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Short-lived Aggregations of *Filograna/Salmacina* Tube Worms in the Gulf of Oman

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Abstract: Dense aggregations of serpulid worms were encountered in the Daymaniyat Islands (Gulf of Oman) during January–March 2021. The species responsible for these aggregations belongs to the *Filograna/Salmacina*-complex (Annelida: Serpulidae). This species has been present in the area and observed along the Oman coastline, but high-density aggregates like this have not been reported before. The most probable cause of the aggregations, supported by field observations and Aqua-MODIS satellite data, was natural eutrophication with a subsequent algal bloom linked to the local winter monsoon. This observation emphasises the importance of documenting biodiversity and dynamics of reef communities along the Oman coastline.

Keywords: Algal blooms; outbreak; bioindicator; coral reefs; eutrophication; infestation; Serpulidae; Monsoon; Daymaniyat Islands

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As sedentary filter-feeders in coastal waters, tube-dwelling polychaetes of the families Sabellidae and Serpulidae are often considered bioindicators owing to potential increases in their abundance in relation to eutrophication [1–3]. Some serpulids occur in clusters and are considered habitat formers, especially as fouling organisms on manmade substrates [4,5]. Furthermore, serpulid worms account for 15% of the alien polychaetes species recognized worldwide [6–8].

Dense aggregations and outbreaks of Serpulidae can be opportunistic responses to changes in environmental conditions [9], specially to nutrient pollution [10]. These worms may thrive in conditions that are unfavourable to many other marine fauna [11,12]. The aggregations often develop in sheltered areas, sometimes at salinity levels outside the normal oceanic range [9,13], and with limited water movement facilitating larval dispersion [14].

In January–March 2021, dense aggregations of serpulid worms were observed in reef communities of Jabal Al Kabir Island (also known as D3 Island) in the Daymaniyat Islands Nature Reserve, north of Oman (Figure 1). The worms were mainly overgrowing hard substrates in the sheltered bays and seaward cliffs, forming fragile, branching clusters up to 20 cm in diameter (Figure 2). The aggregations occurred during a phytoplankton bloom and were relatively short-lived. By the end of April, the density of the worms had

decreased, and only remnants of the tube clusters remained. They were no longer evident in February 2022 when we revisited the area.

This species, although uncommon, has been present in the area and observed along the Oman coastline (Figures 2c, 4), as individuals or in small clusters. However, high density aggregates and outbreaks of the species have not been reported until now and we do not have field observations to confirm the formation of high-density aggregations in other locations.

The observed species can be attributed to the *Filograna*/*Salmacina*-complex. While 788 polychaete species, including 48 serpulids have been recorded from the waters around the Arabian Peninsula, only two nominal species have been reported in this complex: *Filograna implexa* Berkeley, 1835 and *Salmacina dysteri* Huxley, 1855 [16]. *Filograna implexa* is the only valid species in that genus [17], characterised by two spoon-shaped opercula. The genus *Salmacina*, which comes closest to our specimens, includes nine species and one uncertain attribution, all non-operculate, some with inflated radiole tips (Figure 2c). Poor descriptions of most species in this group and lack of assessment of intra-specific variability make it currently impossible to confidently identify the specimens.

Molecular studies have shown that some of the previously reported serpulids with wide, almost circumtropical distributions are actually a mix of several taxa, each with restricted regional distributions [18–20]. For example, the widespread taxa *Spirobranchus kraussii* and *S. tetraceros* (both recorded from Arabian Seas), appear each to consist of more than six species, all with geographically limited distributions [18,19]. The same is likely true for the taxa *Filograna implexa* and *Salmacina dysteri*, both originally described from the temperate coasts of the south-eastern United Kingdom and later reported from around the globe, including the Arabian Seas [16,17,21]. Although it is likely that the worms encountered in Oman represent a new species, any further identification will require genetic studies and a taxonomic revision to establish diversity and relationship within the *Filograna*/*Salmacina* complex [21,22].

Filograna/*Salmacina* species construct calcareous tubes attached to hard substrates. The individual adults are small, usually less than 350 μm in diameter, and a length of only a few millimetres [11,23]. They reproduce sexually, and asexually by scissiparity. Although sexual reproduction can contribute to the growth of aggregates [23], the branching tube pattern is a consequence of asexual reproduction [24]. Although, the worms and aggregates observed in the Daymaniyat Islands show signs of both sexual and asexual reproduction, the asexual reproduction is likely the main mode of pseudo-colony formation [24], followed by settlement of larvae on conspecific tubes [9,25]. The tube accretion rate depends on environmental parameters, such as water temperature, salinity, food availability, and can reach up to several millimetres per day in *S. dysteri* [24]. As a result, "pseudo-colonies" are formed from numerous joined branching tubes, protruding from the seabed [21,26]. Similar aggregations of tubes (Figures 2a, b) were illustrated by Dalyell [27] (for *Salmacina dysteri*, as *Filipora filograna*), Pernet [24] (for *Salmacina amphidentata*), and Bianchi [28] (for *Filograna* sp.). The fragile structures of this group often do not accrete to form reefs and are sensitive to physical disturbances [29,30], unlike some other serpulid species that can grow larger than 1 m in diameter and make extensive bioherms [26,31–34]. All the aggregates encountered in our study site were also fragile and did not accrete to form reef, but grew on the rocky surfaces (Figures 2–4).

Nutrient levels in coastal waters of Oman are mostly linked to monsoonal cycles. A strong, moist, summer southwest monsoon, and a weaker, dry, winter northeast monsoon, both result in upwelling and advection of nutrients to the surface in coastal water [35,36]. These are reflected in the algal bloom patterns, with two annual peaks in January–April and August–September along the northern Oman coastline [37].

Increase in nutrient concentrations create a cascade of effects: shifts in phytoplankton composition and biomass, increase in the abundance of phytoplankton grazers, followed by phytoplankton die-off, decomposition, and oxygen depletion [38,39] particularly

below the thermocline, occasionally accompanied by mass mortalities of other organisms [40–43]. These natural cycles in productivity contribute to ocean acidification and specialized shallow-water communities [44].

Our field observations together with Chlorophyll–*a* data obtained from Aqua–MODIS satellite confirms an algal bloom during February–March 2021 in the Daymaniyat Islands, with monthly averages of 11.17 mg/m^3 and 4.65 mg/m^3 [45] (23.8° N, 58.1° E; 0.1°–pixel), presumably driven by elevated high nutrients levels in the water column. The temporal correlation between the high abundance of *Filograna*/*Salmacina* and the phytoplankton bloom, the rapid growth rate of these animals, and tendency of serpulids to respond to elevated food levels all suggest that the bloom could be partly responsible for the outbreak.

During field work in the Arabian Sea coast of Oman around Mirbat in January 2022 we encountered smaller aggregations of what appeared to be the same species (Figure 4, vouchers deposited at Florida Museum of Natural History, UF Annelida 10242, 10255, 10456). This coast undergoes much more intense upwelling than the Gulf of Oman, and therefore these worms may regularly bloom in that area, lending support to phytoplankton productivity driving these population increases.

Although serpulid outbreaks can be a sign of environmental degradation, it seems that they responded indirectly here to a natural increase in planktonic productivity driven by upwelling-enhanced nutrient levels. It is unknown how these serpulids affected the benthic communities in the Daymaniyat Islands, but they can potentially increase water clarity through their suspension feeding [46] and affect their habitat by providing shelter, food, and substrate for epibiont organisms [9,47–49]. We did not observe any sign of smothering or overgrowth on corals, unlike serpulid infestations in the Persian Gulf [50] and later in the Gulf of Oman following the 2008–2009 *Cochlodinium polykrikoides* bloom [41] and high densities of *Spirobranchus* in the Caribbean [49].

These observations illustrate the need for a better taxonomic coverage of invertebrate biodiversity in the region and the importance of long-term monitoring of benthic communities.

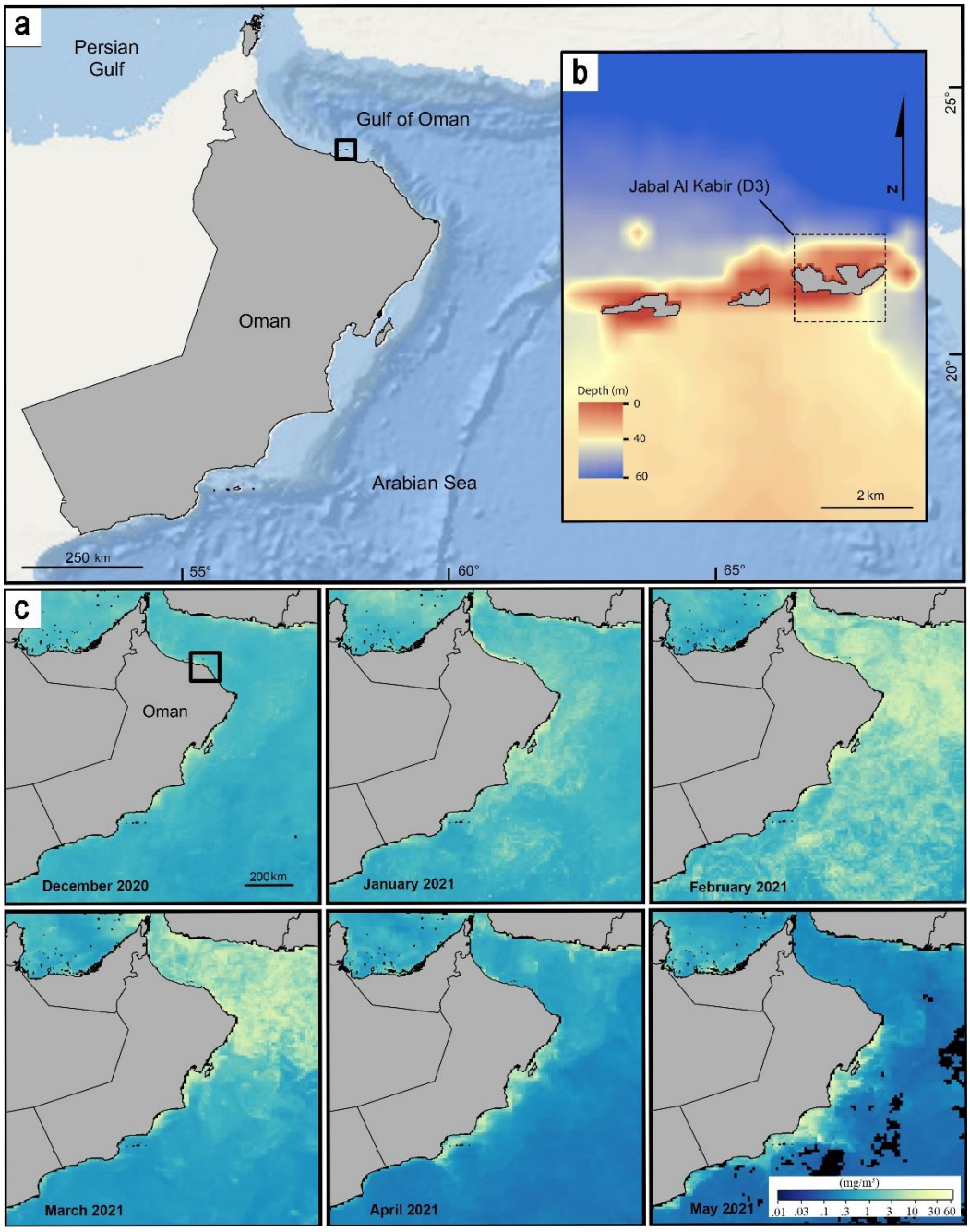

Figure 1. (a) Coastline of Oman with the Daymaniyat Islands in the north (inset). **(b)** The inset shows Jabal Al Kabir (D3) bathymetric data around the islands. Daymaniyat Islands made of nine uninhabited islands (also called as D1-D9 islands), composed of Miocene limestones uplifted by Pliocene folding [15]. The northern shores are small cliffs and narrow embayments, whereas sandy beaches line most of the southern side of the islands. **(c)** Image series of monthly average concentration of Chlorophyll data from the Aqua/MODIS satellite, notice the high concentration in February–March 2021 representing algal blooms.

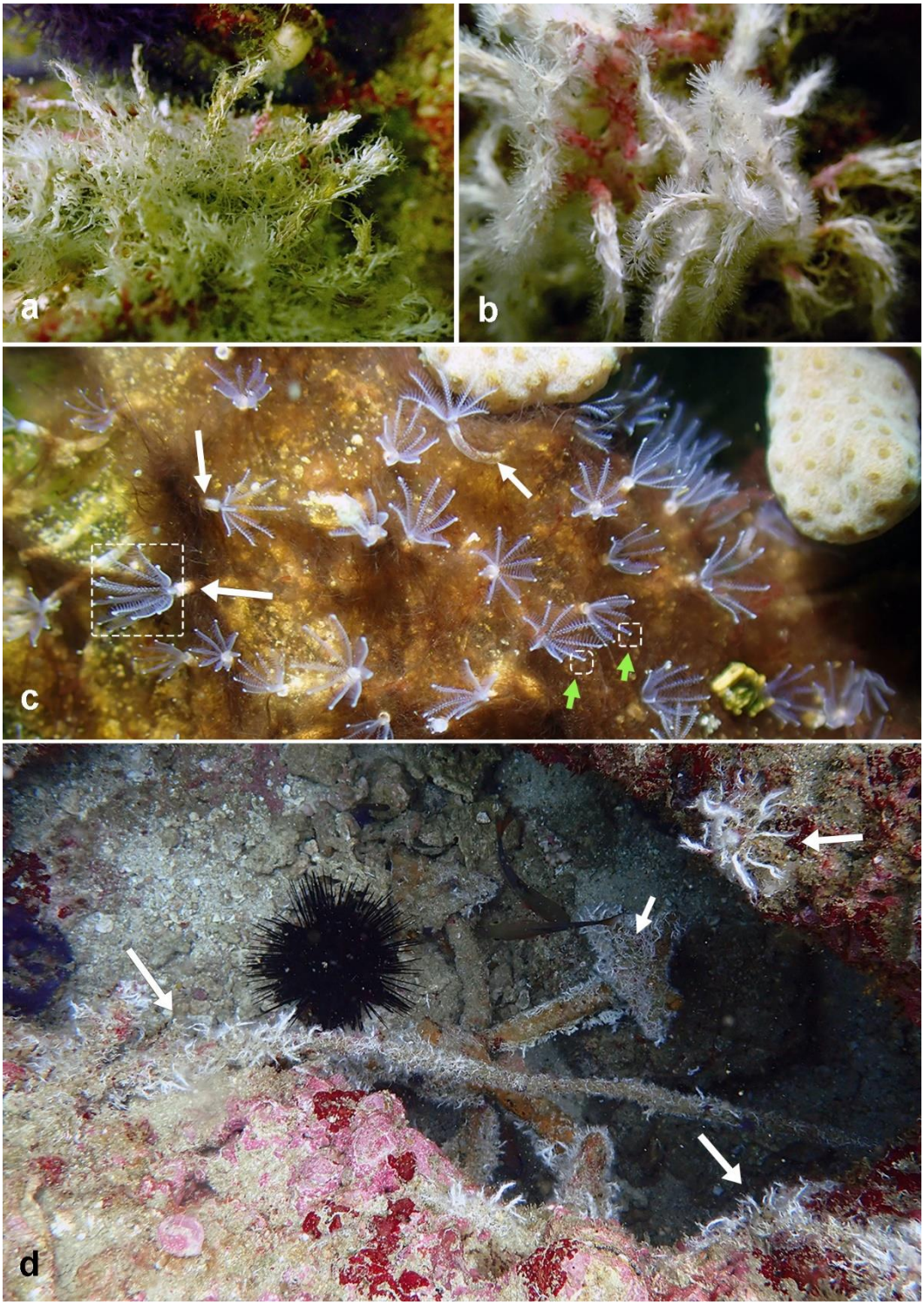

Figure 2. Serpulid aggregations of *Filograna*/*Salmacina*-complex. **(a–b)** pseudo-colonies forming fragile constructions, Jabal Al Kabir (D3). **(c)** Individual polyps covered by algae. Green arrows: inflated tips of the radioles. Square outline: a worm with 16 radioles showing asexual reproduction, with offspring and parent sharing the same tube. Pinnately branched radioles resemble octocoral polyps with eight tentacles and pinnules, Bandar Al Khiran. **(d)** Aggregations over hard surfaces and crustose coralline algae, Daymaniyat islands, D3 (photos a,b,d J. Al Asfoor; c, M. Claereboudt).

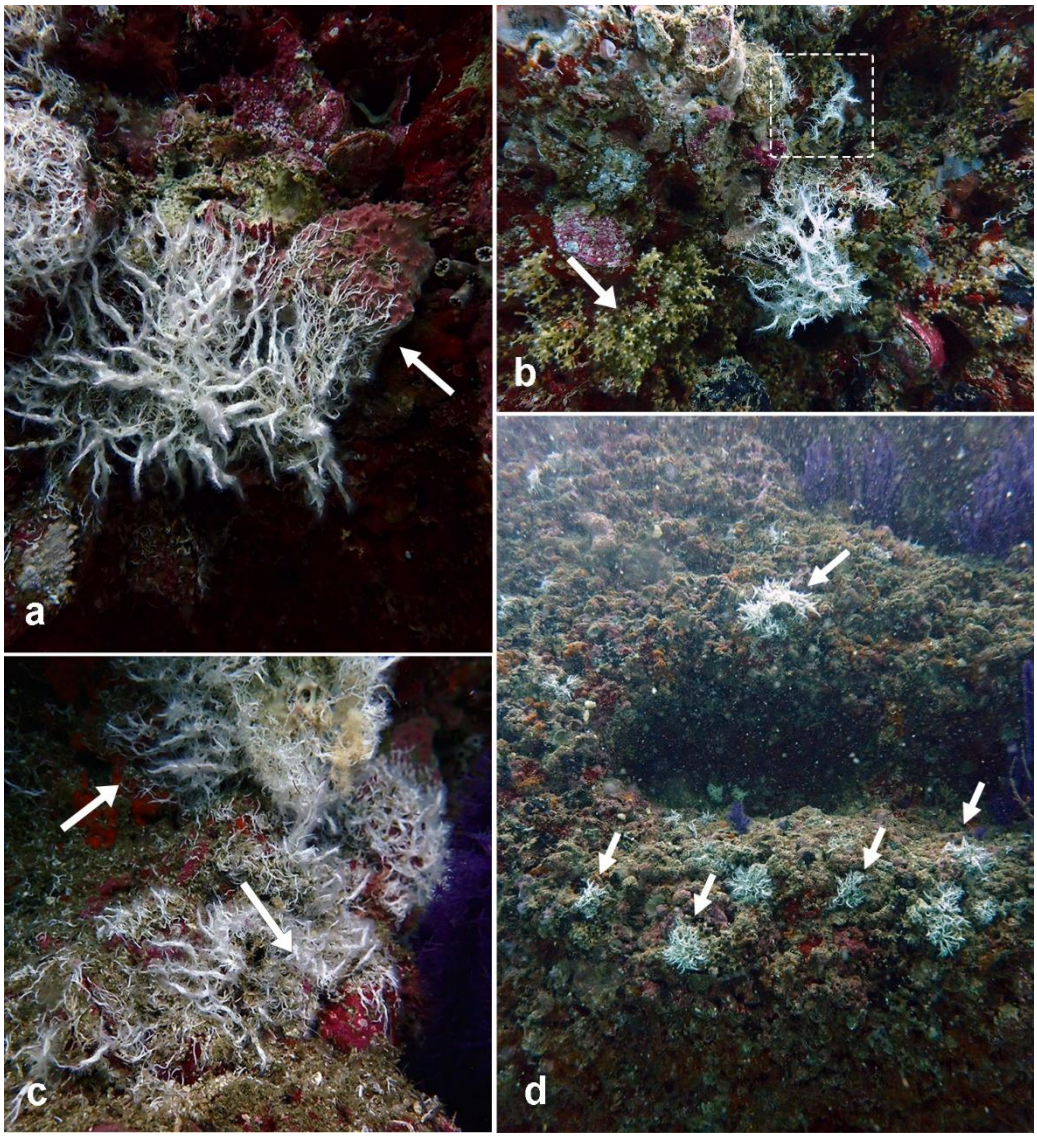

Figure 3. Rocky walls in the seaward side of the Daymaniyat Islands reaching about 30 m depth, covered with species that prefer dark areas, usually gorgonians, scleractinians, covered with serpulid aggregations of *Filograna*/*Salmacina* **(a)** Aggregations starting with tubes overgrowing surfaces, then joining up, and building thicker branches. White arrow: overgrowth on a sponge. **(b)** Aggregations on overhangs, in between gorgonians such as *Bebryce stellata* (white arrow), and *Astrogorgia* sp. (square outline) slowly getting smothered by the overgrowing worms. **(c)** worms growing over rocks, crustose coralline algae, and sponges **(d)** View of the wall in upward direction, with worm pseudo-colonies up to 20 cm in diameter. (photos J. J. Al Asfoor)

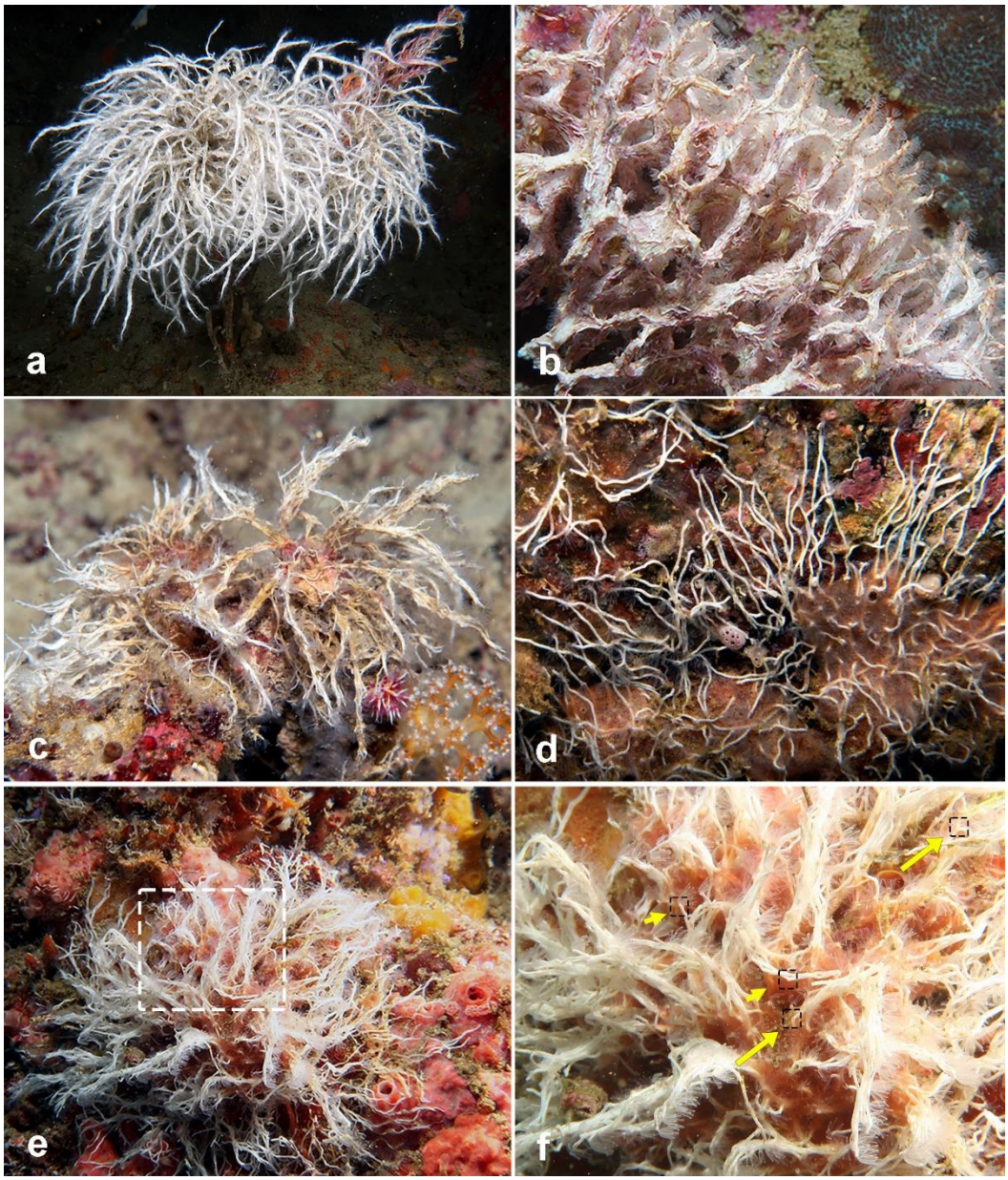

Figure 4. Aggregations of *Filograna*/*Salmacina* from south of Oman, Dhofar region. **(a)** worm clusters over growing black coral stem. **(b–e)** Aggregations growing over rocks, crustose coralline algae, and sponges. **(f)** Square outline in figure c, showing the branching asexual pattern as described by Pernet [24]) (photos M. Claereboudt).

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