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Hidden Depths: A Unique Biodiversity Oasis in the Persian Gulf in Need of Further Exploration and Conservation

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Abstract: The Persian Gulf, a young and shallow epicontinental sea, is known for its unique geological and oceanographic characteristics that foster its diverse and productive marine ecosystems. A substantial portion of the Gulf's seafloor consists of unconsolidated soft sediments, making it unsuitable for colonization by many sessile organisms. Consequently, relatively few hard grounds and submerged banks provide suitable habitats for benthic and substrate dwellers. This study documents a unique marine habitat on an offshore submerged bank, likely a raised salt dome, south of Qeshm Island, Iran. This area is home to a high concentration of ahermatypic coral species and remains relatively sheltered from human activities. The bank's geographic location allows inflow currents from the Strait of Hormuz to transport larvae and nutrients, providing suitable substrates for various sessile invertebrates. Moreover, it causes the formation of Taylor columns, which affect fluid dynamics and circulation patterns, indirectly enhancing biodiversity. Despite facing risks from large-scale regional and localized threats, the bank's remoteness from the main coast and its depth provide some protection. This study emphasizes the need for continued exploration and the implementation of effective conservation measures in the region, along with additional research to clarify the ecological and physical parameters supporting its diversity. It also presents the first in situ photographic evidence for the occurrence of some octocoral genera in the Gulf. Future research should investigate how the species compositions of hidden banks and shoals contribute to the overall biodiversity of the Persian Gulf.

Keywords: biodiversity hot spot; octocorals; deep water; submerged banks; shoals; non-scleractinians; Taylor columns

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The Persian Gulf is a relatively shallow and geologically young epicontinental sea, with distinct and extreme environmental conditions that foster the resilience of its ecosystems [1–4]. It is connected to the Indian Ocean through the Strait of Hormuz (Figure 1). This passage is crucial for the exchange of water, nutrients, and marine life between the two regions. The Gulf is known for its harsh environments and unique species composition, marked by low species diversity but a high degree of endemism compared with the rest of the Indian Ocean [5]. The Gulf's unique geological and oceanographic characteristics contribute to its diverse and productive marine ecosystems [1]. Its shallow depth, warm temperatures, and high salinity levels create distinct habitats that support a wide variety of marine life, including coral reefs, seagrass beds, and mangroves [3].

The dominant composition of the Persian Gulf's seafloor consists of soft sediments, primarily mud, silt, and sand [6]. These sediments are a result of the region's geological history and the natural processes occurring in the Gulf. The composition of the seafloor plays a crucial role in shaping the area's benthic habitats [7]. Although this soft sediment

is ideal for some marine invertebrates, it limits the colonization and growth of sessile organisms. Therefore, the presence of hard grounds and submerged banks can promote species richness at a local scale. It can provide a suitable habitat for a diverse range of marine life, including fishes, corals, and various groups of other invertebrates [8], and can also offer protection from predators. Submerged banks can also influence local currents and play a role in marine ecosystem dynamics. The height of such submerged structures can affect the formation of Taylor columns in rotating fluids, resulting from the Coriolis effect [9]. While not directly increasing biodiversity, their presence can indirectly enhance ecosystems and the biodiversity around those obstacles, such as submerged banks and seamounts, through processes such as nutrient upwelling, enhanced mixing and retention, and habitat creation [10,11]. For example, circulation patterns, including those influenced by Taylor columns, can create retention zones for planktonic larvae and provide sheltered habitats, increasing their chance of settlement and eventually fostering species diversity around those objects [12].

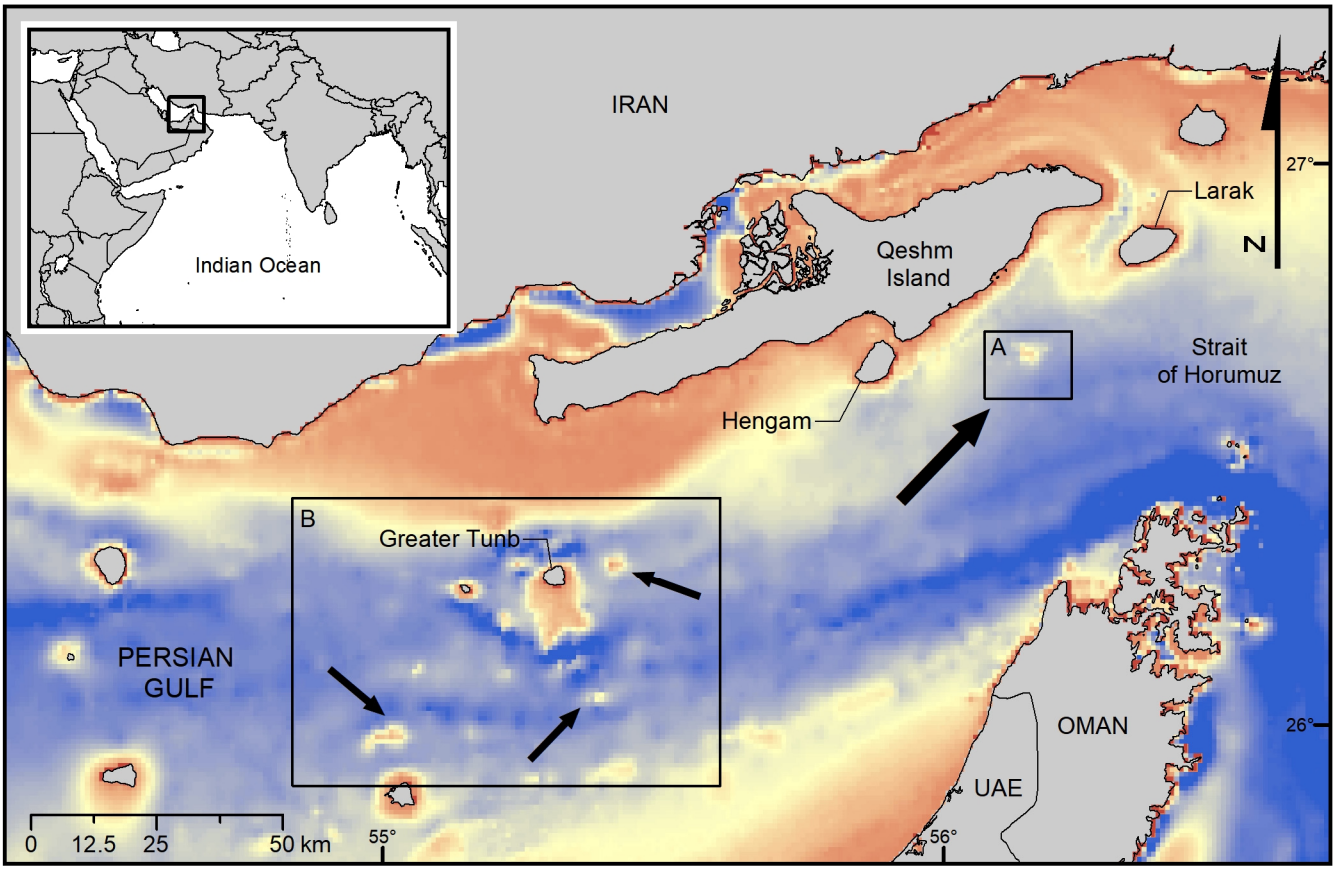

Figure 1. Bathymetric map of the eastern Persian Gulf. Brown = shallow; blue = deep. (**A**) The location of the submerged bank; (**B**) other submerged banks with potential high diversity around Greater Tunb Island indicated by arrows.

A unique and diverse marine habitat, 17 km south of Qeshm Island and 48 km offshore from the Iranian main coast (Figure 1), was surveyed in 2015–2018 during some explorative dives. The oceanographic and bathymetric data suggest that this submerged bank is likely a raised salt dome, with the base at a depth of about 70 m and the top at 25 m below the water surface (Figure 1). Only the shallow top layer of the structure is surveyed. It was mainly composed of unconsolidated and partial-consolidated sand, gravel, pebbles, and cobbles, providing a suitable habitat for various marine sessile organisms surrounded by a sandy–muddy seafloor. The top and upper edges of the bank were densely populated by various sessile organisms, forming a thriving animal forest (Figures 2–4). It was covered by a

diverse and dense population of octocorals, antipatharians, sponges, solitary scleractinians, and other invertebrates (Figures 2–4). Spanning an area of about 35 km^2 (0.01% of the total Persian Gulf area), the surveyed site represents the highest concentration of ahermatypic (non reef-building) coral species ever documented in the Persian Gulf [13,14]. Upon an initial evaluation of the available images and video fragments, and prior to sampling the area, the estimated species richness for octocorals is anticipated to be 40–60 species. Additionally, this study presents the first in situ photographic evidence for the occurrence of the octocoral genera *Ellisella*, *Solenocaulon*, and *Verrucella* in the Gulf (Figures 2–4). While previous records of these genera exist [13,14], they are notably uncommon and predominantly found in deeper waters.

Owing to its geographical location, the bank receives inflow currents from the Strait of Hormuz containing larvae and nutrients, and its hard grounds provide a suitable substrate for larval attachment. This area can act as a source of larvae and potentially seed downstream areas. To our knowledge, no other similar habitat with such diversity has been reported in the Gulf region.

The surveyed area is likely at risk due to large-scale environmental changes, similar to other regions of the Persian Gulf [3,15–17]. On a more localized level, small-scale threats may stem from various fishing activities and recreational diving, which may lead to habitat degradation; however, the area's considerable distance offshore and its greater depth act as protective factors, making it less likely to be adversely affected by these activities.

The northern side of the Gulf, despite having higher diversity compared to the southern part, remains understudied [3,18]. The growing number of publications on the Gulf's biodiversity, covering various groups of marine organisms [13,14,19–24], highlights the need for the further exploration and conservation of deep and remote areas. For example, a recent survey off the coast of Qatar resulted in the documentation of another unique coral community, which was dominated by an aggregation of two mushroom coral species, one of which was previously unknown in the Gulf [25].

The present study confirms the existence of unsurveyed, deeper, remote marine habitats in the Persian Gulf, and their potential value in supporting marine life. Given the presence of numerous submerged banks, shoals, salt diapirs, and depositional features [2,26,27], it is highly probable that other undiscovered structures with similar characteristics and high diversity exist in the region (Figure 1). A lack of information on these deeper geomorphic banks may lead to the underestimation of the extent of suitable habitats and species diversity in the Gulf region. Therefore, it is crucial to study these submerged banks as they can support large, diverse coral communities [8] and potentially serve as vital refuges from environmental disturbances [28,29].

Given the importance of preserving this unique marine biodiversity hotspot, it is essential for authorities and stakeholders to implement effective conservation measures. These measures could include regulating fishing activities, raising awareness about the area's ecological significance, and developing long-term strategies to monitor and protect its ecosystem. Further investigations are underway to understand the ecological and physical parameters supporting this high-diversity habitat and investigate the species richness of corals and other marine biota.

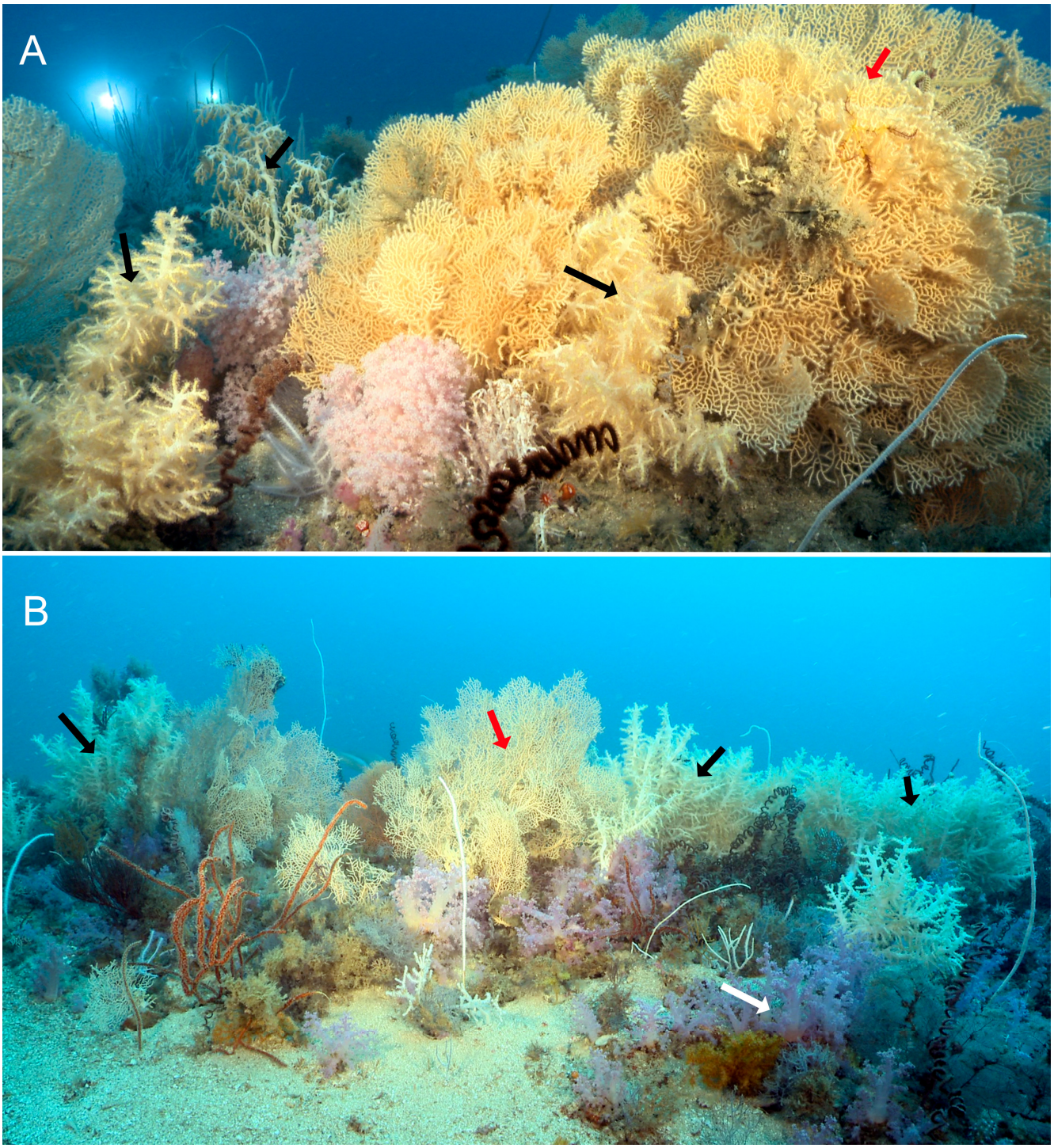

Figure 2. (**A**,**B**) Wide-angle view of the habitat (depth of 25–35 m), mainly covered by octocorals and antipatharians. (**A**) *Verrucella* colonies on the right (red arrow) and *Solenocaulon* colonies (black arrows); (**B**) *Verrucella* colonies (red arrow), *Solenocaulon* colonies (black arrows) in the background, and Nephtheids (white arrow). (Photos: A. J. Abdipour).

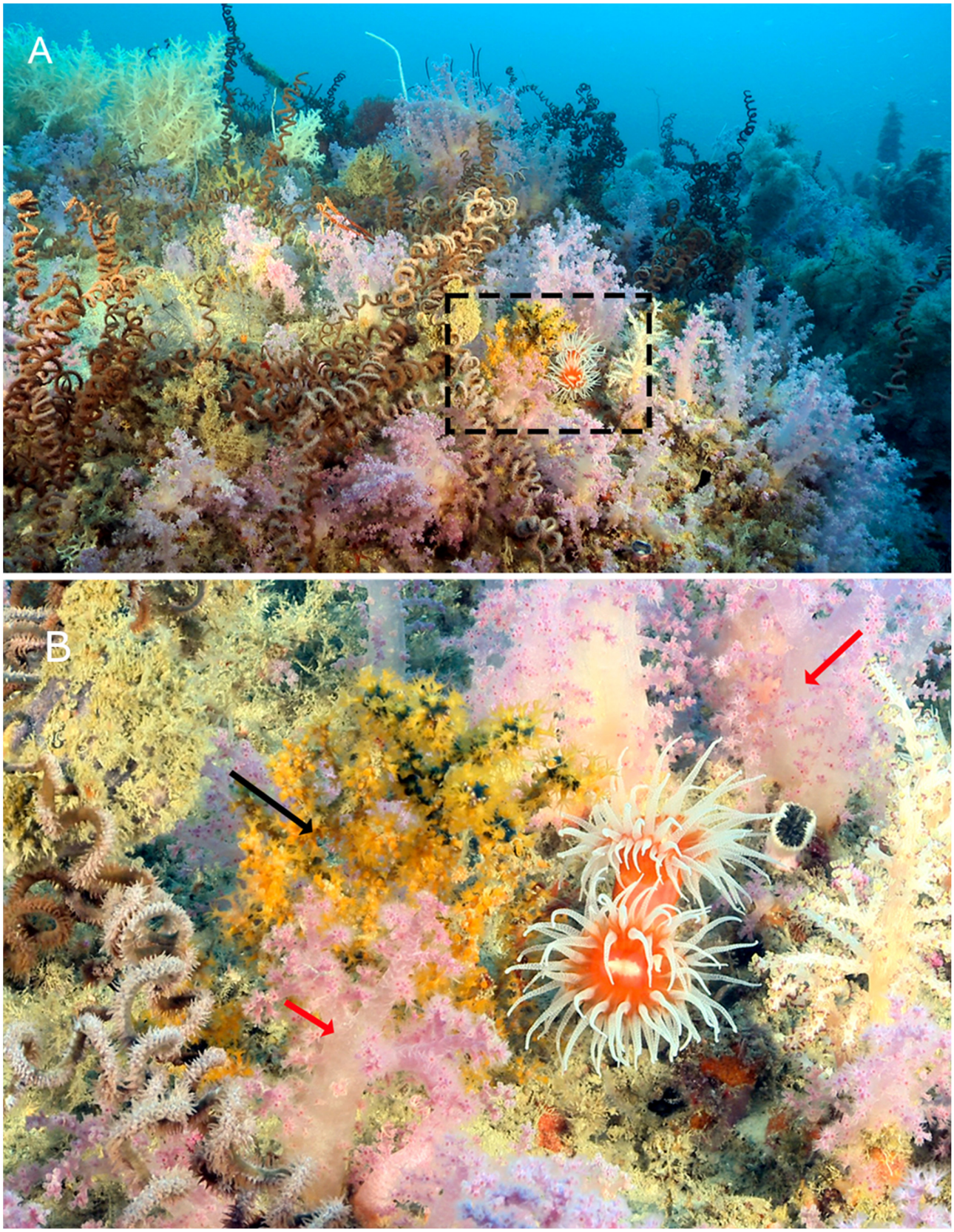

Figure 3. (**A**) High-density coverage of the habitat on a macro- and microscale (depth of 30–40 m), with the substrate mainly covered by octocorals and antipatharians. (**B**) Nephtheids (red arrow), *Astrogorgia* (black arrow), antipatharians, etc.; the solitary scleractinian corals are two *Balanophyllia* sp. (orange) and one *Paracyathus rotundatus* (black center). (Photos: A. J. Abdipour).

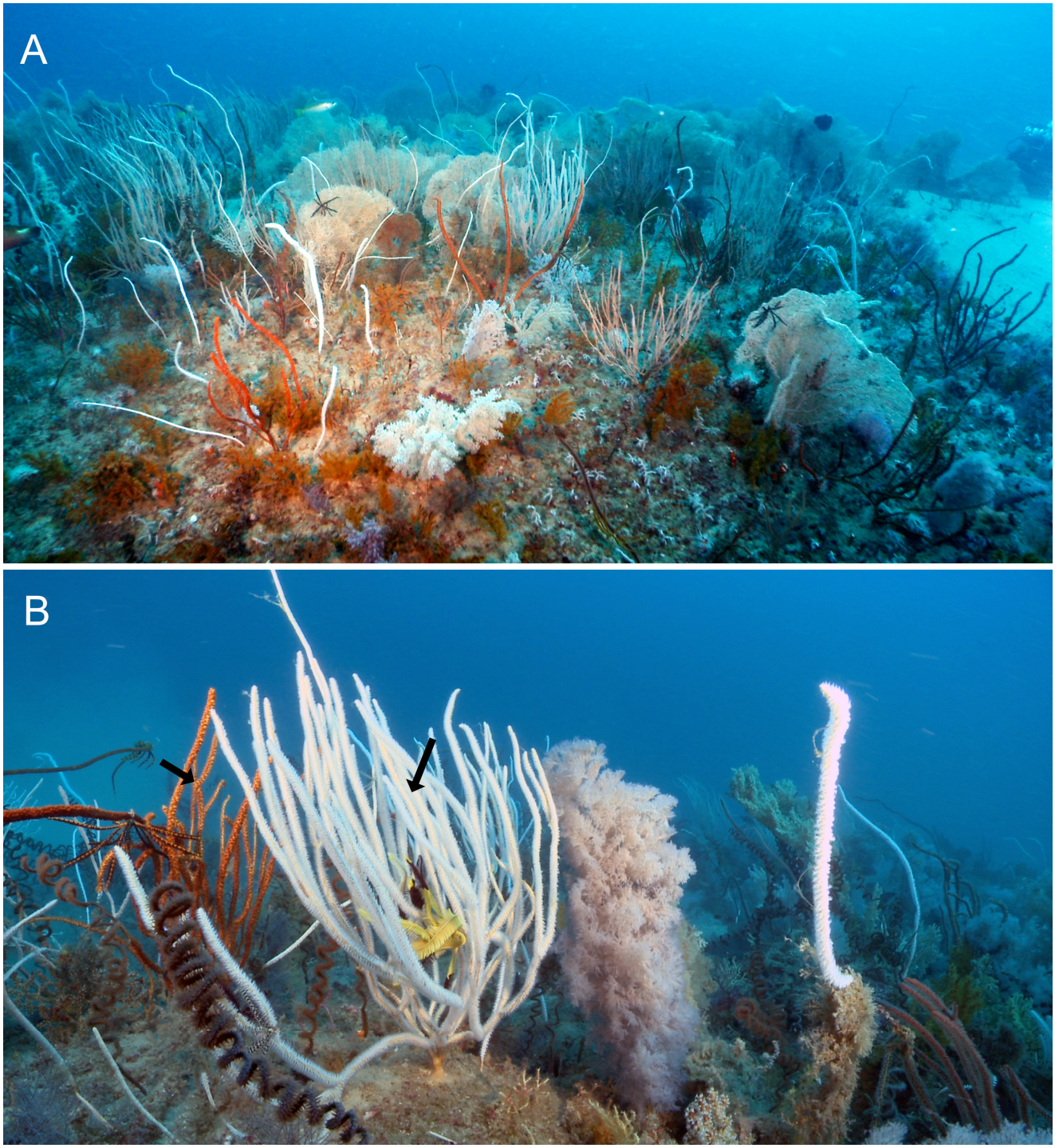

Figure 4. (**A**) Wide-angle view of the habitat (depth of 30–40 m), mainly covered by octocorals and antipatharians. (**B**) *Ellisella* colonies (black arrows). (Photos: A. J. Abdipour.).

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