the family Xenidae is evident in the wider Caribbean and  
156 causes ever increasing concerns in the region (Ruiz-Allais *et al.* 2014, 2021; Espinosa *et al.* 2023; Toledo-  
157 Rodriguez *et al.* 2025a, b; Veglia *et al.* 2025). Since the detection of xeniid colonies in Cuban waters,  
158 initially identified morphologically as *Unomia stolonifera*, an immediate response was executed to limit  
159 further spread and potential ecological impact. This response was motivated by the ecological impacts  
160 reported in Venezuela, where *U. stolonifera* rapidly expanded and monopolized benthic habitats (Ruiz-  
161 Allais *et al.* 2014, 2021). More recently, in Puerto Rico, similar concerns emerged regarding invasive  
162 octocoral colonies initially presumed to be *U. stolonifera* but later confirmed by molecular analysis to be  
163 two separate species of pulsing corals, *X. umbellata* (Toledo-Rodriguez *et al.* 2025a; Veglia *et al.* 2025)  
164 and *Latissimia ningalooensis* (Toledo-Rodriguez *et al.* 2025b). Here, using identical approaches applied  
165 to Puerto Rico specimens, we examined four DNA regions to confirm unequivocally that the invasive  
166 Cuban species is not *U. stolonifera* as originally reported (Espinosa *et al.* 2023), but identified instead as  
167 *X. umbellata*.

168 The phylogenetic footprint of *X. umbellata* is unique within Xenidae (McFadden *et al.* 2017) and  
169 standard DNA barcode sequencing can provide definitive evidence for the presence of the species in the  
170 area (McFadden *et al.*, 2019). Our results therefore confidently indicate that *X. umbellata* may be more  
171 widespread in the region than previously thought, with additional populations possibly occurring along  
172 the coasts of the Dominican Republic and Haiti, or in additional locations in the Caribbean. This  
173 discovery of *X. umbellata* in Cuba and Puerto Rico has changed the prevailing narrative regarding soft  
174 coral invasion in the Caribbean. Rather than addressing a single species scenario—*U. stolonifera*, which  
175 has rapidly expanded from Venezuela (Ruiz-Allais *et al.*, 2014; 2021) to the southern Caribbean—the  
176 region is now confronted with the introduction of multiple species: *Xenia umbellata* (Toledo-Rodriguez  
177 *et al.* 2025a; Veglia *et al.* 2025) and *Latissimia ningalooensis* (Toledo-Rodriguez *et al.* 2025b) in Puerto  
178 Rico, and *X. umbellata* in Cuba (this study). This represents a conservative scenario, as *U. stolonifera* is  
179 likely to continue its range expansion across the Caribbean, beyond Venezuela.

180 The first octocoral aggregations (presumably also *X. umbellata* since we unequivocally confirmed the  
181 identification a colony only from Boca de Calderas) were discovered in Bacuranao Inlet, east of Havana,  
182 in September 2022, nearly a year before the first colonies were observed by recreational divers in southern  
183 Puerto Rico in October 2023. However, based on the size of the aggregations, at least in Puerto Rico, the  
184 initial sightings likely postdate the actual establishment of colonies. The near simultaneous detection of  
185 *X. umbellata* in two Caribbean islands does not point to secondary spread from one place to another.  
186 Together, the available records may be consistent with independent introductions rather than with direct  
187 spread between Cuba and Puerto Rico. Two lines of evidence support this interpretation. First, traffic of

188 commercial vessels between the two islands is very limited or nonexistent, severely reducing the  
189 possibility of spreading between the sites via shipping. Rather, a scenario involving independent  
190 introductions associated with maritime infrastructure (e.g., in ballast water or on fouled hulls or fishing  
191 gear) appears somewhat plausible. This is supported by the proximity of the two Cuban soft coral sites  
192 (Fig. 1) to the port of Havana: approximately 12 km from Bacuranao Inlet and 27 km from Boca de  
193 Calderas, both located east of the port. Similarly, the first documented patches of *X. umbellata* in Puerto  
194 Rico were discovered near the port of Ponce, a busy hub of international maritime traffic (Toledo-  
195 Rodriguez *et al.* 2025a). Second, based on near-surface buoy drifter data, there is a persistent westward  
196 surface flow across the Venezuelan Basin extending as far as the Jamaican Ridge, followed by a  
197 northwestward flow from there to the Yucatán Channel (Centurioni & Niiler 2003). This circulation  
198 pattern suggests that propagules would be transported from east to west—that is, from Puerto Rico toward  
199 Cuba—rather than in the opposite direction. Though the invasion sites in Puerto Rico are located on the  
200 south side of the island so far, whereas in Cuba they were encountered on the north side, suggesting that,  
201 if the east-to-west propagule scenario is possible, there may be additional soft coral aggregations on the  
202 southern coast of Cuba. None have been reported yet from the southern coast, even though between 2023  
203 and 2025 several reef surveys covered the entire southern part of Cuba, under the auspices of “Bojeo a  
204 Cuba 2023”, a scientific expedition of the Cuban archipelago. It is noteworthy that the known distribution  
205 of the invasive octocorals in both jurisdictions is limited to occasional reports from recreational divers or  
206 researchers targeting specific areas, rather than through a standardized monitoring effort, and is thus  
207 likely underestimated. Further, misidentification with native organisms is another factor that may  
208 contribute to the lack of reporting in both Cuba and Puerto Rico.

209 Although the precise route of *X. umbellata* introduction into Cuba remains uncertain, several other  
210 pathways are plausible, with the marine aquarium trade considered the most likely hypothesis above all,  
211 as has been suggested for other invasive xeniid octocorals (Ruiz-Allais *et al.* 2014; Mantellato *et al.* 2018;  
212 Menezes *et al.* 2022; Bolick and Lee 2023). Reports from 2025, although not yet verified in the field,  
213 indicate the presence of three new populations intentionally planted by aquarists. Other possible pathways  
214 of introduction cannot be ignored including biofouling, ballast water transport, floating debris,  
215 macroplastics, *Sargassum* (e.g. Bailey 2015; Mantelatto *et al.* 2018; García-Gómez *et al.* 2021; Menezes  
216 *et al.* 2022; Hoeksema *et al.* 2023).

217 Our study does not rule out the presence of *U. stolonifera* in Cuba; rather, it provides evidence that a  
218 sample from the second documented octocoral aggregate in Boca de Calderas—initially thought to be *U.*  
219 *stolonifera*—was unequivocally identified as *X. umbellata* through molecular barcoding. The sample was  
220 randomly collected by divers as representative of the observed octocoral aggregations. Therefore, unless  
221 new data indicate otherwise, we assume that all other sightings in the area correspond to *X. umbellata*.  
222 Nevertheless, marine vessel traffic between Venezuela and Cuba continued uninterrupted through at least  
223 mid-2020, providing a potential pathway for accidental transport of *U. stolonifera* propagules and other  
224 species via ballast water or on contaminated gear (Ruiz-Allais *et al.* 2021). Therefore, marine resource  
225 managers in Cuba should remain vigilant for the possible introduction of *U. stolonifera* or other marine  
226 invaders into the country's coastal ecosystems.

227 Early detection and aggressive intervention efforts may still reduce the expansion of these invasive  
228 xeniids. Eradication efforts in Cuba have been successful in managing recurrences at a particular site  
229 through contact surveillance and action (Espinosa *et al.* 2023); however, given the regenerative  
230 capabilities of *X. umbellata* (Nadir *et al.* 2023), the action must continue. Reports for other areas of Cuba  
231 could not be confirmed due to limited resources. In Puerto Rico, the distribution is confirmed to be  
232 widespread along the southwest coast, with large colony sizes (unpub. data). Coordinated eradication was  
233 implemented but was limited due to a lack of funds. As expected, the areas were repopulated by  
234 presumably untreated nearby aggregations (unpub. data). Xeniiids are spreading across the Caribbean.  
235 With adequate funding, perseverance, and collaboration, these soft corals could be eradicated—or at least  
236 controlled—if early detection is achieved. A coordinated monitoring approach that integrates wide-area  
237 autonomous underwater vehicle (AUV) surveys, remotely operated vehicles (ROVs), environmental  
238 DNA (eDNA) sampling, and diver-based ground-truthing through direct observations and specimen  
239 collections would establish its current distribution and early detection of outbreaks in areas where it has  
240 not been reported, helping safeguard Caribbean coastal ecosystems.

241

## 242 **Acknowledgments**

243 We thank Dr. Silvia Patricia González Díaz (University of Havana) for reviewing an earlier version of  
244 this manuscript. Valerie Miller (Environmental Defense Fund) assisted in critical communication among  
245 the authors. This publication was made possible with support from the Sequencing and Genomics Facility  
246 of the UPR Río Piedras & MSRC/UPR, funded by NIH/NIGMS-Award Number P20GM103475.

247

## 248 **Conflicts of Interest**

249 The authors have declared no competing interests.

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## Figures

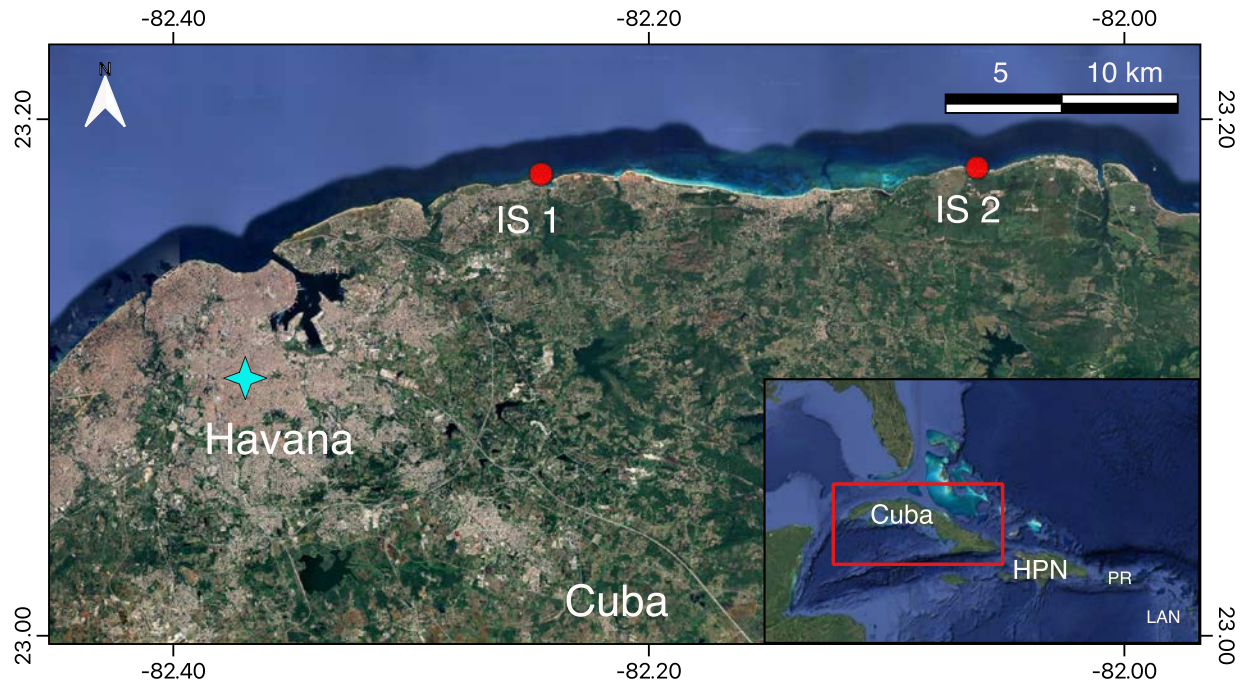
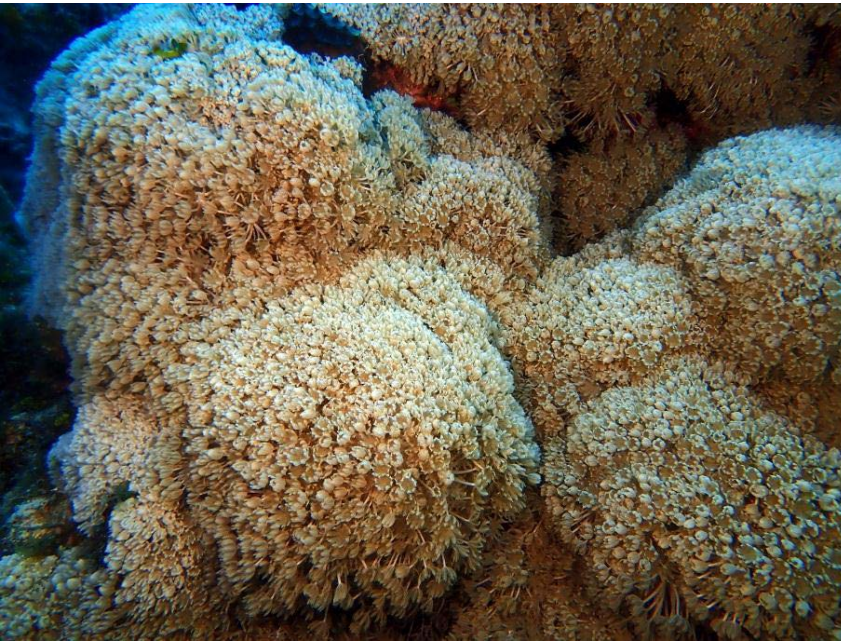


Figure 1: Map showing the geographic location of established colonies of *Xenia umbellata* along the northwestern coast of Cuba. Location of two invasion sites: Bacuranao (IS 1) and Punta Calderas (IS 2). Inset showing the location of Cuba within the Greater Caribbean.



Figure 2. Approximate outline (in red) of the main octocoral aggregate found in Boca de Calderas, Mayabeque, October 7, 2023. Several divers can be seen surveying the site. As reference, the size of the white quadrant is 50 x 50 cm. Photo credit: R. Espinosa Sáez, J. Estrada Estrada, A. Martínez Pérez, Y. del Carmen Luguera González.



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253 Figure 3. Partial view of an aggregate of *Xenia umbellata* in Boca de Calderas, Mayabeque, October 5,  
254 2023. Photo credit: R. Espinosa Sáez, J. Estrada Estrada, A. Martínez Pérez, Y. del Carmen Luguera  
255 González.

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258 Figure 4. Details of colonies of *Xenia umbellata* showing contracted polyps in Boca de Calderas,  
259 Mayabeque, October 5, 2023. Photo credit: R. Espinosa Sáez, J. Estrada Estrada, A. Martínez Pérez, Y.  
260 del Carmen Luguera González.

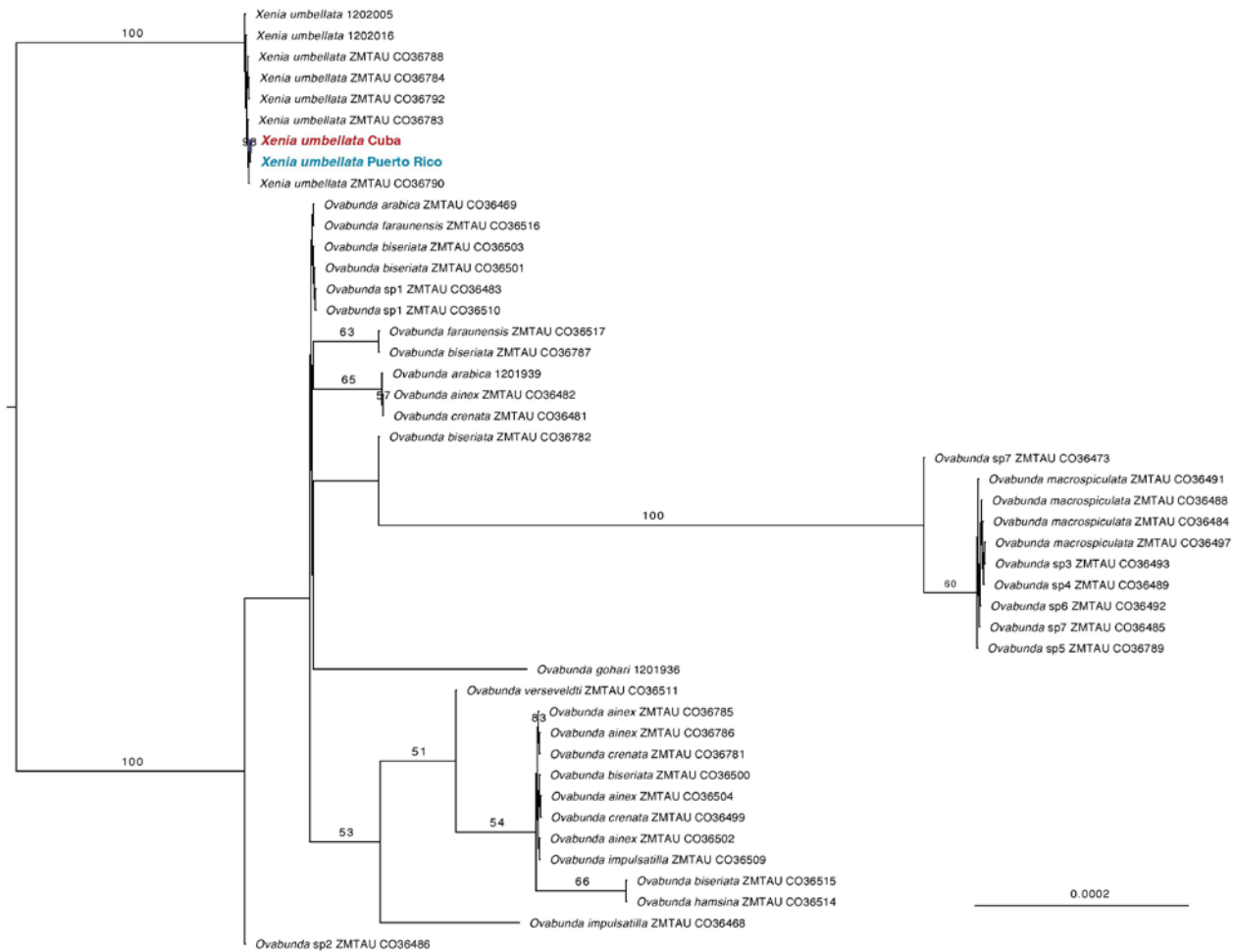
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263 Figure 5. Details of polyps of *Xenia umbellata* in Boca de Calderas, Mayabeque, October 5, 2023.  
264 Photo credit: R. Espinosa Sáez, J. Estrada Estrada, A. Martínez Pérez, Y. del Carmen Luguera  
265 González.

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268 Figure 6: A maximum likelihood tree based on concatenated sequences of mtMutS, 16S/ND2, COI, and  
 269 28S gene regions showing the phylogenetic placement of invasive xeniid corals in Cuba (in bold red)  
 270 and in Puerto Rico (in bold blue) within the *Xenia umbellata* clade. The tree was rooted on the *Xenia-*  
 271 *Ovabunda* branch. Numbers on clades represent parametric bootstrap values (Bp > 50). Voucher  
 272 information follows the specimen's name (see McFadden *et al.* 2017 and Supplementary Table 1).

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