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SHORT COMMUNICATION

Distribution of the parasitic gold coral morphotype *Savalia savaglia* (Bertoloni, 1819) in the eastern Adriatic Sea

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Abstract: The gold coral, *Savalia savaglia,* is generally considered a rare parasitic parazoanthid mainly found in the Mediterranean Sea, with occasional records in the Atlantic Ocean. Recently, more has come to light regarding its distribution patterns, genetic information, and habitat due to the increased research focus. Listed as 'Near Threatened' on the IUCN Red List, *S. savaglia* requires continued monitoring, and updated assessments of its distribution are crucial. Here, we compile recent data and current knowledge on this species, highlighting both confirmed findings and unresolved questions, like the question of possible cryptic species and obligatory parasitism. We also report new records from the eastern Adriatic Sea, helping to fill the existing gaps in the known distribution of the morphotype *S. savaglia*.
Keywords: coral populations monitoring; *Savalia savaglia*; cryptic species; distribution; eastern Adriatic Sea

Sažetak: RASPROSTRANJENOST PARAZITSKOG ZLATNOG KORALJA MORFOTIPA *SAVALIA SAVAGLIA* (BERTOLONI, 1819) U ISTOČNOM DIJELU JADRANSKOG MORA. Zlatni koralj, *Savalia savaglia,* relativno je rijedak parazitski parazoantid koji se primarno nalazi u Sredozemnom moru, ali je zabilježen i u Atlantskom oceanu. Posljednjih godina prikupljeno je više podataka o njegovoj rasprostranjenosti, genetici i staništu. Obzirom na to da se *S. savaglia* nalazi na IUCN-ovom Crvenom popisu kao "gotovo ugrožena", važno je provoditi sustavna istraživanja ove vrste, posebice njezine rasprostranjenosti. U ovom radu analiziramo podatke iz novije literature i postojeća saznanja o ovoj vrsti, ističući i potvrđena otkrića i neriješena pitanja, poput mogućih kriptičnih vrsta i obligatnog parazitizma. Također izvještavamo o novim nalazima iz istočnog dijela Jadranskog mora, kao prilog boljem poznavanju rasprostranjenosti morfotipa *S. savaglia*.
Ključne riječi: sustavno praćenje populacija koralja; *Savalia savaglia*; kriptične vrste; raspostranjenost; istočni dio Jadranskog mora

INTRODUCTION

The gold coral, *Savalia savaglia* (Bertoloni, 1819), is a relatively rare parasitic parazoanthid that acts as an ecosystem engineer by creating the so-called "animal forests''. When abundant, it partakes in storing carbon, reducing resuspension, and enhancing overall biodiversity (Roche and Tixier-Durivault, 1951; Jones *et al.*, 1994). It has been recorded primarily in the Mediterranean Sea (Otero *et al.*, 2017), with recent records also in the Atlantic (de Casamajor *et al.*, 2023), and with a global trend of population decline (Otero *et al.*, 2017). Previously, it has been considered endangered due to human threats of fishing, and damage to the environment due to the anchors and marine litter. As a result, the species has been listed as "Near Threatened" on the IUCN Red List in 2014, and in the SPAMI-Barcelona Convention, in Annex II: List of endangered and threatened species. Species delineation poses a major challenge when identifying organisms with simplified morphologies such as corals (Eytan *et al.*, 2009). This is particularly evident in coral populations that have adapted to decades of environmental change by increasing genetic diversity (Rippe *et al.*, 2021). Since corals exhibit slowly evolving mitochondrial DNA (mtDNA), it has been challenging to track fine-scale differences across lineages (Eytan *et al.*, 2009). However, molecular approaches are advancing, particularly the investigation of nuclear DNA (nDNA) rather than mtDNA (Eytan *et al.*, 2009), leading to a recent increase in the recognition of cryptic species (Ocaña and Brito, 2018). Taking into account the aforementioned findings, here we present the distribution of the morphotype *S. savaglia*, which is likely to comprise more than one species and therefore requires further morphological and genetic studies in the future.

Research on the morphotype *S. savaglia* has identified distinguishing characteristics, such as how it forms its skeleton (Roche and Tixier-Durivault, 1951; Ocaña and

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Brito, 2004, 2018), and its ability to produce ajugasterone-C, a compound typically found only in terrestrial plants (Vallentyne, 1964). Prior to forming its skeleton, *S. savaglia* overgrows its host. Several organisms have been identified as its suitable substrates, mostly the red gorgonian *Paramuricea clavata* (Risso, 1827) (Cerrano *et al.*, 2007; de Casamajor *et al*., 2023), but also *Paramuricea cf. grayi* (de Casamajor *et al*., 2023), *Eunicella* spp., *Leptogorgia* spp., and antipatharians (Giusti *et al*., 2014; Canessa *et al*., 2024). *Savalia savaglia* grows between 5-10 cm y^{-1} (Cerrano *et al.*, 2007). It exhibits distinctive skeletal growth patterns, often forming colonies that develop a basal plate where polyps are produced asexually. These colonies can have multiple branches, either in a single plane or across several planes (Ocaña and Brito, 2004).

Environmental conditions such as weak tidal currents, strong current regimes, bathymetry, salinity, and temperature influence the growth and, therefore, the density of *S. savaglia* in different habitats. The species thrives in areas with moderate water movement, avoiding locations with strong currents (Ocaña and Brito, 2004, 2018). It mainly occurs in the depth range of 15-90 m, but may be found as deep as 900 m in the Mediterranean Sea (Giusti *et al*., 2014). Salinity influences the distribution of gold coral populations, as seen for example in Boka Kotorska Bay, where dense populations inhabit an area near numerous fresh underwater springs (*vruljas*) with daily variations in salinity (Canessa *et al.*, 2024). Temperature is another important factor, since *S. savaglia* is most commonly found in regions with minimal temperature fluctuations throughout the year, with a temperature standard deviation between 0.5 °C and 5 °C (Varotti, 2020). Colonies prefer to inhabit waters between 12.5 °C and 24.9 °C, with a growth threshold of approximately 22 °C (Varotti, 2020; Canessa *et al.*, 2024).

Asexual reproduction, such as budding (Ocaña and Brito, 2004; Pulido Mantas *et al.*, 2022) and stolonisation (Canessa *et al.*, 2024), is the dominant reproductive strategy in *S. savaglia*, particularly at shallower depths (Pulido Mantas *et al.*, 2022). Nonetheless, the exchange of genetic material remains essential for adaptation to varying ecological conditions in coral species (Prada and Hellberg, 2013). Populations of *S. savaglia* inhabit a wide depth range on coralligenous habitats, and depth can act as a physical barrier isolating populations. Such reproductive isolation has contributed to the increasing number of cryptic species identified within the population of *S. savaglia*, but also in other coral species (Eytan *et al.*, 2009; Prada and Hellberg, 2013; Rippe *et al.*, 2021). A depth boundary of around 50 m has been proposed to separate isolated deep- and shallow-water corals (Cairns, 2007). For instance, Eytan *et al.* (2009) reported that *Oculina* populations at the Oculina Banks, positioned below 70 m, are genetically isolated from shallow populations. Similarly, distinct sister species within the genus *Eunicea* have been identified between shallow and deep populations across Caribbean coral reefs (Prada and Hellberg, 2013). In this context, more than 50 individuals of *S. savaglia* were genotyped across five locations on the Mediterranean coast, inhabiting depths from 8 to 60 m (Poliseno *et al.*, 2022). This depth segregation also has a significant effect on the genetic differentiation of *S. savaglia* populations, with shallow populations exhibiting greater genetic diversity (Poliseno *et al.*, 2022).

The existing literature on the distribution of *S. savaglia* is worth reviewing due to its ecological interactions with other anthozoans and its threatened conservation status. The paper aims to (i) summarize existing knowledge on the distribution and biology of the gold coral morphotype *S. savaglia*, (ii) update the list of records for the eastern Adriatic Sea, and (iii) provide an overview of potential future research directions.

MATERIAL AND METHODS

Photographic data were collected between 2000 and 2024 along the eastern Adriatic coast of Croatia by scuba diving on rocky and sandy bottoms, from the surface down to 68 m depth (Fig. 1, Table 1). All individuals at the research stations in the Adriatic were photographed for species identification. The occurrence and population density of the targeted species were analysed through manual identification in the collected photographs. More detailed research on the benthic community was conducted on the cliffs of Lastovo Island, where *Paramuricea clavata* and *Savalia savaglia* had not previously been recorded. Photographic identification of macro-benthic taxa (corals, sponges, bryozoans, etc.) was conducted using a GoPro 8 Black Edition for footage obtained in 2021 and 2022. Footage obtained in 2023 was taken with a TG-6 camera (Olympus) in an underwater housing (Ikelite), including an AOI Q1 Strobe set at northern (Maslovnjak) and southern (Struga) cliffs of the island in the 35 to 40 m depth range. At Struga, an underwater crevice with a depth of 25-40 m was discovered, and its benthic community was analysed in detail.

RESULTS AND DISCUSSION

The morphotype *Savalia savaglia* was mostly sporadically distributed overgrowing the host *Paramuricea clavata*, in the depth range of 40-60 m (Fig. 1, Table 1). The most frequent records were observed in the Middle and Southern Adriatic Sea: Nature Park Telašćica (Aba Gornja and Kampanel) (Kružić, 2007), National Park Kornati, the islands Babuljaš Mali i Veliki, the Kablinac islets, islets near Rogoznica (Velika Smokvica Mulo, Muljica), Šolta Island, and National Park Mljet (Fig. 1, Table 1). An additional discovery was made recently during the ISLAND project field campaign (Ljubešić *et al.*, 2024), where dense populations of *S. savaglia* were recorded in a newly discovered crevice on the cliffs of Lastovo Island (Fig. 2). This record confirms the pre-

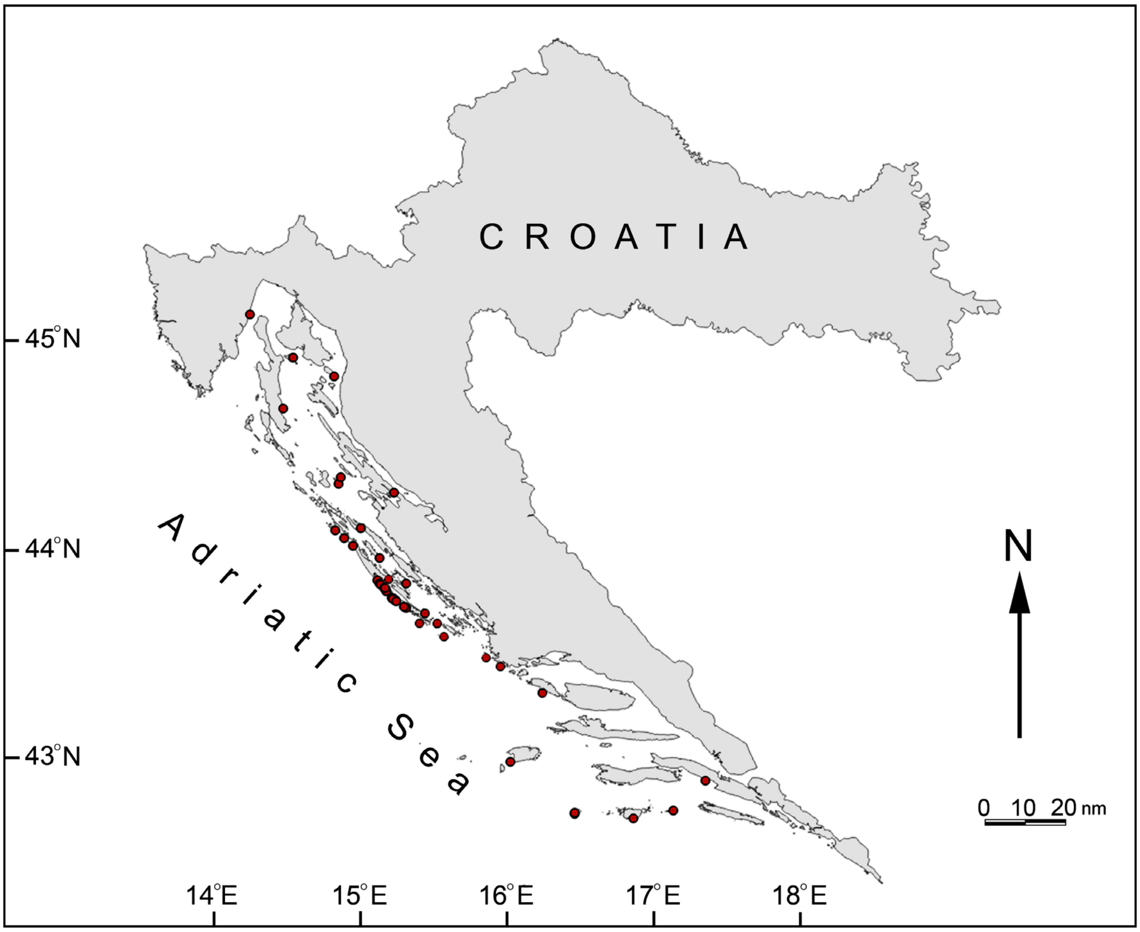

Fig. 1. Locations of new records of the gold coral morphotype *Savalia savaglia* in the eastern Adriatic Sea are denoted as red dots.

sence of a specific micro-environment for this species that may be under freshwater influence, and elucidates similar distribution patterns as observed in Boka Kotorska Bay (Canessa *et al.*, 2024). Notably, *P. clavata* and *S. savaglia* were found only in this crevice on Lastovo Island. Due to daily thermocline movements around Lastovo Island, a less diverse benthic community has been reported, which is in line with a previous study (Novosel *et al.*, 2004), offering an explanation why the stenothermic *P. clavata* was not recorded on the island cliffs.

The tendency of morphotype *S. savaglia* to form small populations was confirmed across 70 localities in the Mediterranean Sea and the eastern Atlantic Ocean (Pulido Mantas *et al*., 2022). Approximately 90% of observed populations consist of fewer than five colonies (Pulido Mantas *et al*., 2022), which is consistent with recent findings from Lastovo Island. *Savalia savaglia* prefers habitats with complex bottoms, such as caverns, arches, and overhangs, where bathymetric variability is high (Pulido Mantas *et al*., 2022). Its depth limit is still debatable. According to the IUCN, the deepest habitat ranges between 15 and 700 m, while Giusti *et al*. (2014) report that colonies are typically found at depths ranging from 10 m to 900 m.

Several observations of the morphotype *S. savaglia* have been reported from environmentally diverse locations, including the Adriatic Sea, the Catalan coast, and the Marmara Sea. Most of these records are listed in the IUCN Red List. However, occurrences in the Bay of Biscay, France (de Casamajor *et al.*, 2023) and the Canary Islands (Poliseno *et al.*, 2022) are not included. Poliseno *et al.* (2022) suggested that *S. savaglia* was historically distributed in deep-sea waters of the eastern Atlantic based on the Bay of Biscay observation. That study concluded that gene flow connects Mediterranean and Atlantic populations. Meanwhile, the Canary Islands contain the highest known densities of *S. savaglia* (Poliseno *et al.*, 2022), along with Boka Kotorska Bay (Canessa *et al.*, 2024), and according to our data, the Lastovo Island crevice. The OBIS database also lacks a complete record of the morphotype's distribution. For instance, its map does not show any observations along the southern coast of Spain or the Algerian coastline (Ocean Biodiversity Information System (OBIS), 2025).

Apart from these collective databases based on field observations, Pulido Mantas *et al*. (2022) predicted suitable locations for *S. savaglia* using a model based on environmental parameters such as temperature, sa-

Table 1. Location, reference, depth range and location coordinates of the morphotype *Savalia savaglia* in the eastern part of the Adriatic Sea, with *Paramuricea clavata* as host except* (host is *Eunicella cavolini*).

Location	Reference	Depth range (m)	Coordinates
Arkanđel Islet	Muljica	45-55	43°28’26” N, 16°0’40” E
Babuljaši Islets	Mali Babuljaš	45-60	43°52’44” N, 15°21’6” E
Babuljaši Islets	Veli Babuljaš	45-60	43°52’29” N, 15°21’14” E
Balkun Islet	Balkun west	49-51	43°37’58” N, 15°35’59” E
Blitvenica Islet	Blitvenica (lighthouse)	56-60	43°37’27” N, 15°34’29” E
Cres Island	Cape Tarej	42-43	44°57’24” N, 14°29’02” E
Ćutin Mali Islet	West part	46-47	44°43’26” N, 14°29’37” E
Dugi Otok Island	Cape Lopata, north	44-48	44°07’43” N, 14°51’52” E
Dugi Otok Island	Mežanj	47-48	44°05’39” N, 14°55’43” E
Glavat Island	Svjetionik-south	46-51	42°45’53” N, 17°08’48” E
Ist Island	Vodenjak	40-45	44°15’58” N, 14°43’50” E
Iž Island	Cape Parda, south	46-49	43°59’46” N, 15°10’03” E
Kornati National Park	Balun	48-53	43°48’14” N, 15°15’15” E
Kornati National Park	Hrid Kamičići (Mana)	45-46	43°47’29” N, 15°16’56” E
Kornati National Park	Panitula Mala Islet	52-54	43°45’20” N, 15°21’07” E
Kornati National Park	Purara Islet	58-59	43°41’51” N, 15°26’17” E
Kornati National Park	Obručan Mali	52-56	43°50’10” N, 15°13’11” E
Kornati National Park	Rašip Mali	49-50	43°47’24” N, 15°17’13” E
Kornati National Park	Samograd	47-50	43°41’11”N, 15°33’33” E
Lastovo Nature Park	Cape Struga	35-58	42°43’38” N, 16°53’05” E
Brseć (Istria Peninsula)	Klančac	48-52	45°11’02” N, 14°1442” E
Pag Island	Cape Fortica	44-47	44°19’17” N, 15°15’18” E
Pelješac Peninsula	Dingački Škoj	48-50	42°54’44” N, 17°22’07” E
Planičić Islet	Planičić, south	48-51	44°21’24” N, 14°52’45” E
Plavnik Islet	Mali Plavnik	49-54	44°58’31” N, 14°32’52” E
Pohlib Islet	Pohlib-south	46-47	44°23’38” N, 14°53’37” E
Prvić Island	Cape Šilo	44-48	44°53’02” N, 14°50’19” E
Rivanj Island	Rivanjski kanal	38-40	44°08’41” N, 15°02’04” E
Rogoznica	Smokvica Vela	40-55	43°30’51” N, 15°56’18” E
Rogoznica	Mulo	45-55	43°30’54” N, 15°55’0” E
Sit Island	Brušnjak Islet	51-54	43°55’28” N, 15°17’07” E
Sušac Island	Bila ponta	57-61	42°45’32” N, 16°29’32” E
Šolta Island	Tatinja*	30-45	43°22’5” N, 16°16’45” E
Telašćica Nature Park	Gornja Aba	40-50	43°53’24” N, 15°14’22” E
Telašćica Nature Park	Mir	44-46	43°52’59” N, 15°09’57” E
Telašćica Nature Park	Sestrica Vela, south	45-62	43°51’02” N, 15°12’26” E
Telašćica Nature Park	Kampanel	48-68	43°51’45” N, 15°11’50” E
Telašćica Nature Park	Veli Garmenjak Islet	48-55	43°51’56” N, 15°10’56” E
Tetovišnjak Island	Hrid Kablinac, west	52-55	43°42’55” N, 15°36 30” E
Vis Island	Cape Stupišće	56-58	43°00’19” N, 16°04’00” E
Žirje Island	Grmeni	45-55	43°37’12” N, 15°37’27” E

linity, dissolved oxygen, current velocity, primary production, and bathymetry. For some locations, such as the southern coast of Sicily and Sardinia, the Balearic Islands, and numerous Greek and Croatian islands, there are no published records to confirm these predictions. Continued research on the distribution of this morphotype is thus needed to test the model and track its response to climate change. Recent publications, such as Di Camillo *et al*. (2018) and Pulido Mantas *et al*. (2022), have contributed to the understanding of *S. savaglia* distribution in the Adriatic Sea, particularly those combining Citizen Science (CS) approaches and Web Ecological Knowledge (WEK) sources. The research, based on data collected through CS databases (e.g., ReefCheck), online surveys targeting diving centres and clubs, and diver-submitted observations, has revealed numerous previously undocumented occurrences of this species. However, the records we present in this study are based on direct field observations and underwater surveys conducted by benthic experts, providing a form of ground-truthing for earlier CS-based findings. This synergistic approach, combining structured scientific research with contributions from non-professionals, reinforces the reliability of WEK and CS methods, and highlights their potential for advancing knowledge on poorly known species such as the morphotype *S. savaglia*. Rather than challenging the validity of previous findings, our results demonstrate how expert verification can strengthen and contextualize citizen-contributed data, underscoring the importance of collaborative efforts in marine biodiversity research.

The observations outlined above raise the question of whether *S. savaglia* is truly rare or simply commonly overlooked due to its typical occurrence at greater depths. According to our data from the eastern Adriatic Sea, it mostly inhabits depths from 40 to 60 m, which can point to overlooked species. Another unresolved question is whether *S. savaglia* can form its skeleton independently of other gorgonians (Gaglioti *et al*., 2019; Canessa *et al*., 2024) or whether a gorgonian forest must predate the settlement of *S. savaglia* (Gaglioti *et al*., 2019). Dense colonies of *S. savaglia* observed in Boka Kotorska Bay (Montenegro) show an unusual skeletal structure, where the basal parts of the trunk exhibit a homogenous skeleton without a gorgonian core (Canessa *et al*., 2024). Instead, the skeleton consists of dense nodules, approximately 0.1 mm in diameter, distributed across the matrix, offering new insights into the skeletal development of this species (Canessa *et al*., 2024, 2025). No comparable structures were identified in this study. New findings of dense populations of *S. savaglia* in a specific habitat on the Lastovo Island may suggest that *S. savaglia* could act as a tracer of lost gorgonian

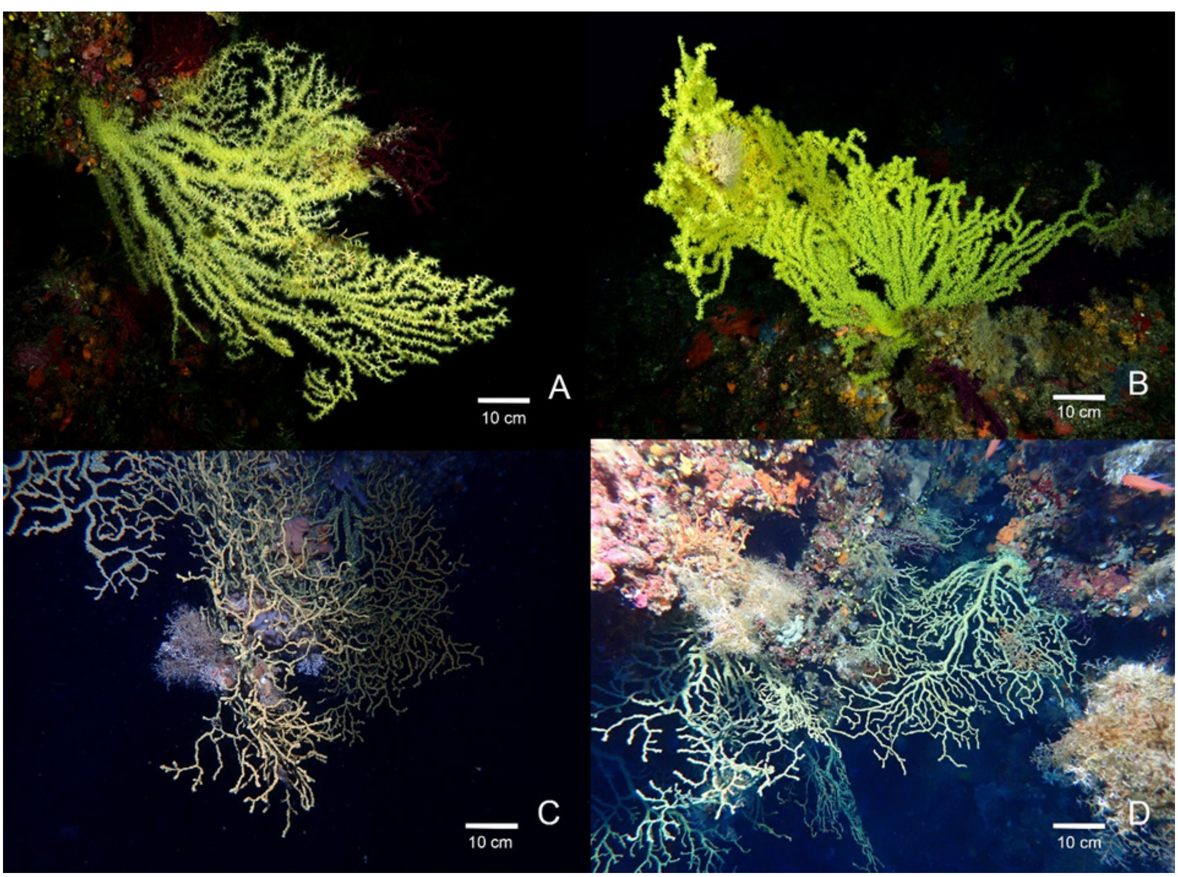

Fig. 2. The morphotype *Savalia savaglia* fully overgrowing its host colony of *Paramuricea clavata* in the Kornati National Park (**A**, **B**) and at the newly discovered crevice in the cliffs of Lastovo Island (**C**, **D**).

populations. Its preference for environmental conditions in comparison to its host may support this hypothesis, indicating that *S. savaglia* is neither rare nor particularly sensitive. New findings at Lastovo Island also support the hypothesis that the narrow temperature niche is more specific to the host than to *S. savaglia* itself. These findings further suggest that *S. savaglia* skeletal formation may take place independently of the gorgonian-based core typically seen in other gorgonians (Canessa *et al*., 2024). Observations on Ustica Island (Italy) also contained growing populations in the absence of other gorgonians (Gaglioti *et al*., 2019). Trunk lengths ranging from 1.3 to 6.0 cm suggest that *S. savaglia* could have been present in this area for hundreds of years. The same study states that *S. savaglia* must have a gorgonian nearby, leading to the conclusion that a gorgonian forest predated the settlement of *S. savaglia* (Gaglioti *et al*., 2019).

Genetic research on *Savalia savaglia* is scarce (Poliseno *et al.*, 2022); thus, further genetic studies on this organism should be encouraged. For instance, the relationship between genetic variation and species distribution remains underinvestigated. Furthermore, it remains uncertain which population acts as the source for others. Poliseno *et al.* (2022) suggested that directional gene flow analyses could clarify these patterns. Future studies should integrate field observations with concurrent environmental measurements and sampling for genetic analysis. Investigating special habitats may reveal more about the micro-distribution of *S. savaglia*, while genetic analyses are essential to gain insight into the possible cryptic species within *S. savaglia*.

Anthropogenic pressures, such as marine litter, fishing activities, and habitat destruction, should also be addressed (Amedeo *et al.*, 2022; Canessa *et al.*, 2024). In northeastern Sardinia, even in the area under protection, fishing gears have been reported as a serious threat, causing mechanical damage to gorgonians (Amedeo *et al.*, 2022; Canessa *et al.,* 2025). On the other hand, in Montenegro, marine litter was observed at the study sites Dražin vrt and Sopot with high densities (up to 0.18 objects per m²) (Canessa *et al.*, 2024). Although areas are under protection resulting from findings from the GEF Adriatic project (2017-2020), human impact is still interfering with the habitat of vital importance for *Savalia savaglia* populations (Canessa *et al.*, 2024). Anthropogenic impact is also visible in the effects of climate change. According to Pulido Mantas *et al.* (2022), the suitable habitat for the species covers approximately 71,000 km², of which only 6.74% (4,809 km²) is under some form of protection (Canessa *et al.*, 2024). This underscores the need for increased conservation efforts. The IUCN database is an invaluable source of information on the distribution of *S. savaglia*; thus, it is essential to incorporate standardized monitoring protocols and effective management. Improved practice will ensure more effective support for conservation efforts for *S. savaglia* and other similarly threatened species, such as gorgonians (Pulido Mantas *et al.*, 2022). For instance, gorgonian forests at depths between 30 and 50 m have been replaced by scattered individuals, indicating their disappearance due to climate change (Gaglioti *et al.*, 2019; Pulido Mantas *et al.,* 2022). Since these species play a vital role in the carbon cycle, specifically its sequestration, the loss of even a single colony can result in a reduction of carbon retention capabilities, which is critical for combating the effects of climate change (Pulido Mantas *et al.*, 2022). Although the temperature of the Adriatic Sea has been increasing in recent decades (Grbec *et al*., 2018; Vilibić *et al.*, 2023), no tissue damage or mortality has been detected at locations with the morphotype *S. savaglia*. This paper describes only the findings of the morthotype *S. savaglia* in the Adriatic Sea; therefore, further research into these lost habitats could provide valuable insights into the ongoing decline of marine ecosystems and inform future conservation strategies.

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AUTHOR CONTRIBUTIONS

Jade Hartkamp: Writing – review & editing; Writing – original draft; Visualization; Formal analysis. Hrvoje Čižmek: Writing – review & editing; Writing – original draft; Methodology; Investigation; Data curation. Barbara Čolić: Writing – review & editing; Writing – original draft; Methodology; Investigation; Data curation. Petar Kružić: Writing – review & editing; Writing – original draft; Visualization; Formal analysis; Data curation. Antonija Matek: Writing – review & editing; Writing – original draft; Project administration. Zrinka Ljubešić: Writing – review & editing; Writing – original draft; Supervision; Resources; Project administration; Methodology; Investigation; Funding acquisition; Data curation; Conceptualization.

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